State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways

# AASHO ROAD TEST EQUATIONS APPLIED TO THE DESIGN OF BITUMINOUS PAVEMENTS IN ILLINOIS

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BY

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AND
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A RESEARCH STUDY BY
ILLINOIS DIVISION OF HIGHWAYS
BUREAU OF RESEARCH AND DEVELOPMENT
IN COOPERATION WITH
U. S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

Prepared for publication by
The Highway Research Board

OCTOBER 1964

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Since the completion of the AASHO Road Test Project, the Illinois Division of Highways has been studying the results and doing research directed towards developing practical applications of the findings. The research work has been done in cooperation with the U.S. Department of Commerce, Bureau of Public Roads. This work has culminated in the development of two interim structural design procedures, one for bituminous pavements and the other for portland cement concrete pavements.

This paper is concerned with the work done in applying the findings of the Road Test flexible pavement research to the structural design of bituminous pavements in Illinois. It presents background information and concepts used in developing the design procedure, describes the development of the procedure, and demonstrates its application.

The procedure provides for establishing the types and thicknesses of materials to be used in the various layers of the pavement structure consistent with the volume and composition of traffic, the length of time the pavement is to serve this traffic, the strength characteristics of the subgrade soils and pavement materials, and the minimum level of service to be provided by the pavement during its lifetime.

The AASHO Road Test flexible pavement performance equation serves as the basis of this design procedure. The equation explains performance of the test sections as related to pavement design, the magnitude and configuration of the axle load , and the number of axle load applications. This equation necessarily is limited to the physical environment of the Project; to the materials used in the test pavements; to the range in pavement thicknesses

The system of measuring present serviceability was derived through the use of the subjective serviceability ratings of a great number of typical pavements. The pavements were rated on a scale of zero to five by a panel of men selected to represent many important groups of highway users. A mathematical index (Present Serviceability Index) was then developed for estimating the subjective ratings from objective measurements taken on the pavement.

The following equation was developed to determine the level of serviceability of flexible pavement sections on the AASHO Road Test:

$$p = 5.03 - 1.91 \log (1 + \bar{SV}) - 0.01 \sqrt{C + P} - 1.38 \bar{RD}^2$$

where: $p$ = the present serviceability index,

$\bar{SV}$ = the mean of the slope variance in the two wheelpaths as measured by the AASHO Longitudinal Profilometer,

$C + P$ = a measure of cracking and patching in the pavement surface, and

$\bar{RD}$ = a measure of rutting in the wheelpaths.

By relating the results of the AASHO profilometer and Illinois roadometer, the present serviceability index equation becomes:

$$p = 10.91 - 3.90 \log \bar{RI} - 0.01 \sqrt{C + P} - 1.38 \bar{RD}^2$$

where: $\bar{RI}$ = Roughness Index in inches per mile, as obtained by the Illinois Roadometer.

Performance of a pavement is then determined by relating its serviceability records to the corresponding numbers of axle load applications.

<u>Performance Equation from AASHO Road Test.</u> Present Serviceability Index values were determined every two weeks for each Road Test section. Serviceability trends were developed for the sections by plotting the Present Serviceability Index values against the corresponding axle load applications. These trends represent the performance of the pavement sections.

where : $a_1$, $a_2$, $a_3$ are coefficients of relative strength of surface, base, and subbase as related to performance (for the Road Test $a_1 = 0.44$, $a_2 = 0.14$, and $a_3 = 0.11$),

$D_1$ = thickness of bituminous surface course in inches,

$D_2$ = thickness of base course in inches, and

$D_3$ = thickness of subbase in inches.

Equivalent Axle Load Concept. As previously stated, the Road Test equations express the performance of the test sections in terms of pavement design, axle load and configuration, and number of axle load applications. The term "$W_t$" in the performance equations denotes the number of axle load applications of a given magnitude and configuration. This was possible on the Road Test because the traffic on any one test section had identical axle loads and arrangements.

Before any attempt could be made to apply the equations for design purposes, it was necessary to reduce normal mixed traffic axle loadings to some common denominator, or basic loading. The system developed reduces mixed traffic axle load applications to an equivalent number of 18-kip (18,000-lb.) single axle load applications. The selection of 18-kip single axle load applications as the common denominator has no particular significance except that 18,000 pounds is the legal single axle load limit in Illinois.

This system makes use of "equivalency factors" that were derived from the Road Test performance equations. The equivalency factor for any given axle load expresses the number of applications of an 18-kip single axle load that are equivalent to one application of the given axle load.

## DEVELOPMENT OF DESIGN PROCEDURE

### General

This prodecure for the structural design of bituminous pavements in Illinois has been prepared on the basis of the findings of the AASHO Road Test supplemented with the results of research studies[3/] conducted by the Illinois Division of Highways. The procedure reflects engineering experience and judgement of the Divsion, and recommendations of the AASHO Committee on Design.[4/]

The design of a pavement structure requires the compilation and correlation of the following factors: (1) the volume and axle load distribution of the traffic that the pavement will be expected to carry; (2) the type and strength of the roadbed soil upon which the pavement will be built; (3) the length of time and quality of service expected from the pavement; (4) the environmental and climatic conditions of the region where the pavement is to be built; and (5) the relative ability of the available pavement materials to support loads.

All of these factors have been taken into consideration in the development of this design procedure. Variations in climatic conditions as they exist from one part of the State to another, and particularily between the extreme northern and extreme southern portions, undoubtedly affect pavement performance. However, the relative effects of these variations on pavement performance are not sufficiently distinguishable at the present state of knowledge to be taken into account in pavement structural design. Therefore, climatic effects have been considered only on a Statewide basis. This involved the assumption that, based on present knowledge, climatic conditions throughout the State do not differ sufficiently from those of the Ottawa area (site of the AASHO Road Test)

count data were used to determine the distribution of single and tandem axle weights for the various classifications of vehicles in the mixed traffic stream.

Preliminary analyses demonstrated the need to give special consideration to average axle loadings as they exist for the various individual classifications of commercial vehicles. Variations in the distribution of vehicle classifications in the commercial traffic stream from one highway to another are too great to permit the use of a Statewide average commercial vehicle in evaluating the effects of mixed traffic axle loadings on pavement performance. In the final analysis, consideration was given to the differences in average axle loadings as they exist for passenger cars, single units (all two-axle and three-axle single unit trucks and all buses), and multiple units (three-axle, four-axle, and five-axle truck tractor semitrailers and all full trailer combinations).

