

Research Report
UKTRP-86-14

THICKNESS DESIGN CURVES FOR ASPHALTIC CONCRETE
ON A 4-INCH LAYER OF DENSE-GRADED AGGREGATE, OR
ON 6, 9, OR 12 INCHES OF STABILIZED SOIL, OR
FOR MAXIMUM UTILIZATION OF DENSE-GRADED AGGREGATE

by

Herbert F. Southgate, P.E.
Chief Research Engineer

Kentucky Transportation Research Program
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with
Transportation Cabinet
Commonwealth of Kentucky

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May 1986

ASPHALTIC CONCRETE ON 4 INCHES
OF DENSE-GRADED AGGREGATE

The Kentucky Department of Highways has four sets of thickness design curves (1), each for a fixed percentage of asphaltic concrete thickness of the total thickness. All four sets of curves are based on the same criteria (2), thus permitting the designer to choose a proportion based on an economic analysis. The tensile strain-fatigue relationship (for the asphaltic concrete) for an asphalt concrete modulus of 480 ksi is given by

$$\log e_a = -2.649752 - 0.1705123 * (\log EAL) \quad 1$$

in which e_a = tensile strain at the bottom of the asphaltic concrete, and
EAL = number of 18-kip equivalent loadings.

The subgrade strain-fatigue relationship is defined by

$$\log e_s = -3.3034474 + 0.1257711 * (\log EAL) \\ - 0.024835709 * (\log (EAL))^2 \quad 2$$

in which e_s = vertical compressive strain at the top of the subgrade.

The Division of Construction, Kentucky Department of Highways, has determined that the desired compaction of the first layer of asphaltic concrete placed directly on the subgrade is not being obtained. Thus, the Kentucky Department of Highways requested a set of design curves (Figure 1) using a 4-inch layer of dense-graded aggregate as a working platform for constructing the remainder of the pavement structure using asphaltic concrete.

MAXIMUM UTILIZATION OF DENSE-GRADED AGGREGATE

The Kentucky Department of Highways requested a set of thickness design curves based on the maximum utilization of dense-graded aggregate. A minimum of 4 inches of asphaltic concrete is to be utilized. The same fatigue criteria (2) (Equations 1 and 2) used to develop the other pavement thickness design curves were used, but the proportioning scheme had to be modified. The minimum thickness of asphaltic concrete must increase with increasing fatigue such that the allowable tensile strain at the bottom of the asphaltic concrete is not exceeded. Figure 2 illustrates the relationship of the thicknesses of the two materials based upon the limiting strain criteria. Using CBR 4 as an example, the limiting vertical compressive strain at the top of the subgrade permits the thickness of dense-graded aggregate to decrease by 12.5 inches for a 4-inch increase in asphaltic concrete. However, the tensile strain criterion for the asphaltic concrete permits the thickness of dense-graded aggregate to decrease 12.5 inches for a corresponding increase of

