Commonwealth of Kentucky
Department of Highways

THE APPLICATION OF KENTUCKY FLEXIBLE PAVEMENT DESIGN METHOD TO WASHO TEST ROAD CONDITIONS

by

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INTRODUCTION

In the summer of 1952 the Flexible Pavement Design Committee of the Highway Research Board began the sponsoring of a comparative design project. Several state highway departments and other organizations were invited to submit flexible pavement designs, based upon their own current practices, for the subgrade, materials, and traffic conditions of the Western Association of State Highway Officials (WASHO) test road. This road was being constructed in Malad, Idaho, through the participation of 13 western states and the Bureau of Public Roads. The Kentucky Department of Highways was one of the organizations invited to participate in the comparative design project.

After the organizations invited had indicated their interest and willingness to participate in the study, they were each furnished with samples of the subgrade, subbase, and base materials, as well as a statement of certain specific traffic patterns, some of which would be used in testing the road. All test vehicles would be of the semi-trailer type, with two loaded axles. Single-axle loads would be 18,000 and 24,000 lb., while the tandem-axle vehicles would have 32,000 and 40,000-lb. loads. It was intended that a total of 200,000 passes would be made by each vehicle.

The surface course of the entire WASHO roadway was bituminous concrete with 12-150 penetration asphalt, 4.8 percent by weight. This course was placed in compacted thicknesses of two and of four inches. The base course consisted of graded-crushed gravel, ranging from 100 percent passing the 1-in. sieve to seven percent passing the No. 200 sieve, and placed four inches thick in sections paved with two inches of asphaltic concrete, and two inches thick in sections with a 4-in. surface course.

The gravel for the subbase was pit run, with 100 percent passing the 2-in. sieve and five percent passing the No. 200 sieve.

There were two specific objectives for the design project:

a.) To determine the pavement thickness indicated necessary by the methods of the various participating organizations for a given type of subgrade soil, given pavement materials, and for definite patterns of traffic.

b.) To compare the designs obtained in (a.) with those indicated to be adequate under the actual traffic imposed upon the WASHO test pavement by the four test axle loads.

The Design Problem

The problem of design for the organizations participating in the study was actually three fold. It consisted of determining, with their own construction standards but for conditions at the Idaho test site, the following:

1. Subbase thickness specifications necessary for 200,000 passes of each test vehicle, for each of the variable surface course and base thicknesses indicated in the table below:

TABLE 1. SUBBASE DESIGN PROBLEM

Pavement Component	Axle Load (lb.)							
	Single				Tandem			
	18,000		22,400		32,000		40,000	
Surface (in.)	2	4	2	4	2	4	2	4
Base (in.)	4	2	4	2	4	2	4	2
Subbase (in.)	?	?	?	?	?	?	?	?

2. The number of trips of vehicles with each of the four axle loadings required to produce failure for the following designs:

TABLE 2. WASHO TEST PAVEMENT DESIGNS

Component	Thickness in Inches									
Surface	2	2	2	2	2	4	4	4	4	4
Base	4	4	4	4	4	2	2	2	2	2
Subbase	0	4	8	12	16	0	4	8	12	16
Total	6	10	14	18	22	6	10	14	18	22

3. The pavement thickness necessary for the climatic conditions where the particular design procedure is normally used (in this department's case, for Kentucky) but for certain specified traffic conditions. Thicknesses of surface, base, and subbase were to be selected as thought necessary. The traffic conditions specified included the already detailed WASHO pattern, with the 200,000 passes of each vehicle; as well as certain other traffic patterns as indicated in the table below:

TABLE 3. COMPOSITE TRAFFIC PATTERNS

	Pattern (a)	Pattern (b)	Pattern (c)	Pattern (d)
Passenger Cars (No. of Vehicles/Day)	80	800	3200	1000
Commercial Vehicles (No. Axles/Day)				
10,000 lb. or less	10	100	400	600
12,000 lb.	4	40	160	800
14,000 lb.	3	30	120	1000
16,000 lb.	2	20	80	520
18,000 lb.	1	10	40	80
Design EWL	339,450	3,394,500	13,587,000	63,734,000