The preliminary analyses also indicated the need for considering the differences in average axle weights of both single units and multiple units operating on highways ranging from high volume major highways with heavy commercial hauling to low-volume local roads with farm-to-market type hauling. To accomplish this the entire highway system was divided into four general classifications:

(1) Class I Roads and Streets - roads and streets being designed as four-lane or more facilities, or as part of future four-lane or more facilities;

(2) Class II Roads and Streets - roads and streets with structural design traffic greater than 1000 ADT and being designed as two-lane or three-lane facilities;

(3) Class III Roads and Streets - roads and streets with structural design traffic between 400 and 1000 ADT, and

(4) Class IV Roads and Streets - roads and streets with structural design traffic less than 400 ADT.

$$\text{Log}\ \frac{W_{t18}}{W_{t_x}} = 4.79 \log (x \neq 2) - 4.79 \log (18 \neq 1) - 4.33 \log (2) + \frac{G_t}{\rho_{18}} - \frac{G_t}{\rho_x} \qquad (7)$$

The terms $W_t$, $\rho$, $G_t$, and $\rho$ are as previously defined.

The ratios between $W_{t18}$ and $W_{t_x}$ in Equations (5) and (7) express the relationship between an 18-kip single-axle load and any other axle-load (x). As shown by the equations, the equivalency factors vary with pavement design and serviceability level as well as with axle load and axle configuration. Therefore, averages of the values obtained for designs varying from D = 1.0 to D = 6.0 and for present serviceability levels of 2.0 and 2.5 have been used. The 18-kip equivalency factor was determined for each 2000-pound increment of load for single axles and for each 4000-pound increment of load for tandem axles (Table 1).

These factors were used in combination with loadometer survey data and traffic classification count data to reduce mixed traffic to a fixed number of 18-kip equivalent single axle load applications. Loadometer data, dating from 1945 to 1962, were available from 19 loadometer stations located on the primary system of highways in Illinois (Class I and Class II roads and streets). Traffic classification count data were available for highways carrying traffic volumes corresponding to Class I, Class II, and Class III roads and streets. Neither loadometer data nor adequate traffic classification count data were available for highways carrying traffic volumes corresponding to Class IV roads and streets.

The loadometer data were adjusted in accordance with the traffic classification count data to provide more representative samples since only a small percentage of vehicles were weighed. The adjusted data provided the distribution of single and tandem axles in each weight group for each classifi-

As previously stated, neither loadometer data nor adequate traffic classification count data were available for highways carrying traffic volumes corresponding to Class IV roads and streets. This made it impossible to determine the performance of these highways and to correlate this performance to the Road Test equation. Thus, to extend the design procedure to include Class IV roads and streets, it was necessary to assume a basic structural design and traffic loading consistant with previous experience.

The 18-kip equivalent single axle-load application factors per vehicle classification for Class I, Class II, Class III, and Class IV roads and streets are given in Table 2.

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As can be seen from Table 2, the results of the analysis yielded two important facts regarding reducing mixed traffic to a number of equivalent 18-kip single axle-load applications: (1) the effect of passenger cars is small in proportion to the effect of single and multiple units; and (2) the effect of multiple units is eight to nine times greater than the effect of single units. Thus, the total number of equivalent 18-kip single axle load applications to be generated by mixed traffic can depend more on the distribution of the various classifications of vehicles in the traffic stream than on the total volume of traffic.

The values listed in Table 2 were used in developing equations to convert mixed traffic into a traffic factor for use in structural design.

In developing the equations, special attention was given to the structural design traffic and to the number of single units and multiple units per day in the design lane. While the structural design traffic represents an estimate of the average daily traffic in both directions that will be carried by the highway facility, the pavement structural design will

total number of equivalent 18-kip single axle-load applications representing the traffic carried by the pavement to this point in time. The present serviceability index was determined from roadometer measurements and a patching and cracking survey. The total number of equivalent 18-kip single axle load applications was determined from the recorded numbers of passenger cars, single units, and multiple units, and the developed 18-kip equivalency factors for these three vehicle classifications (See Table 2).

The analyses of the data from the selected pavements showed that the Road Test performance equation cannot be applied directly, as it predicts, on the average, higher levels of performance than were actually obtained. However, there was evidence of definite trends which indicated that performance of the selected pavements agrees closely with the performance of pavements on the Road Test of lesser thickness. This suggested the hypothesis that the general form of the performance equation is applicable, and that the equation could be suitably modified for practical application in structural design by developing a factor for adjusting the design thickness term in the equation for $\rho$ and $\beta$. This factor has been termed a Time-Traffic Exposure Factor, T.

The relationship between Road Test pavement thickness design and Illinois pavement thickness design that can be expected to give the same performance is:

$$D = \frac{D_t}{T}$$

where $D$ = Road Test thickness Index,

$D_t$ = Illinois structural number,

$T$ = Time-traffic exposure factor.

where: $D_t$ = Illinois structural number,

$a_1, a_2, a_3$ = coefficients of relative strength of the surface, base and subbase, respectively, and

$D_1, D_2, D_3$ = thicknesses in inches of the surface, base, and subbase, respectively. For composite pavement $D_2$ = thickness of the existing slab.

Values of the coefficients $a_1$, $a_2$, and $a_3$ for the pavements included in this study are as follow:

Surface Course

| | |
|---|---|
| Bituminous Concrete Subclass I-11 | $a_1 = 0.40$ |

Base Course

| | |
|---|---|
| Crushed Stone, Grade 8 | $a_2 = 0.13$ |
| Existing PCC slab | $a_2 = 0.40$* |

Subbase Course

| | |
|---|---|
| Gravel, Grade 7 | $a_3 = 0.12$ |

The thickened edge slabs were converted to effective uniform thicknesses for use with the structural number equation by a procedure which makes use of Westergaard's equation for corner loading as follow:

| Slab Thickness, inches | Effective Thickness, inches |
|---|---|
| 7-8-7 | 7.00 |
| 9-6-9 | 7.06 |
| 9-7-9 | 7.71 |
| 9-9-7-9-9 | 8.75 |
| 10-10-8-10-10 | 9.75 |

The results of the analyses for the 63 pavement sections are depicted in Figure 1, where the time-traffic exposure factor, T, has been plotted against

*Mean value determined from analysis of data from Illinois composite pavements. Also, it is the value suggested for use in the "Manual of Instructions for Pavement Evaluation Survey", dated August 1962, by the AASHO Committee on Highway Transport.