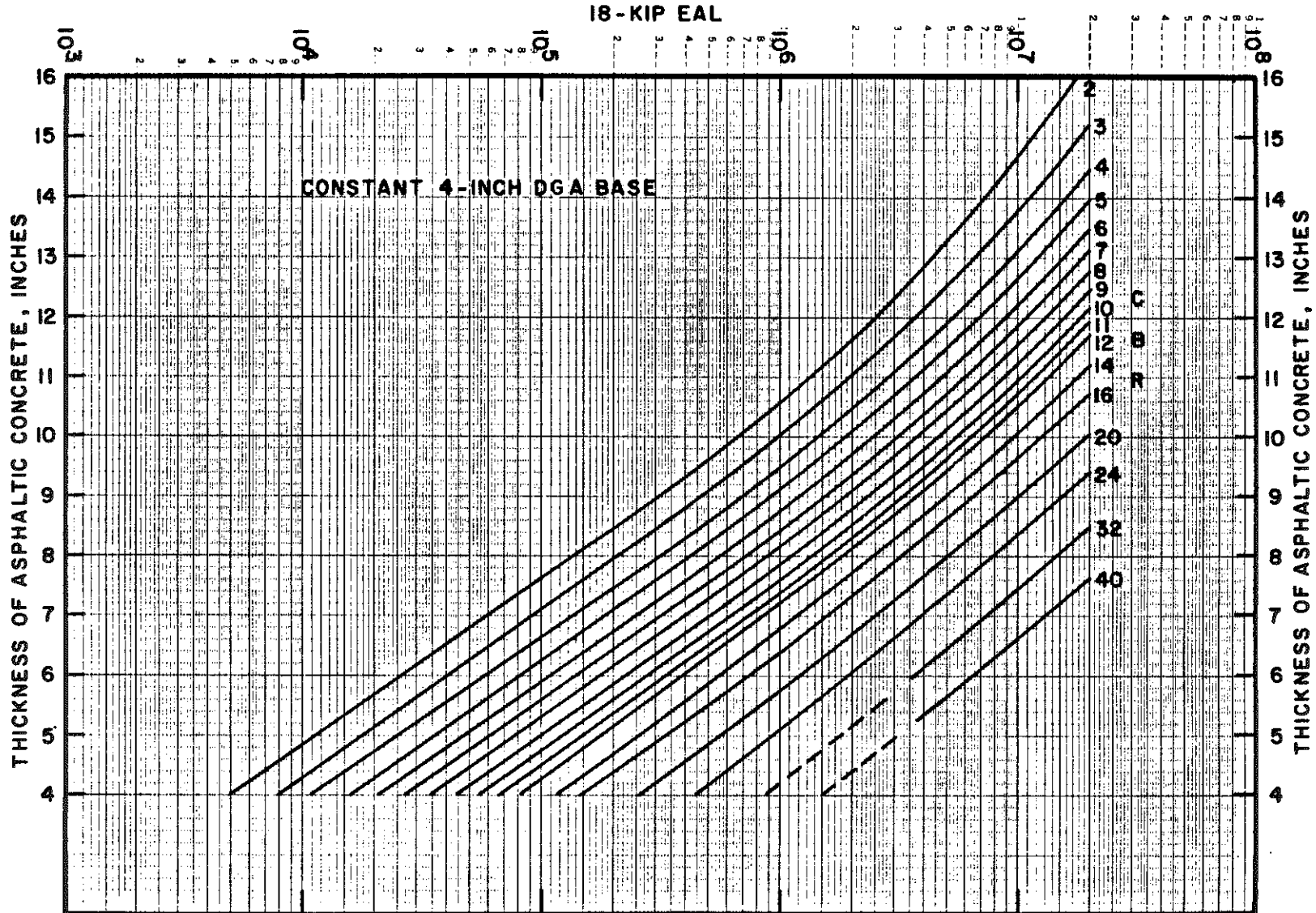


Figure 1. Asphaltic Concrete Pavement Thickness Design Curves Having a Constant 4-Inch Thickness of Dense-Graded Aggregate.