Kentucky Design

Kentucky Flexible Pavement Design is based on a modification of the CBR method. Traffic is evaluated by the equivalent 5000-lb. wheel-load method (EWL). The pavement design curves are based on Kentucky's experience, having been developed from the results of a comprehensive study made by the Department of Highways in 1947 and 1948. These curves have since been extended and modified to provide for the greater volumes and weights of present and expected traffic. The curves in Fig. 1 show the combined thickness of high-type macadam base and asphaltic-concrete pavement required for certain CBR values and various traffic ranges. Anticipated axle loads of 10,000 lb. and greater are converted to the equivalent number of 5000-lb. wheel loads. A 10,000-lb. axle is equal to one 5000-lb. wheel load, while a 12,000-lb. axle is equivalent to two 5000-lb. wheel loads and an 18,000-lb. axle equal to sixteen 10,000-lb. axles. The table of equivalents was worked up by the California Department of Public Works and is generally accepted. Total 20-yr. anticipated traffic is calculated in EWL values.

The CBR method for determining bearing values of soil has been modified for Kentucky use. This value is determined in the laboratory for subgrade samples from the project.

Subgrade, subbase, and base samples from the WASHO test track were tested in the Highway Department's testing laboratory by the Division of Materials. The subgrade soil was found to have a CBR of 5.5 percent. The crushed-gravel base was found to be about equal in bearing value to Kentucky macadam base, while the uncrushed-gravel subbase had only 80 percent of the bearing value of the crushed material (tested