In plotting the soil support CBR scale on the charts, only one point (CBR = 3.0) was obtained directly from the performance equation. A second point on Chart 2 was obtained by the procedures recommended by the AASHO Committee on Design. The Committee studied the performance of several sections having the greatest thickness of crushed stone base that were on the loop carrying the 18-kip single axle-loads. The study indicated that approximately 4.5 inches of bituminous concrete on a sufficient thickness of crushed stone to minimize the effects of the roadbed soils should carry approximately 1,000 18-kip single axle-load applications per day for a 20 year period and, at the same time, retain a present serviceability level at or above 2.0 for the entire period. The Road Test Thickness Index, D, for this section is 1.98 (4.5 x 0.44) which is equivalent to a value of 2.18 on the structural number scale included in Chart 2 (1.98 x 1.1). The 1,000-18-kip single axle load applications per day for 20 years is equivalent to a value of 7.3 on the traffic factor scale of Chart 2.

Thus, a second or maximum point on the soil support CBR scale of Chart 2 was established by projecting a line through 2.18 on the structural number scale and 7.3 on the traffic factor scale. The intersection of this line with the soil support CBR scale was assigned a value of 110, corresponding to the results of Illinois CBR tests on the Road Test crushed stone material. This point represents the supporting value of soils having the support characteristics of the crushed stone base material used on the AASHO Road Test. A logarithmic scale between CBR values of 3.0 and 110 was assumed and extended to 1.

Similar procedures were used to establish a second or maximum point on the soil support CBR scale of Chart 1. A Road Test Thickness Index of 1.98 on a crushed stone embankment is equivalent in performance to a Road

determined by a survey conducted in 1961 by the Bureau of Public Roads in cooperation with the State highway departments at the request of the AASHO Committee on Highway Transport.[5/] A study of the terminal serviceability level of highway pavements in Illinois has fairly well substantiated this value as an average value for Illinois. However, pavements of four-lane divided expressways in Illinois are being retired at serviceability levels above 2.0, and generally averaging 2.4. Further, the AASHO Committee on Design[4/] has recommended that the design period for major highways be considered ended at a present serviceability index of 2.5. For these reasons the design requirements have been based on a terminal serviceability level of 2.5 for Class I roads and streets (expressways and Interstate highways), and 2.0 for all others.

Pavement Structure Materials

The developed design procedure reflects the pavement structure thickness in terms of a structural number. The structural number is related to the thickness of the various layers of the pavement structure as follows:

For pavements with granular and stabilized granular base courses,

$$D_t = a_1D_1 + a_2D_2 + a_3D_3$$

For pavements with portland cement concrete base course,

$$D_t = a_1D_1 + a_2D_2$$

where: $D_t$ is the structural number,

$a_1$, $a_2$, and $a_3$ are coefficients of relative strength of the surface course, base course, and subbase, respectively.

$D_1$ = thickness of surface course in inches,

$D_2$ = thickness of base course in inches, and

$D_3$ = thickness of subbase in inches.

granular materials, granular materials stabilized with bituminous materials, granular materials stabilized with portland cement, and granular materials stabilized with lime-fly ash.

re Figure 3 depicts the relationship developed between coefficients for granular base materials and laboratory CBR values. The upper limit represents the Road Test crushed stone base material. The value of $a_2$ for this material is 0.14 and the CBR value, as determined by Illinois, is 110. The lower point represents the Road Test sand-gravel subbase material when used as a base course. The coefficient for this material when used as a base course was estimated from the Road Test data to be 0.07, and the CBR value of the material was determined to be 30.

The coefficient for bituminous stabilized granular base course materials was considered to vary with Marshall Stability. The developed relationship is re shown in Figure 4. The upper point on the curve represents the bituminous treated base on the Road Test. The sand-gravel subbase material was mixed with 5.2 percent of 85-100 penetration grade paving asphalt. A value of 0.34 was estimated from the Road Test data for this material, and the Marshall stability tests conducted by Illinois indicated a value of 1900. The intermediate point represents Grade 11 gravel stabilized with either emulsified or liquid asphalts. The coefficient was taken as equal to 0.16 and the equivalent Marshall Stability as 300. The lower point represents the Road Test sand-gravel material without treatment ($a_2 = 0.07$).

It was assumed that the coefficient for portland cement stabilized granular base course material varies with the 7-day compressive strength of the re material, determined from field and related laboratory tests, as shown in Figure 5. The curve was developed from three points. The upper represents the Road Test cement treated base material (sand-gravel subbase material) with 4 per cent cement.

re Division. This relationship is shown in Figure 7. The point at $a_3 = 0.11$ and CBR = 30 represents the sand-gravel ssubbase material used on the Road Test. The lower point was established at $a_3 = 0.05$ and CBR = 5. This is considered to represent a sandy-clay material. The upper point was established at $a_3 = 0.14$ and CBR = 110 for 100 percent crushed material with rough textured surfaces.

## SPECIAL CONSIDERATIONS

### General

The structural design procedure presented in this paper establishes a means of determining the structural number ($D_t$) and, subsequently, the thicknesses of subbase, base, and surface courses required for a bituminous pavement to give satisfactory performance while carrying a given volume of mixed traffic for a definite period of time. The factors affecting pavement design that are considered in this procedure include the volume and composition of mixed traffic, the support strength of the roadbed soils, the strength characteristics of the materials used in the pavement structure, and the length of time the pavement is being designed to serve traffic (design period).

This procedure has been developed specifically for application in the structural design of bituminous pavements in Illinois. Applying the procedure in the design of pavements in regions where climatic and environmental conditions vary widely from those in Illinois must be done with extreme caution. It is expected that modifications to reflect variations in climatic and environmental conditions will be necessary to permit direct application of this procedure in pavement design for other regions. Further, the differences in axle loadings as they exist on Illinois highways and on highways in other regions should be considered.

be reduced by increasing the thickness of the pavement structure, but it may be necessary to take other steps to assure adequate pavement performance. The problems that can be encountered because of the roadbed soils being subject to permanent deformation, excessive volume changes, excessive deflection and rebound, frost susceptibility, and non-uniform support from wide variations in soil type or state should be recognized at the design stage, and corrective measures should be included in the design. These corrective measures are in addition to the design thicknesses determined by the procedure.