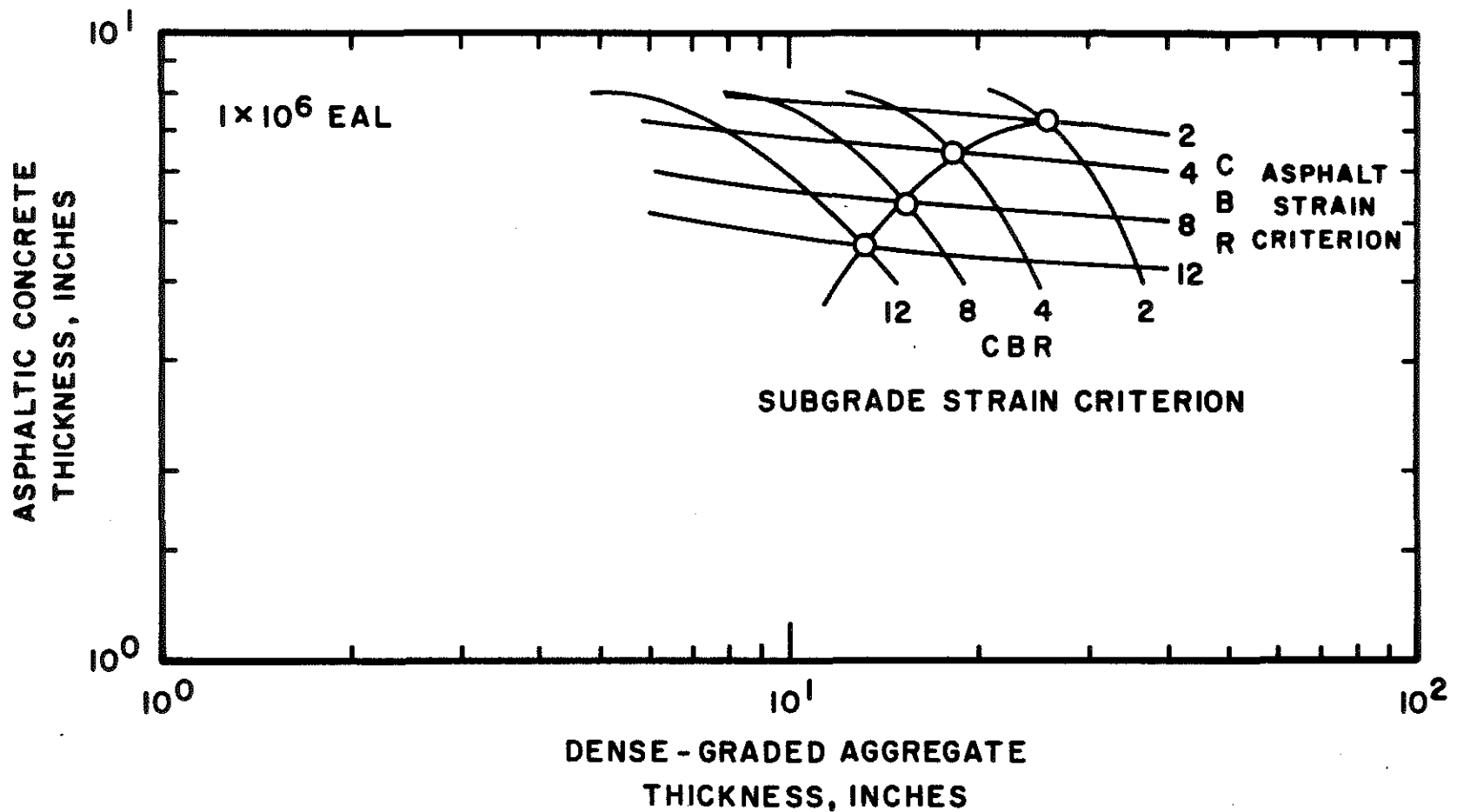


Figure 2. Relationship of the Thicknesses of Asphaltic Concrete and Dense-Graded Aggregate Based upon Limiting Strain Criteria.

only 0.75 inch of asphaltic concrete. To develop design curves that maximize the thickness of dense-graded aggregate, both criteria must be satisfied and appropriate design relationships determined.

The total pavement thickness for 7,300 18-kip EAL or less is that associated with a limiting tensile strain at the bottom of the asphaltic concrete. For 4 million EAL or greater, the total thickness is that required by the limiting vertical compressive strain at the top of the subgrade. Between 7,300 and 4 million EAL, the proportioning total pavement thickness was obtained from

$$TD = TA + P (TS - TA), \quad 3$$

in which TD = total design thickness,

TA = design thickness according to the tensile strain criteria at the bottom of the asphaltic concrete,

TS = design thickness according to the vertical compressive strain criteria at the top of the subgrade,

P = $-1.4116683 + 0.36529028 * (\log EAL)$, and

EAL = number of 18-kip equivalent loadings.

Maximum utilization of dense-graded aggregate requires a minimal thickness of asphaltic concrete, but that thickness must increase with increasing EAL and be sufficient to respect the limiting tensile strain criterion. Thus, proportioning according to Equation 3 cannot be used.