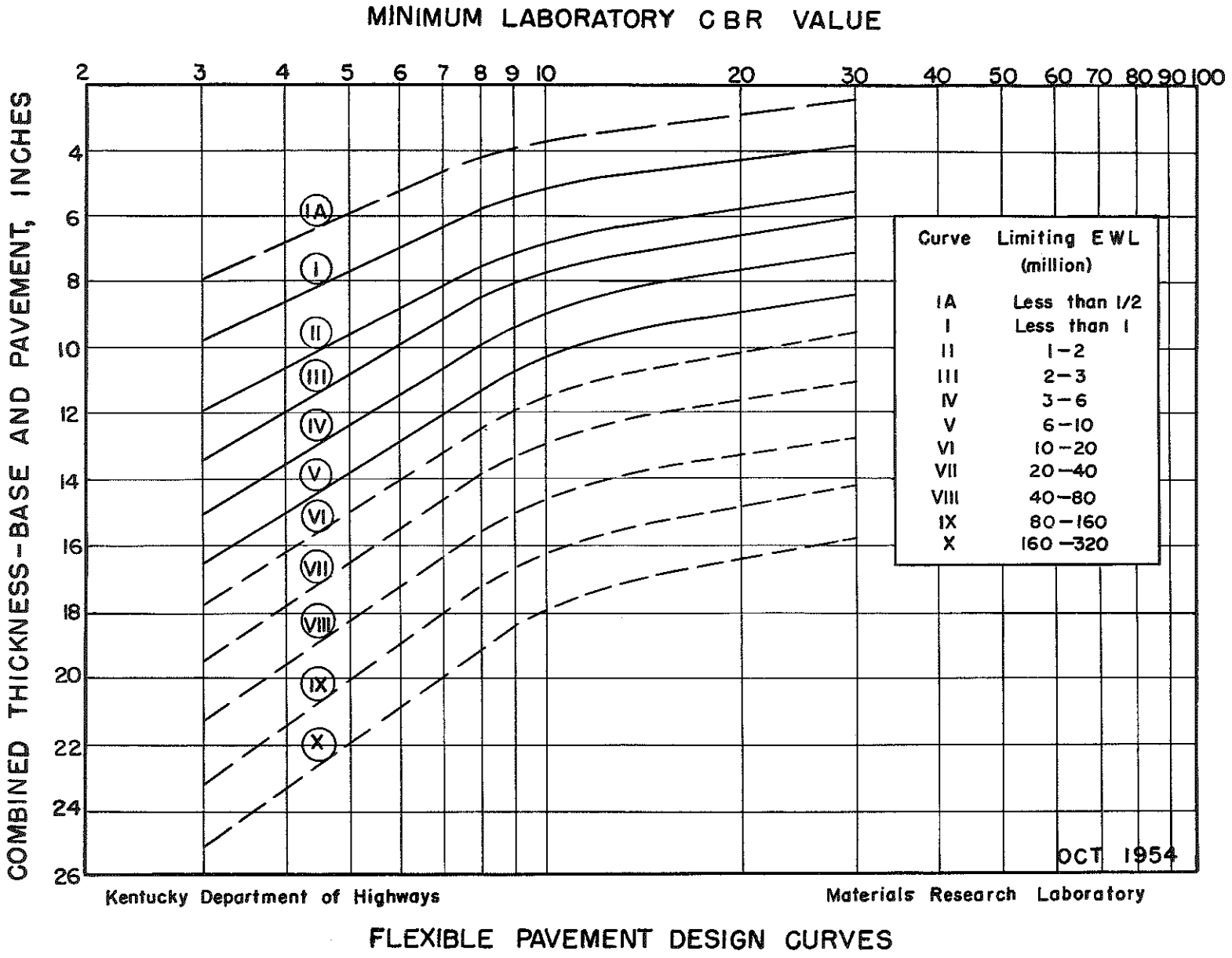


Fig. 1. Kentucky Flexible Pavement Design Curves.

by the CBR method). Because of these evaluations, crushed-gravel base thickness was determined in the designs on an equal basis with macadam; while the subbase material, when used, was increased 25 percent in thickness, to compensate for its lower quality. Consideration in the overall design was given for the 4-in. asphaltic concrete thickness versus the 2-in. surface. The thickness required was lowered somewhat for the 4-in. surfaced sections.

The pavement designs and failure estimations determined by the Kentucky Department of Highways for the problems are shown in the following tables. Table 4 contains the subbase designs for the first portion of the problem.

TABLE 4. SUBBASE DESIGNS

Pavement Component (in.)	Single Axle				Tandem Axle			
	18,000 lb.		22,400 lb.		32,000 lb.		40,000 lb.	
Surface	2	4	2	4	2	4	2	4
Base	4	2	4	2	4	2	4	2
Subbase	12	11	17	16	12	11	17	16
Total	18	17	23	22	18	17	23	22

Table 5 below, presents the findings for the second portion, listing the number of passes of the various vehicles which each of the pavement designs used in the test track was calculated to withstand adequately. These values were determined from the Kentucky flexible pavement design curves. At the bottom of the table are listed the subbase thickness values

that were found to be adequate for 119,000 passes of the various vehicles at the test track. (It was decided during the running of the tests that the originally planned 200,000 passes would not be feasible, and the traffic was stopped on May 29, 1954, after all vehicles had made 119,000 trips over their respective sections.)

TABLE 5. NUMBER OF TRIPS TO PRODUCE FAILURE

Thickness	18,000 Single		22,400 Single	
	2-in. A.C. 4-in. Base	4-in. A.C. 2-in. Base	2-in. A.C. 4-in. Base	4-in. A.C. 2-in. Base
0	31,250	46,900	7,810	11,720
4	78,100	93,000	19,550	23,500
8	226,200	312,000	56,600	78,200
12	938,000	1,563,000	235,000	391,000
16	1,750,000	5,620,000	938,000	1,420,000
	WASHO FINDINGS			
	(Subbase Thickness Found Adequate for 119,000 Trips)			
	10 in.	4 in.	13 in.	4 in.

Table 6, which follows, shows the designs for the third portion of the design problem, for the WASHO traffic pattern of 200,000 passes of each vehicle.

TABLE 6. PAVEMENT DESIGNS FOR TOTAL THICKNESS
(Using Any Selected Component Thickness)