Pavement Structure

A bituminous pavement consists of a two-layer or a three-layer structure, including a surface course and base course or a surface course, base course, and subbase course. Each layer must have sufficient strength and thickness to sustain the load imposed upon it and to distribute it over a sufficient area that the structural strength of the next succeeding layer will not be exceeded. Thus, the composition of the pavement structure must be such that the strength characteristics of the surface course material are higher than those of the base course or subbase, and that the strength characteristics of the base course material are higher than those of the subbase. This must be borne in mind in selecting the materials to be used in the pavement structure. In other words, if two granular materials having different strength characteristics are selected for use, the higher strength material must be used as the base course and the lower strength material as the subbase. If only one material is to be used for both the subbase and the base course, then the pavement structure must be considered as a two-layer system consisting only of a surface course and a base course.

structural design generally will permit the use of a granular base under a bituminous mat, and the Nationwide average life of this type of pavement is about seventeen years. Data from the AASHO Road Test has demonstrated that the level of performance of a bituminous pavement is increased considerably when the granular base material is stabilized with bituminous materials or portland cement. Thus, it is recommended that the longer design period be used for Class I and Class II roads and streets since the structural design generally will require a stabilized granular base course.

The design period may or may not be the actual service life of the pavement. The actual service life may be longer or shorter than the design period, depending upon the differences between conditions under which the pavement actually serves and the conditions assumed in design. Highly significant are the differences between the structural design traffic and the actual traffic carried by the pavement, and between the structural design terminal serviceability level and the actual serviceability level at which the pavement is retired from service.

Stage Construction

Planned stage construction is the construction of roads and streets in two stages according to design and a predetermined time schedule. The first stage includes the complete construction of the required thickness of subbase and/or base course along with the application of a bituminous surface treatment to serve as a temporary surface course. The second stage includes the construction of the required type and thickness of bituminous mat.

It is recommended that planned stage construction be used only on roads and streets requiring structural numbers not in excess of 2.49. The required structural design should be determined for the full selected design period. The pavement structure may then be scheduled for construction in two

The traffic equations in Table 4 and the per cent of vehicles in the design lane, Table 3, are used to convert structural design traffic into a traffic factor representing the total number of equivalent 18-kip single axle-load applications to be carried by the pavement during the entire design period. Any special case, such as that described under Traffic and Loads in SPECIAL CONSIDERATIONS will require a special analysis.

The soil support CBR value should be determined from the soil survey and from laboratory CBR tests on the soil samples. In the absence of laboratory CBR tests, or other approved test procedures, the CBR value may be estimated as shown in Table 5. It is necessary that the soil support CBR value be taken as a minimum value. In addition, corrective measures must be provided for any and all isolated areas where the support of the roadbed soils falls below the minimum so that the minimum requirement will be met throughout.

The structural number, $D_t$, required for the conditions under which the pavement is being designed to serve is determined from Chart 1 for Class I roads and streets, and from Chart 2 for all other classifications of roads and streets. A line passing through the determined point on the traffic factor scale and on the soil support CBR scale will intersect the structural number scale at the required $D_t$ value.

The thicknesses of the various layers of the pavement are then determined from the structural number equations and from the data in Table 6. By setting the thicknesses of two of the layers, the thickness of the third layer can be determined. Trial designs with variations in thicknesses and with various types of pavement materials will enable the designer to arrive at the most practical and economical design. To assist in this, the minimum thickness and material requirement given in Table 7 should be followed.

To do this it is first necessary to refer to the minimum thickness and material requirements which serve as guides in selecting the types of materials and determining the actual thicknesses to be used. Referring to Table 7, the minimum requirements for $D_t$ = 4.0 to 4.99 are:

Surface Course - not less than 4 inches thick and not less than I-11 bituminous concrete.

Base Course - not less than 8 inches of stabilized granular material having a minimum compressive strength of 650 psi or a minimum Marshall Stability of 900.

Subbase - not less than 4 inches thick and not less than Grade 11 gravel, if used.

Using these minimum requirements as guides, it is now possible to select the materials to be used in the surface, base, and subbase courses, and to calculate the corresponding thicknesses using the equation:

$$D_t = a_1D_1 + a_2D_2 + a_3D_3$$

The values of the coefficients for the materials selected for trail designs in this sample problem are obtained from Table 6 as follow:

| Surface Course | $a_1$ |
|---|---|
| I-11 bituminous concrete (minimum Marshall stab. = 1700) | 0.40 |

| Base Course | $a_2$ |
|---|---|
| Bituminous Stabilized Granular Material (900 minimum Marshall Stability) | 0.24 |
| Portland Cement Stabilized Granular Material (7-day minimum compressive strength - 650 psi) | 0.23 |
| Lime-Fly Ash Stabilized Granular Material (21-day minimum compressive strength = 650 psi) | 0.23 |

| Subbase | $a_3$ |
|---|---|
| Grade 11 gravel (30 minimum CBR) | 0.11 |

and materials to be used for the pavement structure from those determined by the trail designs is basically a problem of economics. The one selected generally should be the one that can be built and maintained for the least amount of money. This can be determined by applying current unit prices to the various combinations of materials and thicknesses and to maintenance operations.

Single Axle[6/] - an assembly of two or more wheels, whose centers are in one transverse vertical plane or may be included between two parallel transverse vertical planes 40 inches apart extending across the full width of the vehicle.

Tandem Axle[6/] - any two or more consecutive axles whose centers are more than 40 inches but not more than 96 inches apart, and are individually attached to and/or articulated from a common attachment to the vehicle including a connecting mechanism designed to equalize the load between axles.

Axle Load[6/] - the total load transmitted to the pavement by either a single or tandem axle, usually expressed in kips (1000 pounds).

Single Axle Load - the total load transmitted to the road by a single axle when spaced more than 8 feet apart.

Tandem Axle Load[6/] - the total load transmitted to the road by two or more consecutive axles whose centers may be included between parallel transverse vertical planes spaced more than 40 inches and not more than 96 inches apart, extending across the full width of the vehicle.

Weighted Axle-Load Application - that axle load application resulting after the use of the AASHO Road Test seasonal weighting to describe the relative serviceability loss potential of a pavement during an index period.

