

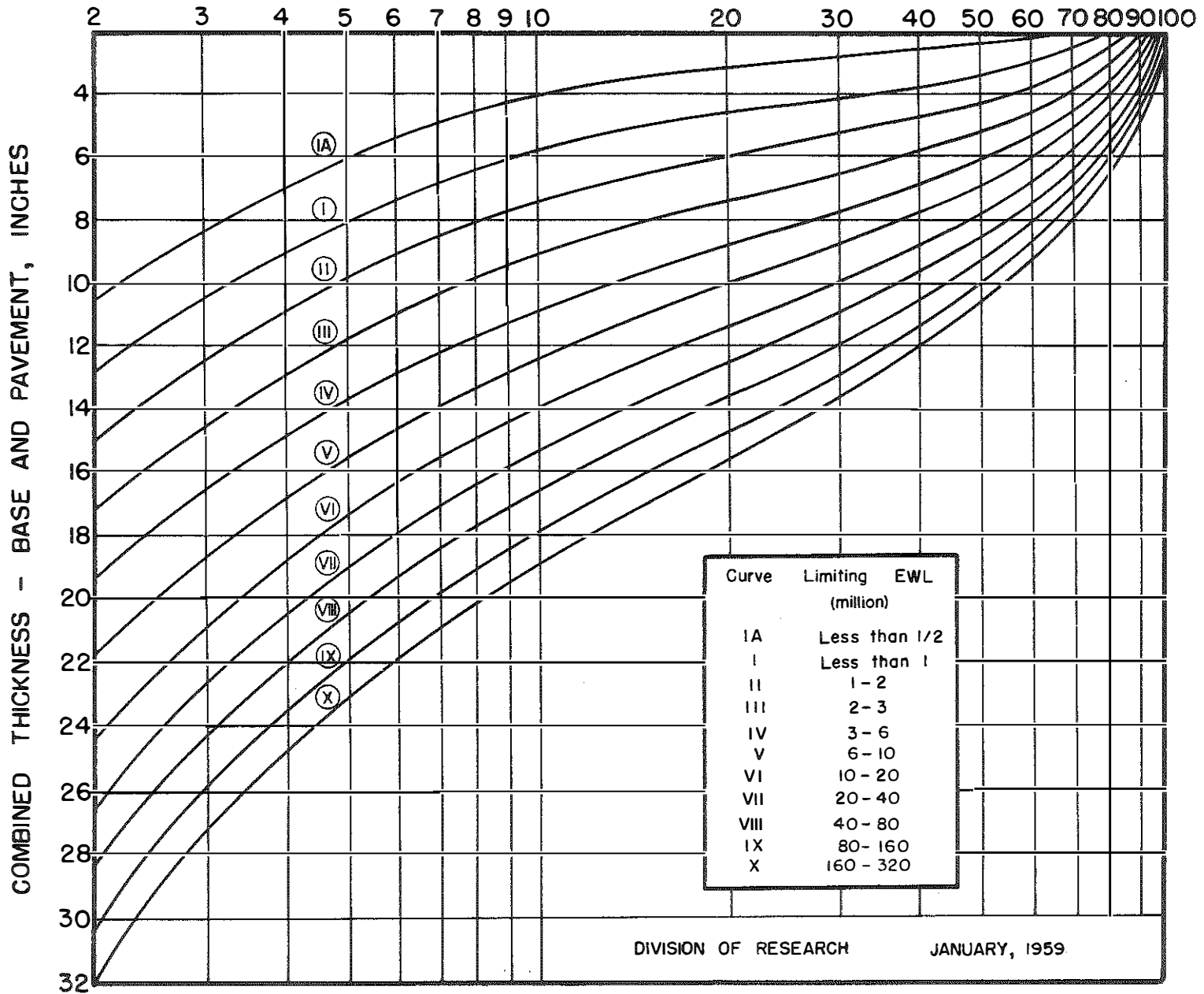
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## DISCUSSION OF THE KENTUCKY CRITERIA FOR DESIGN OF FLEXIBLE PAVEMENT THICKNESSES

The Kentucky Department of Highways, in 1946, sought a more systematic criteria and basis for designing the thickness of bituminous concrete pavements. The Research Division was authorized to pursue this work and to develop the criterion. These efforts were embodied in a report (1) to the Department, which offered a system of design based upon CBR's and EWL's. EWL's were computed originally for a 10-year period but this practice was revised in 1954 to encompass 20-year traffic (more realistic with respect to average road life). Then, in 1957, the Department requested a re-evaluation of the criteria from the standpoint of experience and performance of pavements designed thereby. This re-study, and recommendations therein, was reported to the Department and to the Highway Research Board (2)(3). A copy of current design chart is shown on the following page (Fig. 20, Ref. 2 and 3).