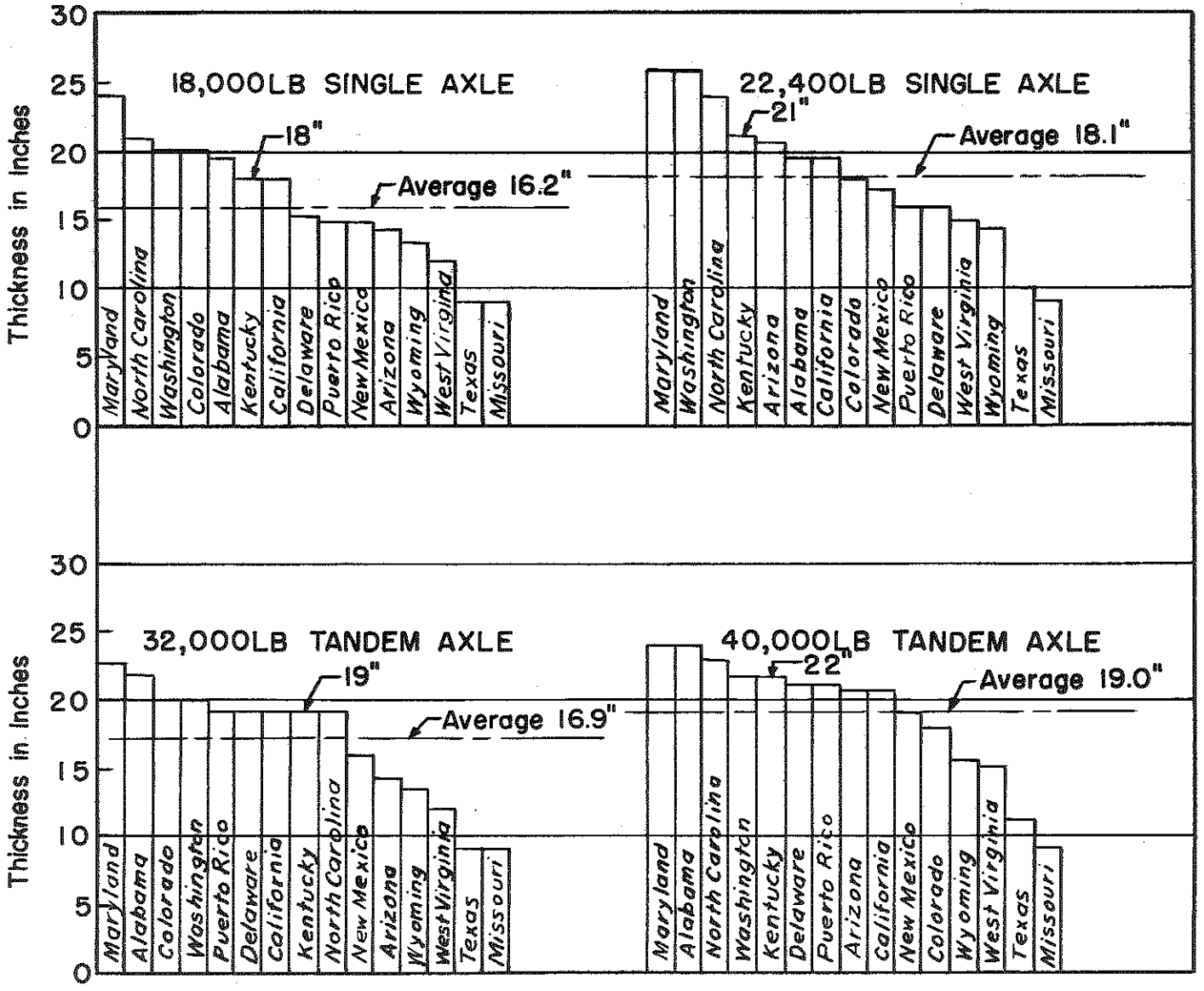
Pavement Component (in.)	Single Axle		Tandem Axle	
	18,000 lb.	22,400 lb.	32,000 lb.	40,000 lb.
Surface	3	3	3	3
Base	4	6	4	6
Subbase	11	12	12	13
Total	18	21	19	22

Fig. 2 indicates graphically the designs selected by each of the participating agencies for this portion of the problem, in which the individual thicknesses of all components were left to the choice of the designer. The Kentucky total thicknesses were made up of the components already shown in Table 6.

Table 7, below, shows the designs for the composite traffic patterns (listed in Table 3) for the third portion of the problem.

TABLE 7. PAVEMENT DESIGNS FOR COMPOSITE TRAFFIC PATTERNS

Pavement Components (in.)	Pattern (a)	Pattern (b)	Pattern (c)	Pattern (d)
Surface	2	2.5	2.75	3
Base	2	4	4	6
Subbase	5	7	10	11
Total	9	13.5	16.75	20



TOTAL PAVEMENT THICKNESS
FOR 200,000 VEHICLE TRIPS WITH WASHO MATERIALS

Fig. 2. Pavement Designs Submitted by the Co-operating Agencies for 200,000 Vehicle Trips. All component thicknesses were selected by the designers.