Equivalency Factor - a numerical factor that expresses the relationship of a given axle load to another axle load in terms of their effect on the serviceability of a pavement structure. In this guide all axle loads are equated in terms of the equivalent number of repetitions of an 18-kip single axle-load.

Time-Traffic Exposure Factor - a numerical factor applied to the thickness index indicated by the Road Test flexible pavement performance equation to modify the equation to be more representative of the behavior of pavements serv-

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6. AASHO Highway Definitions (1962)

TABLE 2
Equivalent 18-Kip S.A.L. Applications Per Vehicle Classification

| Road or Street Classification | 18-Kip Equivalent S.A.L. per Vehicle | | |
|---|---|---|---|
| | Passenger Cars | Single Units | Multiple Units |
| Class I | 0.0004 | 0.117 | 0.947 |
| Class II | 0.0004 | 0.109 | 0.924 |
| Class III | 0.0004 | 0.098 | 0.794 |
| Class IV | 0.0004 | 0.027 | 0.216 |

Table 4 - Traffic Factor (T.F.) Equations

| Class of Road or Street | Equation |
|---|---|
| Class I | $T.F. = D.P. \left[ \frac{(0.146\ P.C.xP) + (42.705\ SUxS) + 345.655MUxM)}{1,000,000} \right]$ |
| Class II | $T.F. = D.P. \left[ \frac{(0.146P.C.xP) + (39.785SUxS) + (337.260MUxM)}{1,000,000} \right]$ |
| Class III | $T.F. = D.P. \left[ \frac{(0.146P.C.xP) + (35.770SUxS) + (289.810MUxM)}{1,000,000} \right]$ |
| Class IV | $T.F. = D.P. \left[ \frac{(0.146P.C.xP) + (9.855SUxS) + (78.840MUxM)}{1.000,000} \right]$ |

D.P. = Design Period
P.C., S.U., M.U. = Total daily passenger cars, single units, and multiple units (structural design traffic)
P, S, M = Percentages of P.C., S.U., and M.U. in design lane (see Table 3)

TABLE 6 - MINIMUM COEFFICIENTS FOR PAVEMENT STRUCTURE MATERIALS

| Materials | Minimum Strength Requirements | | | Coefficients 4/ | | |
|---|---|---|---|---|---|---|
| | M.S. 1/ | CBR | PSI | $a_1$ | $a_2$ | $a_3$ |
| Bituminous Surface, Subclass: | | | | | | |
| B-1, B-2, B-3, and B-4 | 300 | | | 0.20 | | |
| B-5 and J-1 | 900 | | | 0.30 | | |
| I-11 | 1700 | | | 0.40 | | |
| Base Course | | | | | | |
| Granular | | | | | | |
| Gravel, Grade 7 | | 50 | | 0.10 | | |
| Gravel, Grade 9 | | 70 | | 0.12 | | |
| Crushed Stone, Grade 8 | | 90 | | 0.13 | | |
| Waterbound Macadam | | 110 | | 0.14 | | |
| Selected Soil Stabilized With Portland Cement | | | 300 2/ | 0.15 | | |
| Granular Material Stabilized With Portland Cement, Plant Mix | | | 450 2/ | 0.20 | | |
| | | | 650 2/ | 0.23 | | |
| Granular Material Stabilized With Lime-Fly Ash | | | 450 2/ | 0.20 | | |
| | | | 650 3/ | 0.23 | | |
| Granular Material Stabilized With Bituminous Materials | | | | | | |
| Emulsified Asphalts | 300 | | | 0.16 | | |
| Liquid Asphalts | 400 | | | 0.18 | | |
| Paving Asphalts | 600 | | | 0.20 | | |
| | 900 | | | 0.24 | | |
| | 1700 | | | 0.33 | | |
| Portland Cement Concrete (new) | | | 2500 2/ | 0.50 | | |
| Subbase | | | | | | |
| Gravel | | | | | | |
| Grade 11 | | 30 | | 0.11 | | |
| Grade 7 | | 50 | | 0.12 | | |
| Grade 9 | | 70 | | 0.13 | | |
| Crushed Stone | | | | | | |
| Grade 8 | | 90 | | 0.14 | | |

1/ Marshall Stability or equivalent.
2/ 7-day compressive strength (value that can be reasonably expected under field conditions).
3/ 21-day compressive strength (value that can be reasonably expected under field conditions).
4/ These coefficients may be considered as minimums for the materials listed in the table. For use of materials with minimum strengths in excess of those given above, the coefficients may be determined from Figures 2 through 7. Other approved materials of similar strengths may be substituted for those listed in the table.