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- (1) Baker, R. F. and Drake, W. B., "Investigation of Field and Laboratory Methods for Evaluating Subgrade Support in the Design of Highway Flexible Pavements," Bulletin No. 13, Engineering Experiment Station, University of Kentucky, Sept. 1949.
  - (2) Drake, W. B. and Havens, J. H., "Re-Evaluation of Kentucky Flexible Pavement Design Criterion," Bulletin No. 233, Highway Research Board, 1959.
  - (3) Drake, W. B. and Havens, J. H., "Kentucky Flexible Pavements Design Studies," Bulletin No. 52, Engineering Experiment Station, University of Kentucky, 1959.

MINIMUM LABORATORY GBR VALUE



FLEXIBLE PAVEMENT DESIGN CURVES

Fig. 20: Revised Flexible Pavement Design Curves.

### Equivalency of Traffic

Somewhere between the magnitude of the load on a pavement structure that would cause rupture in one application and the magnitude of load that the same pavement structure would withstand an infinitely large number of times lies a broad region of fatigue in which the effects of load repetitions is accumulative and somehow proportional to the magnitude of the loads. The EWL concept of mixed-traffic loads is purely a fatigue analogy. In fact, the EWL and fatigue concepts are applicable only within certain limits. Of course, this is a recognized condition in the EWL method of resolving mixed traffic loads into a single parameter. Logically, pavement design criteria based on EWL's should include some consideration of the effects of a single, heavy-axle load. In other words, a relatively thin pavement should be analyzed so as to establish a limit on the maximum safe single load. Fergus (2)(3) derived a formula relating EWL's to equivalent single axle load. A slightly modified derivation is offered below as a matter of interest:

1. Axle loads, in tons (P) increase arithmetically:

$$L = a + (n - 1) d$$

$$a = \text{1st term} = 5 \text{ tons (basic)}$$

$$n = \text{no. of terms}$$

$$d = \text{common difference} = 1$$

$$L = \text{last term} = P$$

$$P = 5 + (n - 1) 1$$

$$P - 5 = n - 1$$

2. Both EWL's and California Factors increase geometrically:

$$L = a r^{n-1}$$

$$L = \text{last term} \qquad L = a(2)^{n-1}$$

$$a = \text{1st term} = k \text{ (basic)}; \quad n - 1 = P - 5$$

$$r = \text{common ratio} = 2$$

thus:

$$\text{EWL's} = k(2)^{P-5}$$

and:

$$f = k'(2)^{P-5}, \quad k' = 1 \text{ (basic)}$$

3. Since:

$$\overline{\text{EWL}} = \overline{n} \overline{f} = n_1 f_1 + n_2 f_2 \dots$$

$$\text{EWL (millions)} = \overline{n} (2)^{P-5}$$

Assuming that soil or foundation conditions are more or less average and constant, it has been suspected for quite a long time that pavement thickness requirements correlate approximately with the logarithm of the number of load repetitions, thus for a given load:

$$T = (\log N) + C \qquad (1)$$

where:

T = thickness,

N = number of repetitions, and

C = a constant.

As suggested in Fig. 16, U. of Ky., Engr. Exp. Sta. Bulletin No. 52, there is an approximate linear relationship between thickness and the logarithm of EWL's, thus:

$$T = k (\log \text{EWL's}) + C \quad (2)$$

(In Fig. 16, Bulletin No. 52:  $T = 6.2 \log \text{EWL} - 29.2$ )

EWL's are also the product of the average number of load repetitions,  $\bar{N}$ , and the average load factor,  $\bar{f}$ , thus:

$$\text{EWL's} = \bar{N} \times \bar{f}. \quad (3)$$

Here, the load factor,  $\bar{f}$ , is fixed by whatever equivalent, single, axle load is assumed or sought, i. e. 10,000 lbs. or 18,000 lbs.; thus, for one 18-kip basic axle:

$$\bar{f} = (2)^{P-5} = 16 \quad (4)$$

where:

$P$  = axle-load in tons or wheel-load in thousands of pounds.

Substituting Equation (3) into Equation (2) yields

$$T = k (\log N + \log \bar{f}) + C \quad (5)$$

Substituting for  $\bar{f}$ , from Equation (4) gives:

$$T = k \log N + (P-5) \log 2 + C$$

$$T = k \log N + (4 \times .3) + C$$

$$T = k (\log N + 1.2) + C. \quad (6)$$

Now, assuming that Traffic Group X, 256 million EWL's (20-years, 2-direction; Ky. basis), represents the traffic anticipated on the highest type of roads,

$$\frac{256 \times 10^6}{365 \times 20 \times 2} = \bar{N} \times 16 \quad (7)$$

N = 1100 equivalent number of 18,000 lb.  
axles per day per lane.