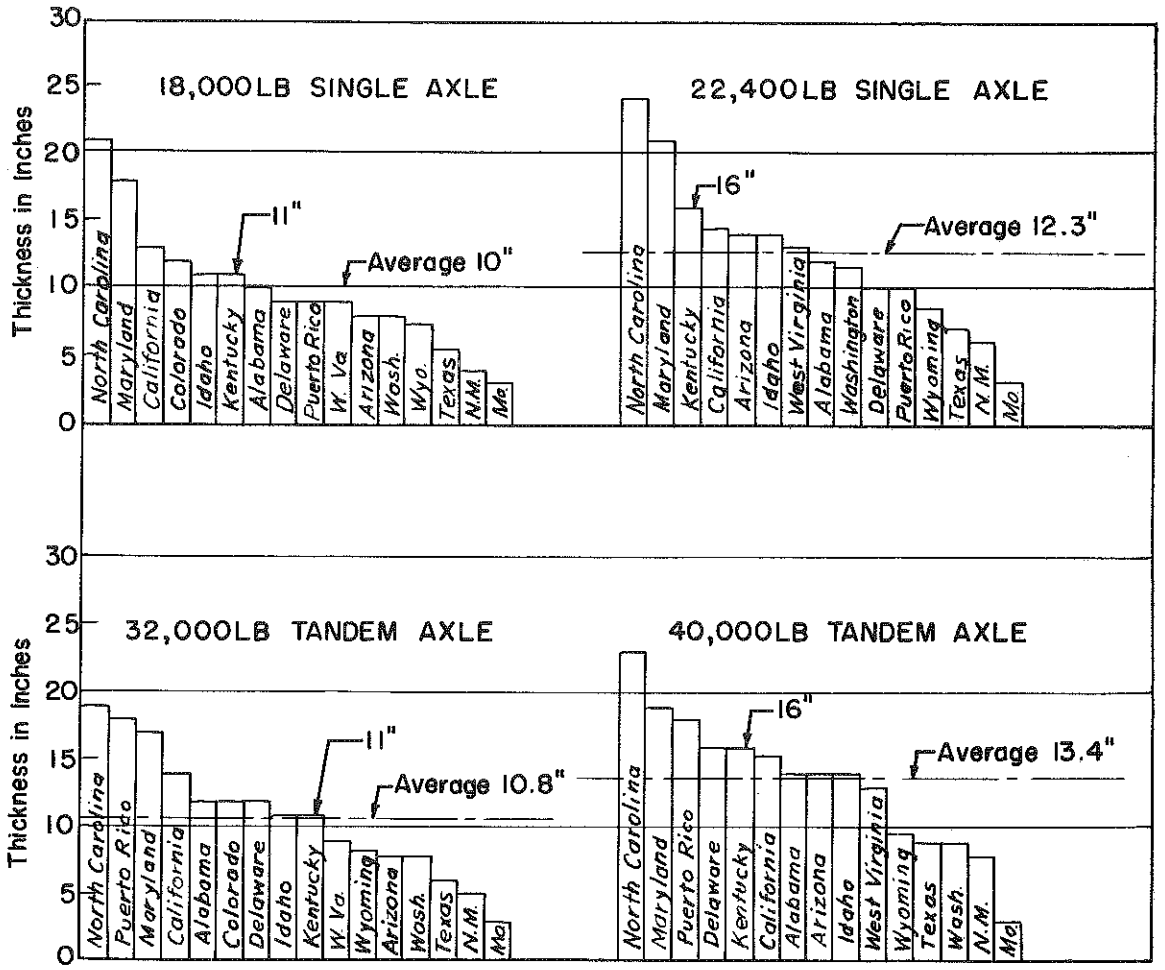
WASHO FINDINGS

During the period from November, 1952, through May, 1954, the test track was subjected to 119,000 trips of the test vehicles on all test sections.

The minimum total thicknesses that were found to withstand adequately the 119,000 vehicle passes in the outer wheel path, for the 2-in. surfacing of asphaltic concrete, were 16 in. for the 18,000 lb. single axle, 19 in. for the 22,400 lb. single axle, 17 in. for the 32,000 lb. tandem, and 20 in. for the 40,000 lb. tandem.

In the inner wheel path, the 14-in thick pavement sections were undamaged by any of the four loadings. Comparable values found for the 4-in. asphaltic concrete pavement, outer wheel path, 10 in. for the first three loadings and 14 in. for the 40,000 lb. tandem axle load. For the inner path they were 6 in. for the two single axle loading and 10 in. for the two tandem axle loads.