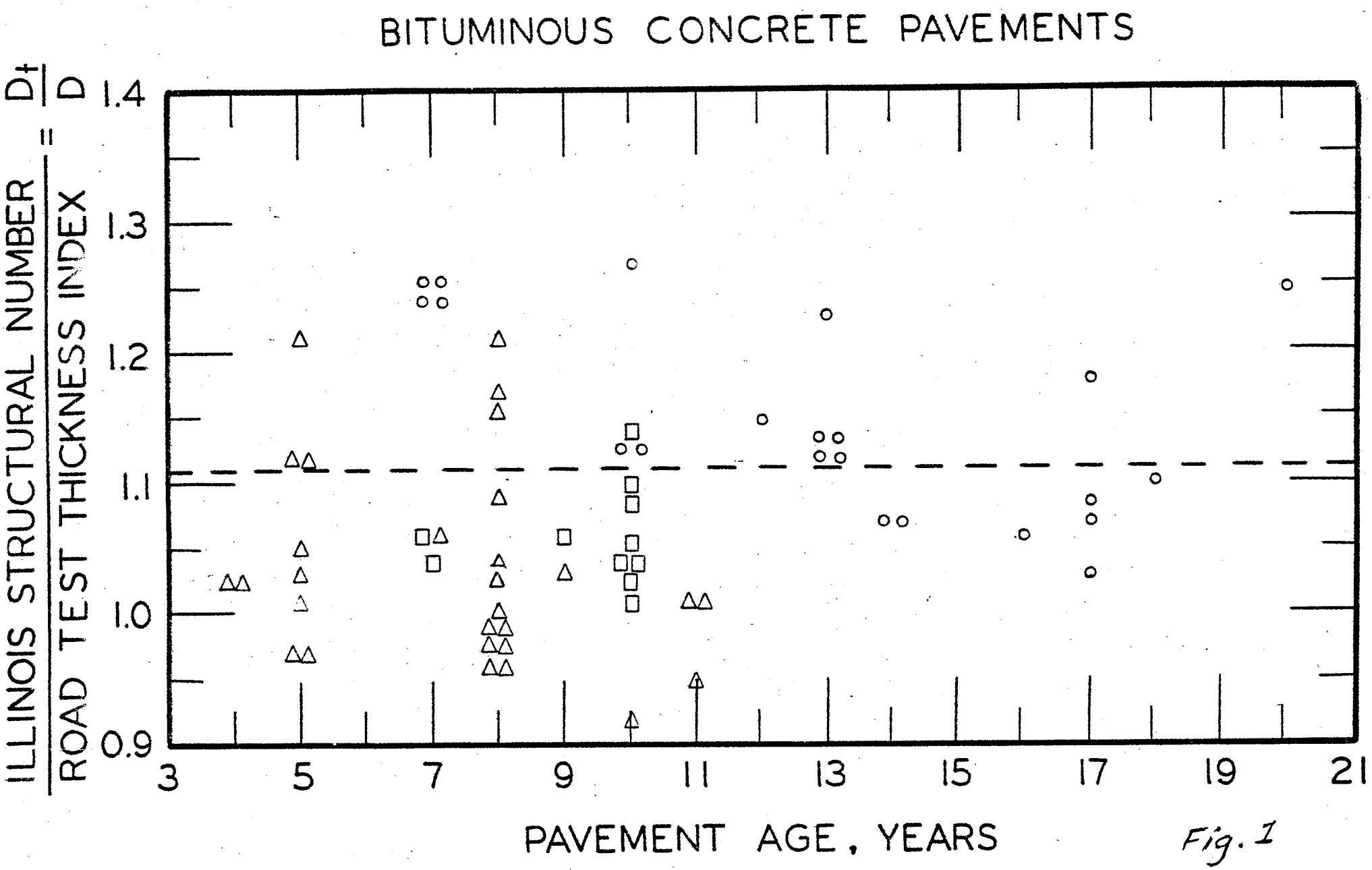

BITUMINOUS CONCRETE PAVEMENTS
ILLINOIS STRUCTURAL NUMBER / ROAD TEST THICKNESS INDEX = Dt/D
1.4
1.3
1.2
1.1
1.0
0.9
3
5
7
9
11
13
15
17
19
21
PAVEMENT AGE, YEARS