Figure 2 illustrates the relationships between CBR and thicknesses of asphaltic concrete and dense-graded aggregate for a specific EAL. For a CBR 4, the curve having a flat slope defines the required thickness of asphaltic concrete and dense-graded aggregate to meet the limiting tensile strain criterion at the bottom of the asphaltic concrete. The curve with a steeper slope defines the required combination of material thicknesses respecting the vertical compressive strain criterion at the top of the subgrade. The intersection of the two curves yields the thicknesses of the two materials that satisfies both sets of limiting strain criteria. Similar analyses for other values of EAL permitted creation of Figure 3.

In the bottom portion of Figure 3, the required thickness of asphaltic concrete is given. Thus, the design thickness of dense graded aggregate is the difference between the total thickness from the upper set of curves and the asphaltic concrete thickness from the lower set of curves.

While comparisons of designs using "substitution ratios" may give reasonable results for the original four sets of design curves and Figure 1, such an analysis for Figure 3 may lead to peculiar results because the same proportioning (Equation 3) could not be used. While Figure 3 respects the same strain criteria, results are not directly comparable.

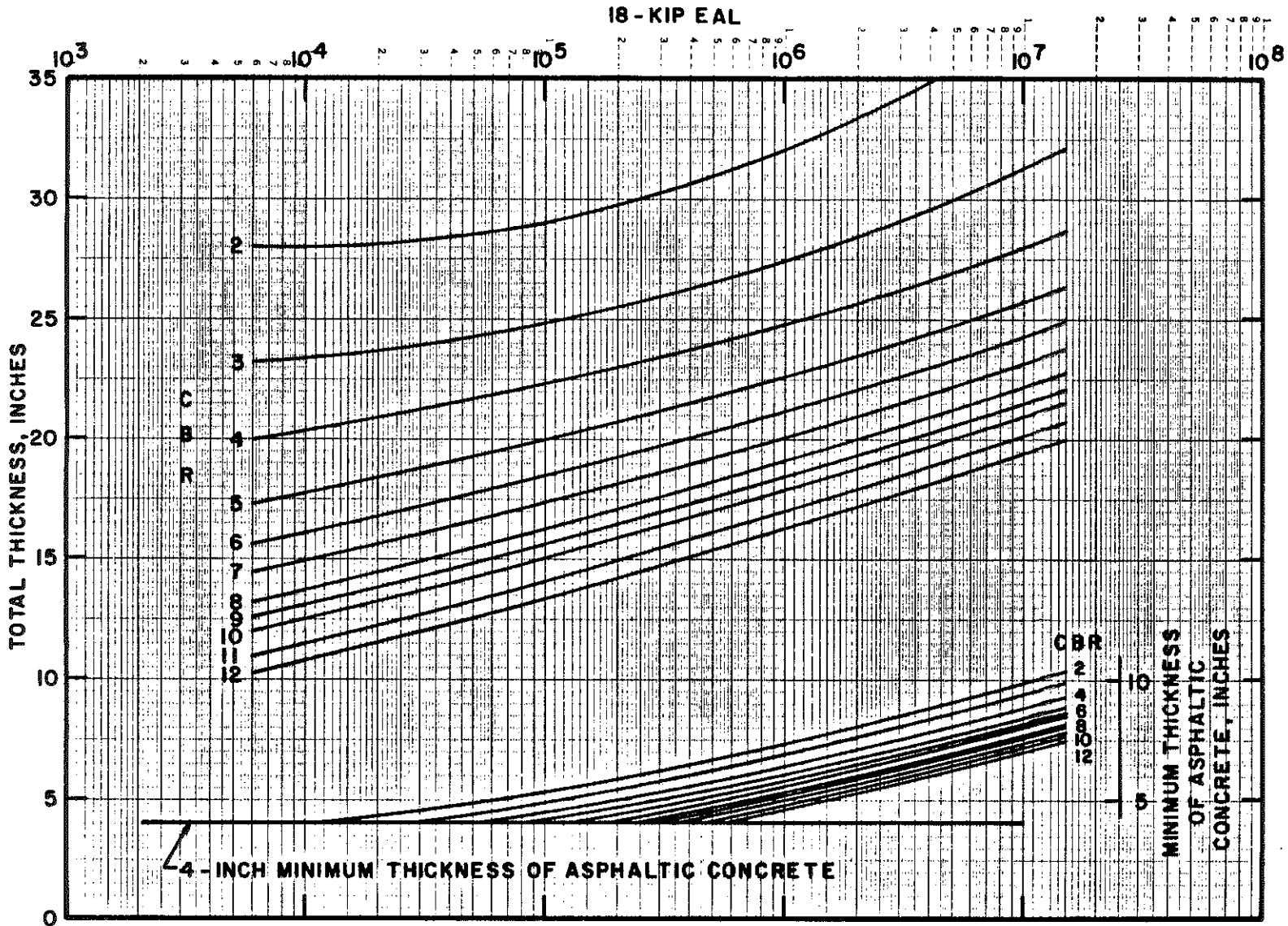


Figure 3. Asphaltic Concrete Pavement Thickness Design Curves Using a Maximum Thickness of Dense-Graded Aggregate.

THICKNESS DESIGNS EMPLOYING A SOIL STABILIZATION LAYER

Thickness design curves for 6 inches, 9 inches, or 12 inches of a stabilized soil layer also were prepared. The remaining pavement structure would employ a 4-inch layer of dense-graded aggregate and the thickness of asphaltic concrete to resist the fatigue loading of the design traffic (EAL). The limiting strain criteria and thickness proportioning system (Equation 1) employed for the original four sets of thickness design curves were used to create the sets of curves shown in Figures 4 through 6.

RECOMMENDATIONS

Regardless of the thickness of the stabilized soil layer chosen, the pavement design must be based on the weak subgrade condition.