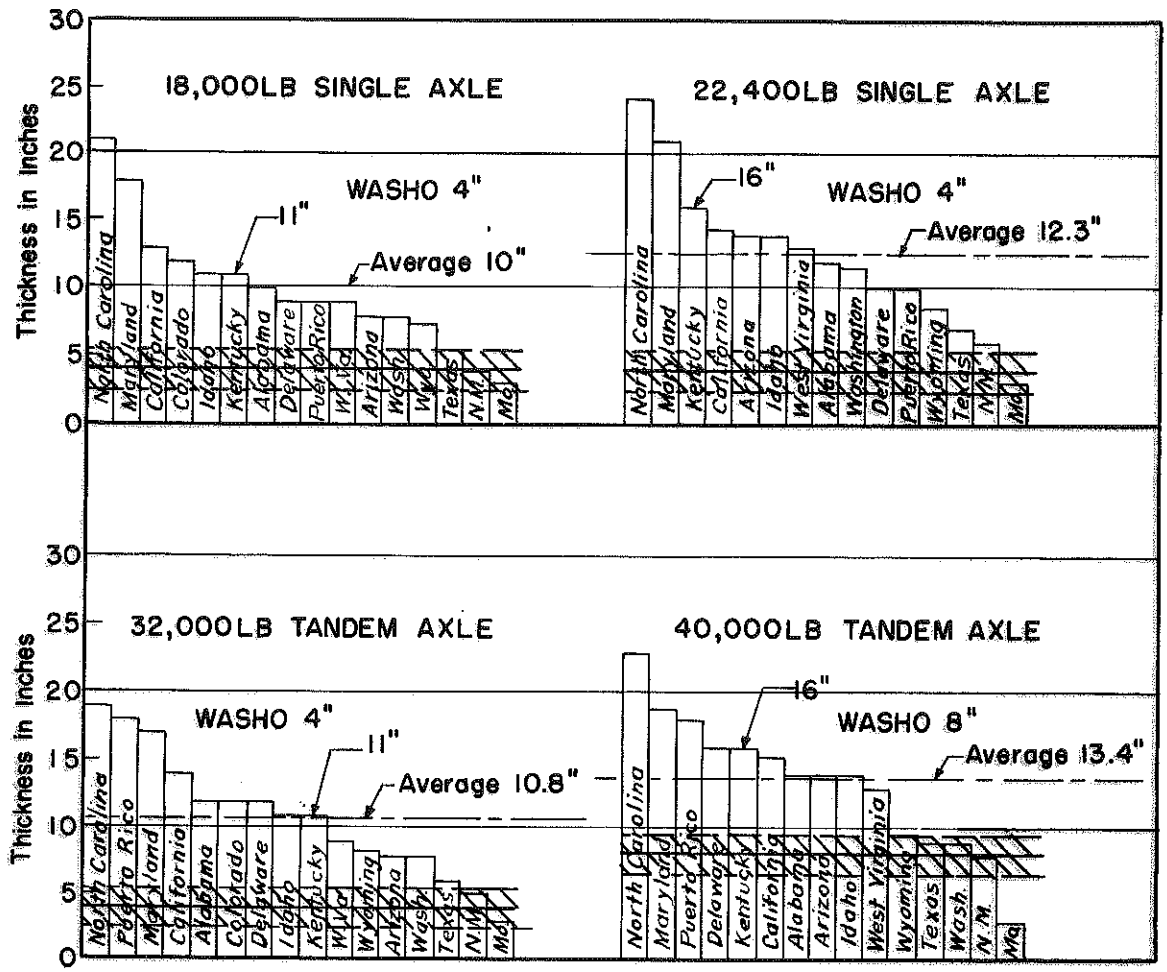
In the section of this report which follows, graphs are used to present a comparison between the findings of the WASHO test and the designs submitted by the participating organizations. The Kentucky designs are indicated on each of the graphs.