Fig. 1

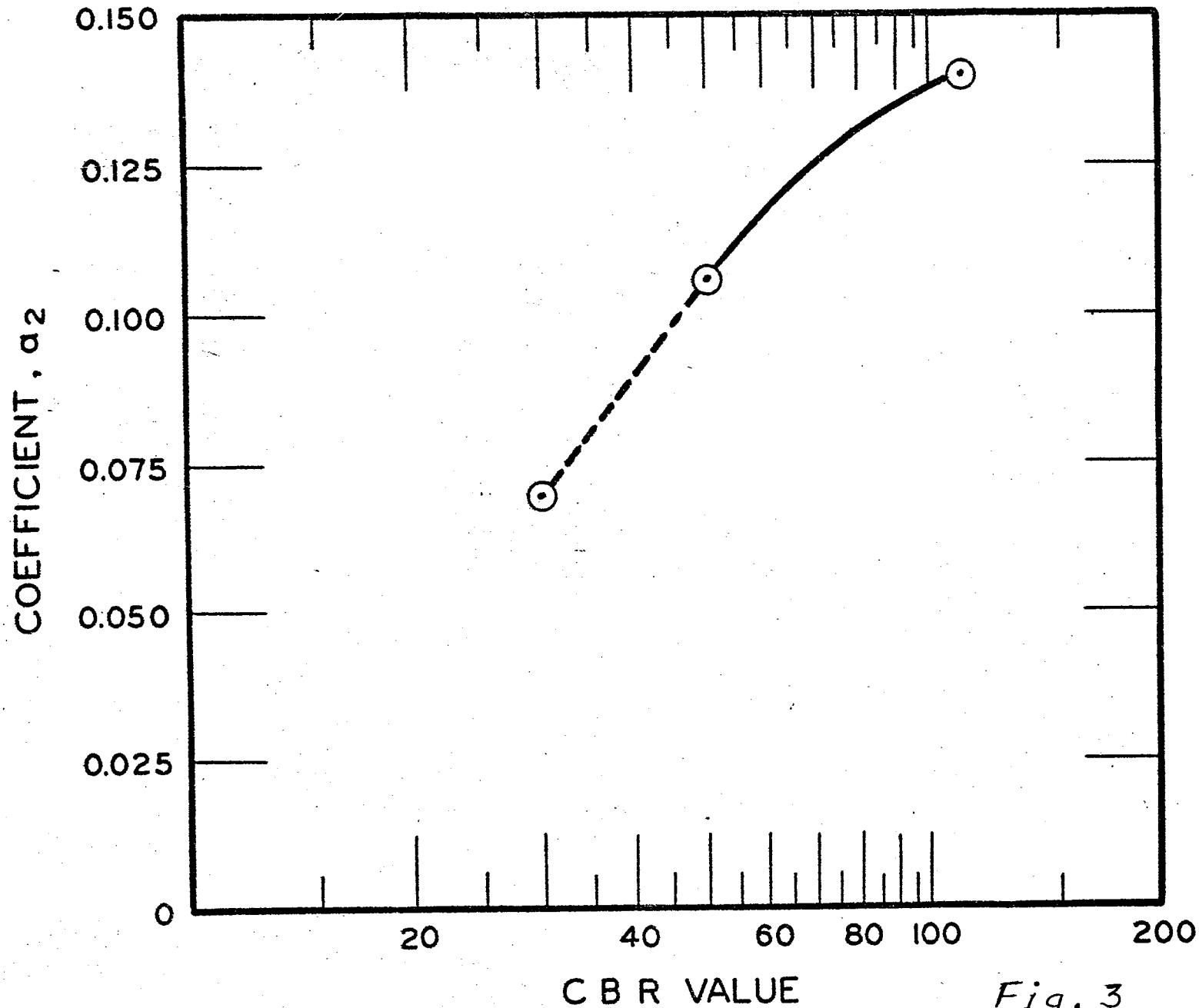

0.150
0.125
0.100
0.075
0.050
0.025
0
COEFFICIENT, $a_2$
20
40
60
80
100
200
C B R VALUE

*Fig. 3*

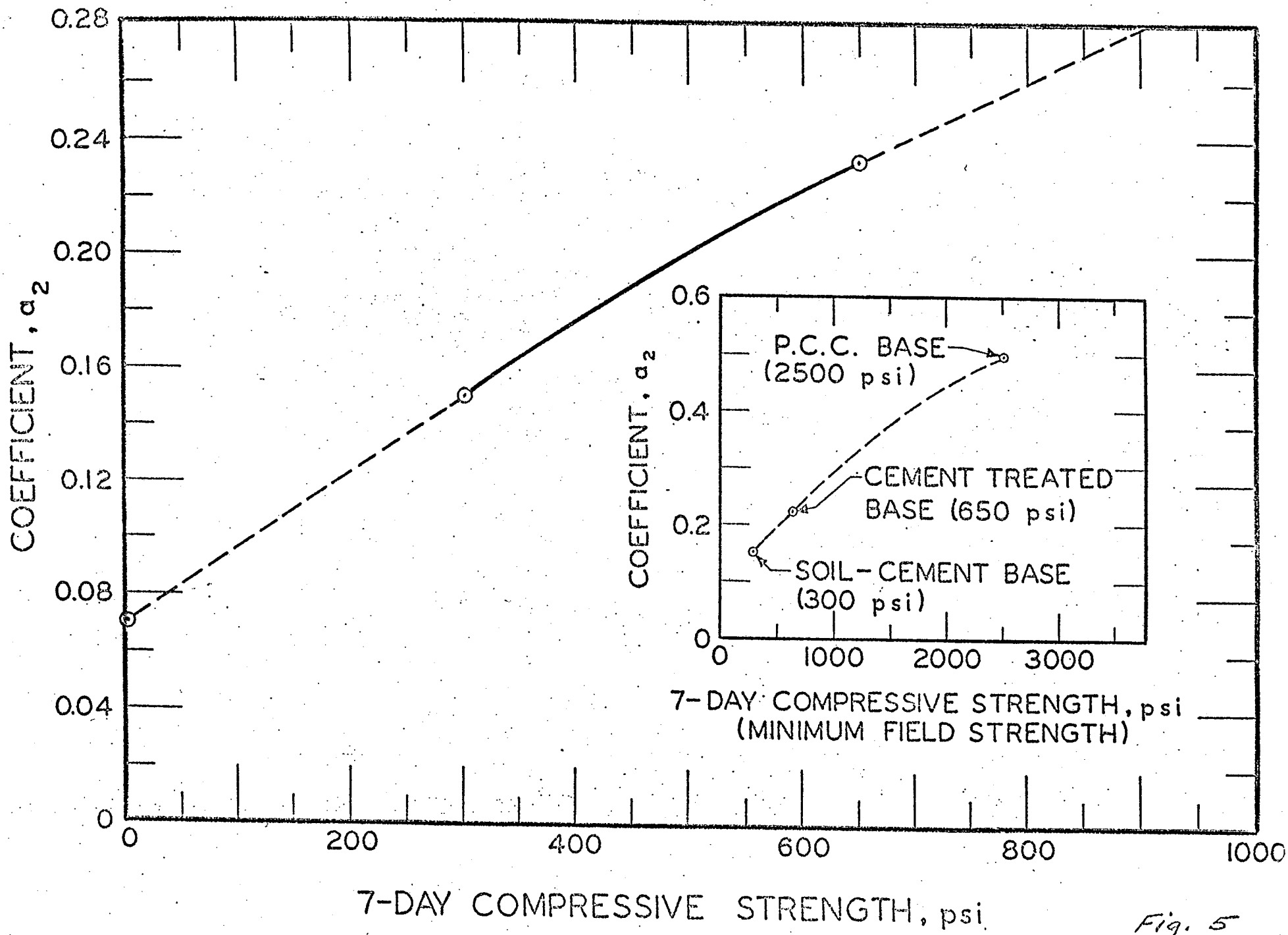

0.28
0.24
0.20
0.16
0.12
0.08
0.04
0
COEFFICIENT, $a_2$
0
200
400
600
800
1000
7-DAY COMPRESSIVE STRENGTH, psi
0.6
0.4
0.2
0
COEFFICIENT, $a_2$
P.C.C. BASE
(2500 psi)
CEMENT TREATED
BASE (650 psi)
SOIL-CEMENT BASE
(300 psi)
0
1000
2000
3000
7-DAY COMPRESSIVE STRENGTH, psi
(MINIMUM FIELD STRENGTH)