Soil stabilization should be considered for soils having a CBR of 6 or less. The specific stabilizing material should depend upon the type of soil.

Portland cement should be considered when the soil has a medium- to coarse-grained texture, but it is not suited for fine-grained soils such as fat clays. Problems will be encountered during in-place mixing to crush or break up the soil so that 100 percent passes the 1-inch sieve and 80 percent passes the No.-4 sieve as required by Kentucky Department of Highways specification Section 304. Portland cement stabilization has one disadvantage, in that once the soil cement layer cracks, autogenous healing will not take place because the cement already has hydrated.

Stabilization with hydrated or quick lime should be considered for fine- and medium-grained soils. Either type of lime has the ability to heal itself whenever it cracks because lime is slow to hydrate. However, lime does not work well with coarse-grained soils.

The type and amount of stabilizing admixture should be determined from laboratory tests on the soil for the specific project. The optimum amount of cement or lime should be used. Literature review suggests that strength characteristics drop significantly on either side of optimum. Where less than the optimum amount is used, insufficient cementation takes place and the partially cemented material breaks up prematurely and reverts to its original state. When the amount exceeds optimum, premature shrinkage cracking may occur, resulting in small-sized slabs rocking on a very weak material.

Extreme care should be taken to prevent the stabilized soil layer from cracking. Heavy loads could pump the underlying soft material through the cracks and into the layers above, thus weakening the entire structure. These loads may be from heavy construction equipment. Construction trucks should carry partial loads until sufficient pavement structure has been constructed to minimize premature cracking and/or failure by those loads. Analyses should be made to determine the thickness of the partial pavement structure to prevent premature cracking by loaded