UNCRUSHED-GRAVEL SUBBASE THICKNESS FOR 200,000 VEHICLE TRIPS
4" A.C. + 2" CRUSHED GRAVEL BASE

FIGURE 3

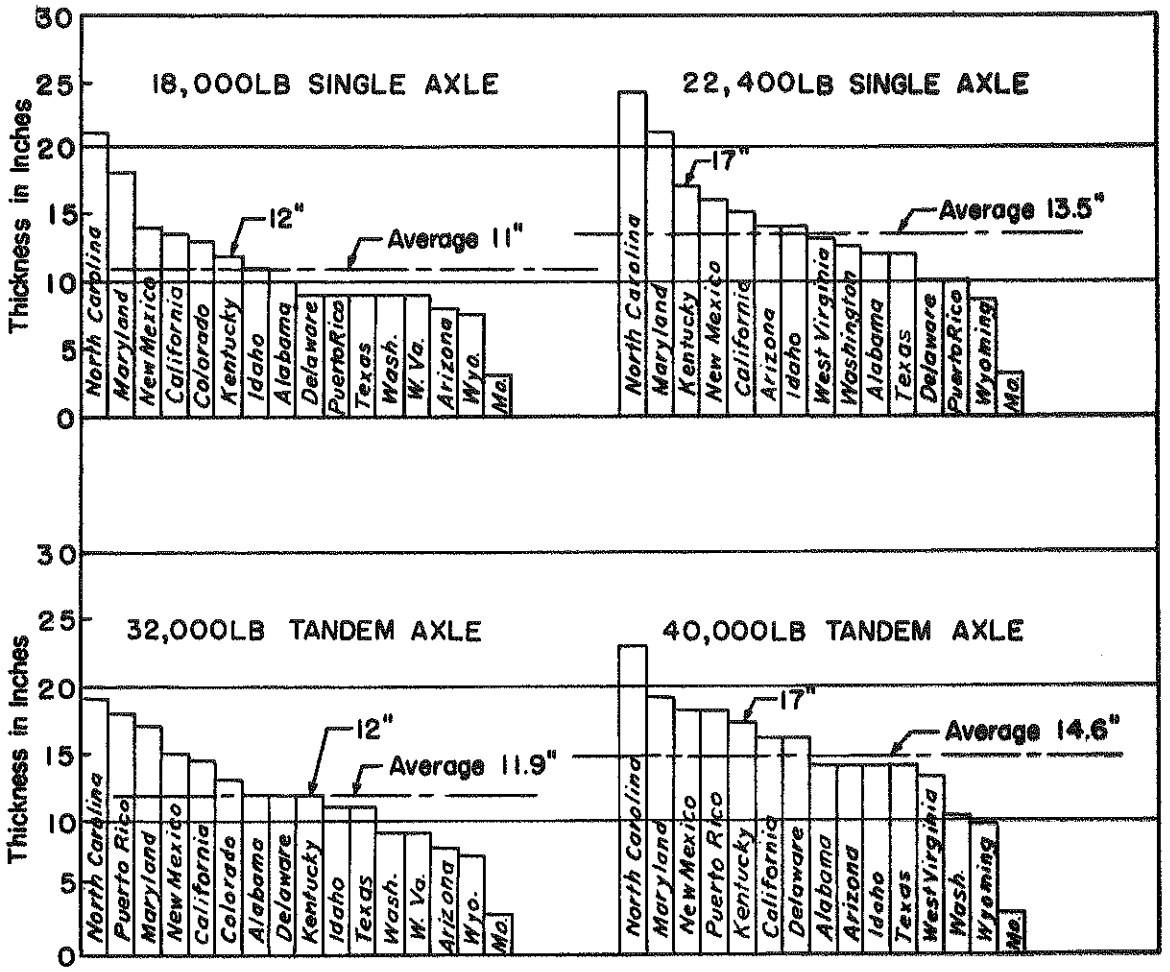
This chart shows the subbase thicknesses that each of the cooperating agencies submitted for 200,000 trips of each test vehicle, with a 4-in. asphaltic concrete surface and a 2-in. base course. Note the average subbase thickness submitted and the Kentucky design for each traffic loading.