Fig. 5

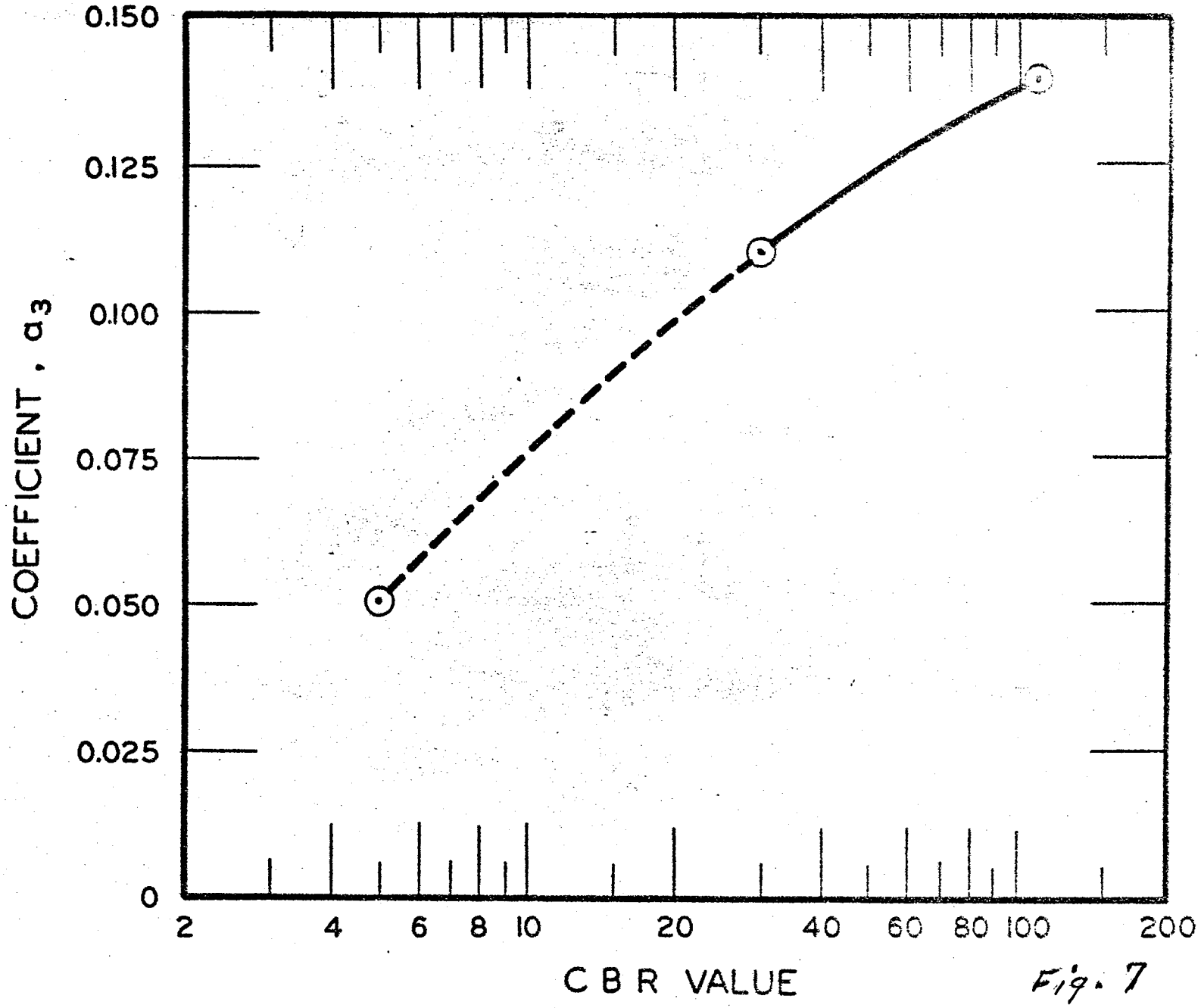
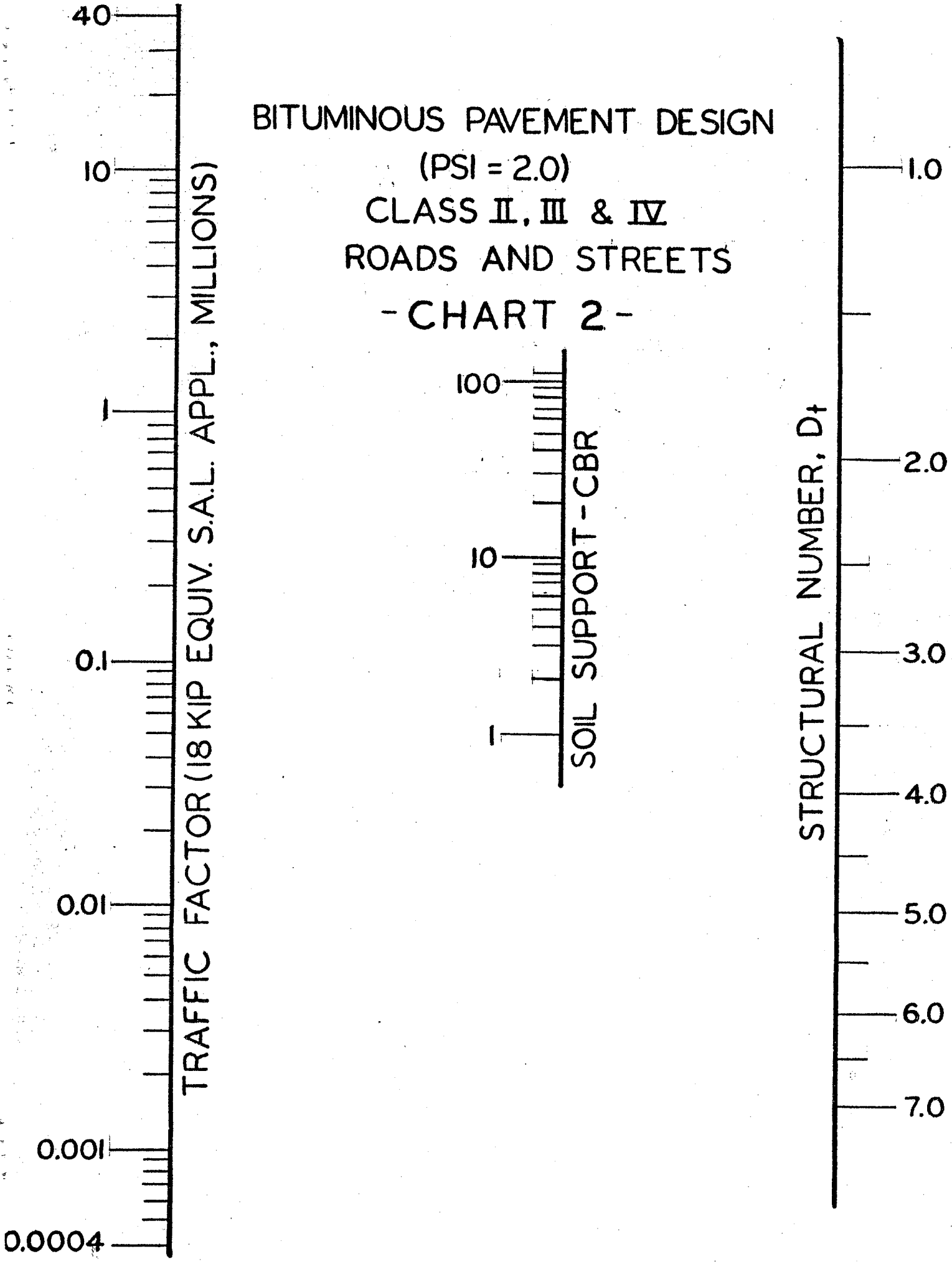

0.150
0.125
0.100
0.075
0.050
0.025
0
COEFFICIENT , $a_3$
2
4
6
8
10
20
40
60
80
100
200
C B R VALUE

Fig. 7

# BITUMINOUS PAVEMENT DESIGN
(PSI = 2.0)
CLASS II, III & IV
ROADS AND STREETS
-CHART 2-