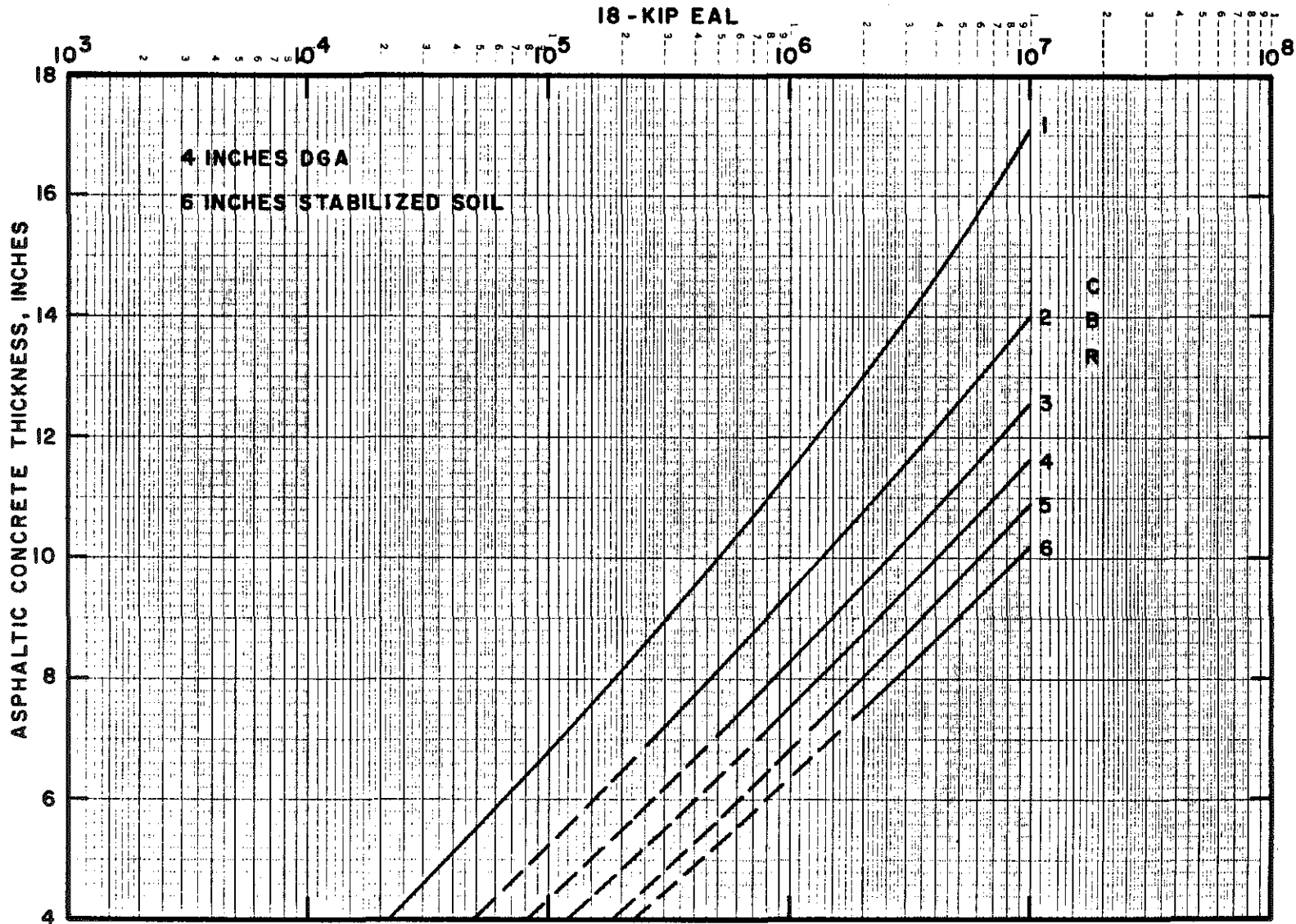


Figure 4. Asphaltic Concrete Pavement Thickness Design Curves for a Combination of 4 Inches of Dense-Graded Aggregate and 6 Inches of Stabilized Soil.