UNCRUSHED-GRAVEL SUBBASE THICKNESS FOR 200,000 VEHICLE TRIPS
4" A.C. + 2" CRUSHED GRAVEL BASE

FIGURE 4

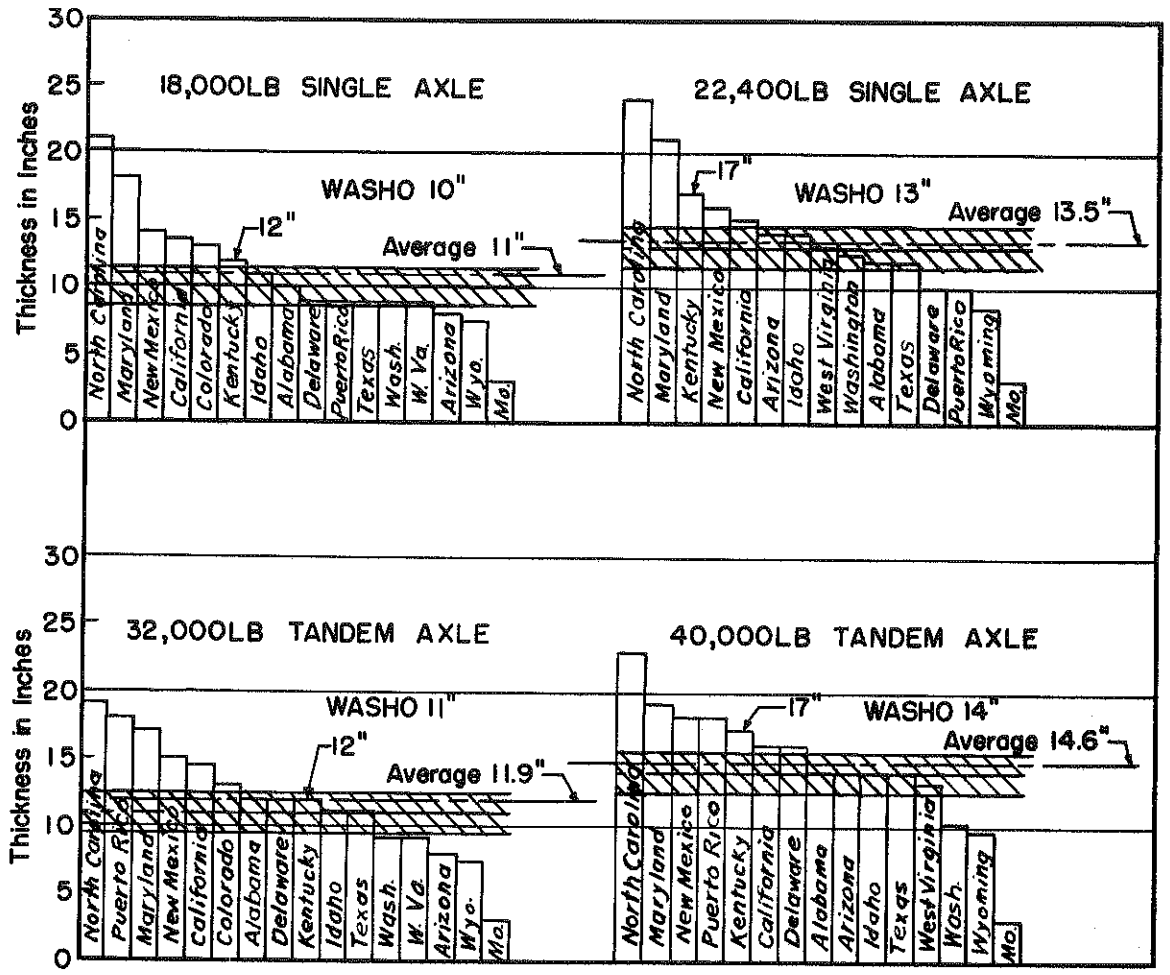
WASHO adequate thicknesses for 119,000 vehicle trips plotted on chart showing designs submitted by the agencies for 200,000 vehicle trips. A 3-in. band 1-1/2 in. above and below the determined value is shown.



UNCRUSHED-GRAVEL SUBBASE THICKNESS FOR 200,000 VEHICLE TRIPS
2" A.C. + 4" CRUSHED-GRAVEL BASE

FIGURE 5

The graph indicates the subbase thickness designs submitted by the participating organizations for sections with a 2-in. asphaltic concrete surface and a 4-in. crushed gravel base. The traffic component was 200,000 trips of each test vehicle.



UNCRUSHED–GRAVEL SUBBASE THICKNESS FOR 200,000 VEHICLE TRIPS
2" A.C.+ 4" CRUSHED–GRAVEL BASE

FIGURE 6

WASHO adequate thickness for 119,000 vehicle trips is plotted here on the chart which shows designs for 200,000 trips. The average thickness submitted and the WASHO findings are each shown by a horizontal line, and the shaded area represents a band of 1-1/2 in. on each side of the test-determined thickness.

The Kentucky Department of Highways welcomed the opportunity to participate in the design correlation study and to evaluate its design method in the light of the controlled traffic and performance data. The results of the road test and of the companion studies have been most helpful in evaluating Kentucky procedures and will undoubtedly aid in future Kentucky flexible pavement designs.