Substituting for N in Equation (6):

$$T = k (\log 1100 + 1.2) + C$$

$$T = k (3.042 + 1.2) + C$$

$$T = k (4.24) + C$$

$$T/k = 4.24 + C' \quad (8)$$

Similarly, the numerical values of T/k for each of the ten  
Kentucky Traffic Groups are found to be:

<u>EWL Group</u>	<u>T/k</u>
X	4.24 + C'
IX	3.94 "
VIII	3.64 "
VII	3.34 "
VI	3.04 "
V	2.74 "
IV	2.44 "
III	2.14 "
II	1.84 "
I	1.54 "
IA	1.24 "

Of course, the Kentucky traffic data are compiled by using the  
original California factors (basic wheel load of 5,000 lbs., for which  
f = 1), and wheel loads of less than 5,000 lbs. are not considered.

Ky. Design Curve	Ky. EWL's 20-Yr. (Millions) (2-direction)	Ky. Eq. Daily 10-kip Axles (1-direction)	Ky. Eq. Daily 18-kip Axles (1-direction)	Total Thickness CBR-5 Ky. Chart	Probable Structures	
					B.C.	DGA
II	1	68.5	4.28	10"	3.5"	6.5"
III	2	137	8.56	12"		
IV	4	274	17.13	14"	3.5"	10.5"
V	8	548	34.25	15.5"		
VI	16	1096	68.50	17.5"	4.0"	13.5"
VII	32	2192	137.70	19.0"	4.5"	14.5"
VIII	64	4384	274.00	20.5"		
IX	128	8768	548.00	22.0"	6.5"	15.5"
X	256	17536	1096.00	23.0"	7.5"	15.5"

Note: In previous discussion, it was shown that 256 million Ky. EWL's = 1100 daily, 18-kip axles, each direction.

No environmental parameters per se are used in the Kentucky design criterion, although average existing conditions controlled this item in the development of the original design curves. The basis for design was performance of pavements in Kentucky.

Soils having a CBR of less than three are not considered to be suitable for use as subgrade material. The most suitable soils available from cut-and-fill excavation for use as subgrade material are customarily determined from soil surveys. High-CBR materials may be reserved for this use. Where CBR's vary only slightly throughout a reasonably

great distance, the median, average, or minimum value might be used safely for determining the thickness of pavement. However, where CBR's vary greatly within a given project, such that it would be impractical to vary the design thickness, it is usually more practical to judiciously select a CBR value for design and to require that all subgrade materials falling below this minimum be improved.

The minimum thickness of bituminous concrete surfacing considered to be adequate for heavy traffic is four inches. Additional thicknesses of bituminous concrete, when provided as base, are considered to be structurally equivalent, on a per inch thickness basis, to 1.5 inches of dense-graded, crushed limestone base; however, it is recommended in so doing that the total thickness of pavement not be reduced by more than 15%. Experiences in Kentucky with greater thicknesses of bituminous concrete bases, though limited, seem to indicate that the equivalency ratio presently used is somewhat conservative; and it is hoped that the findings of the AASHO Test Road, soon to be formally released, will confirm these indications.

Preparations are being made, of course, to correlate the Kentucky design criterion with the results of the AASHO Test Road. The Kentucky method utilizes only the three basic parameters, i. e. EWL's, CBR's, and total thickness. No particular difficulty is foreseen in the correlation of EWL's. In 1957, the AASHO Road Test Co-operative Materials Testing Program provided an opportunity to evaluate the CBR parameter.



Although the summary report on the "...Co-operative Testing Program" (4) indicates that Kentucky evaluated the subgrade material at CBR-7.6, 120.2 lbs/cu.ft., 12.8% m.c.; the subgrade material as actually placed at the Test Road had a density of 114.5 lbs./cu.ft., and a moisture content of 15.3%. At the present time, the adjudged comparative CBR is considered to be five or slightly less -- at least the initial correlation will be sought on the basis that the subgrade material used in the road test is best represented by a Kentucky CBR of 5. The correlation doubtlessly will be further facilitated by the assumption of a more-or-less constant ratio of depth of bituminous concrete to total pavement thickness, i.e. one-fourth to one-third, and by the fact that the unbound base material used in Kentucky, i.e. DGA is uniformly high in quality and serves as the second component of a two-component pavement system.

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(4) Shook, J. F., and Fang, H. Y., Special Report No. 66, Highway Research Board, 1961.