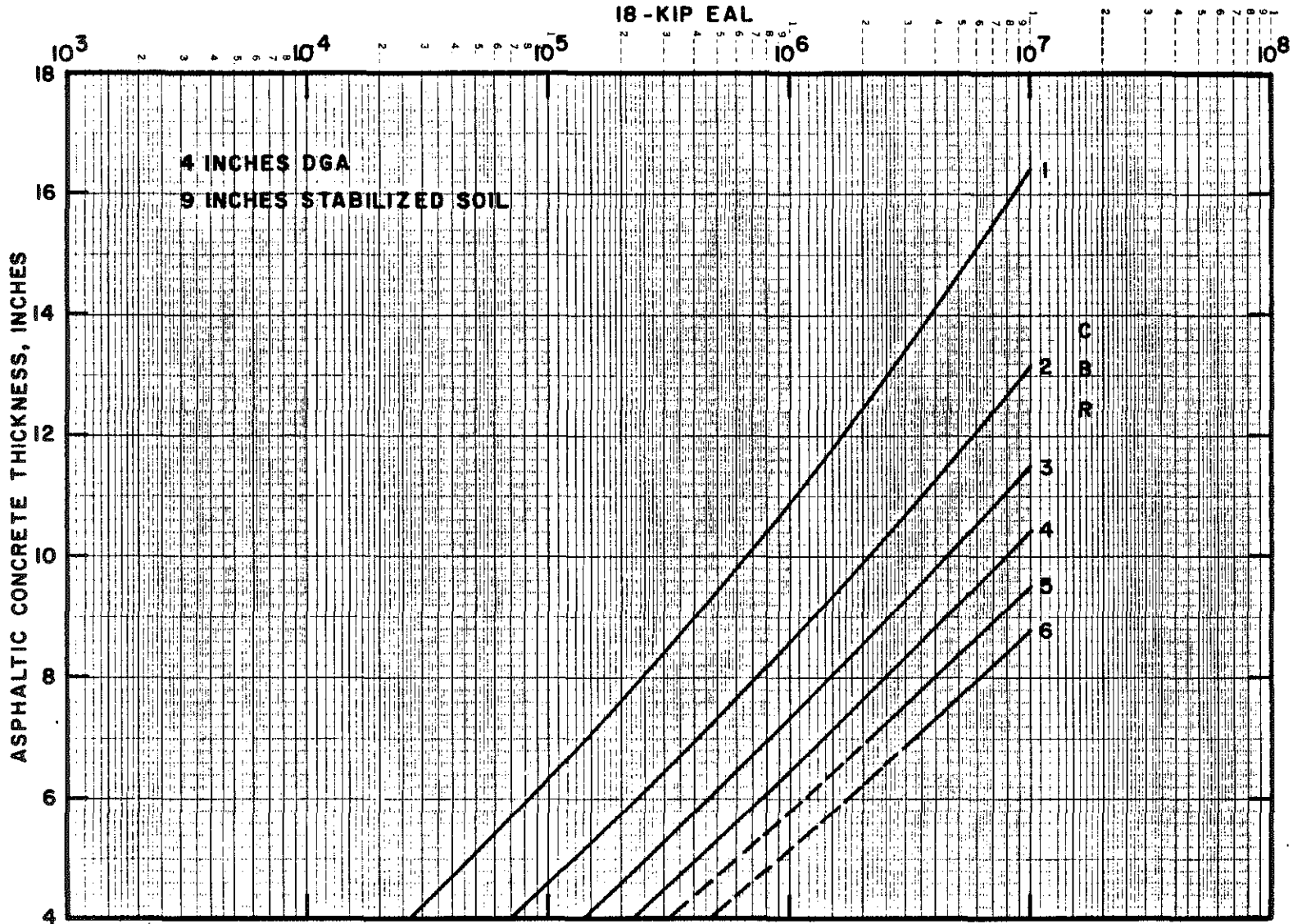


Figure 5. Asphaltic Concrete Pavement Thickness Design Curves for a Combination of 4 Inches of Dense-Graded Aggregate and 9 Inches of Stabilized Soil.

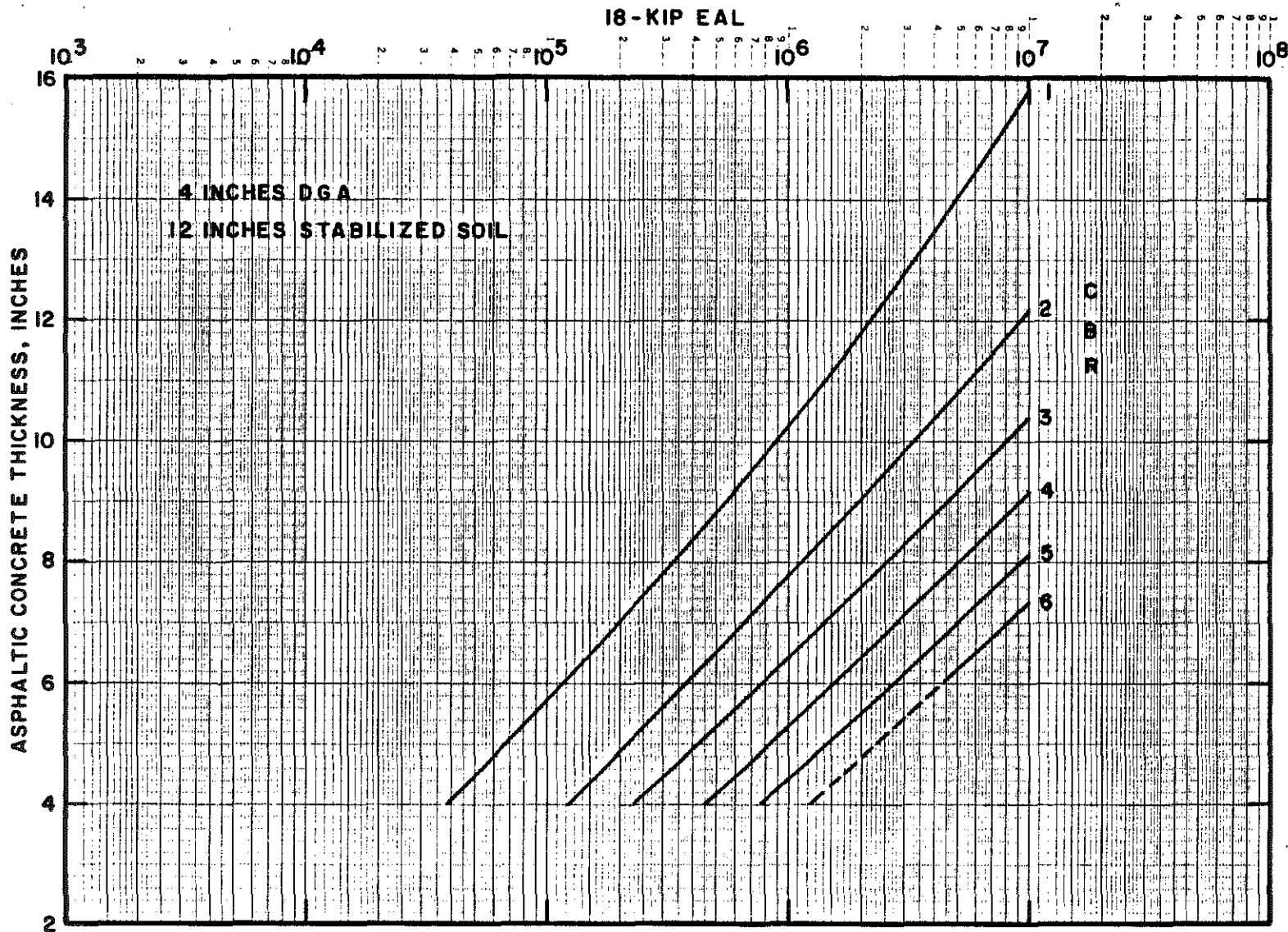


Figure 6. Asphaltic Concrete Pavement Thickness Design Curves for a Combination of 4 Inches of Dense-Graded Aggregate and 12 Inches of Stabilized Soil.

construction vehicles.

REFERENCES

1. J. H. Havens, R. C. Deen, and H. F. Southgate, "Design Guide for Bituminous Concrete Pavement Structures", Kentucky Transportation Research Program, University of Kentucky, Lexington, Research Report UKTRP-81-17, August 1981.
2. H. F. Southgate, R. C. Deen, and J. H. Havens, "Development of a Thickness Design System for Bituminous Concrete Pavements", Kentucky Transportation Research Program, University of Kentucky, Lexington, Research Report UKTRP-81-20, November 1981.