DESIGN OF OVERLAYS FOR FLEXIBLE PAVEMENTS BASED ON AASHTO ROAD TEST DATA

by

Dr. N. K. Vaswani
Senior Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The need for a suitable method of designing the thickness of overlays and predicting the performance of the overlaid pavement has recently been recognized. The AASHTO Road Tests included studies on 99 overlays, but they failed to produce conclusive results and hence provided no guidance for overlay designs.

In the present investigation the raw data on the 99 overlays tested at the AASHTO Road Tests were evaluated. In the process, the raw data on the pavements that were overlaid also had to be evaluated. A relationship between pavement serviceability, 18-kip equivalents, and the thickness index of the pavements before the overlay was determined. The relationship so developed was found to apply to the overlaid pavements. Based on this relationship, the strength coefficient of the overlay was determined and a method of designing the thickness of an overlay was developed. This design method does not require the use of pavement deflection data by which the thicknesses of overlays are usually designed.

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INTRODUCTION

Since 1962 the AASHTO Road Test Results* have provided the fundamental guidance for the design of pavements in this country. The road tests included studies on 99 overlays, but these failed to produce conclusive results. Hence, the test results provide no guidance for the design of overlays. The conclusions from the study of overlays stated in part that "Attempts at mathematical analysis designed to establish a specific relationship between performance and overlay design were unsuccessful". However, the need for a suitable method of designing overlay thicknesses and predicting their performance was recently recognized, and it became imperative that the AASHTO results be further investigated to provide suitable guidance for the design of overlays.

OBJECTIVE AND SCOPE

The object of this investigation was to utilize the raw data given by the AASHTO Road Tests to determine the strength coefficient of overlays and to design overlay thicknesses. The objective was met by accomplishing the following three tasks:

1. Development of a relationship between serviceability, accumulated traffic, and structural strength of the pavement before and after the overlay.

2. Determination of the strength coefficient of the overlay.

*The AASHTO Road Test — Report 5: Pavement Research, Special Report 61E, Highway Research Board, 1962.

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3. Development of a method for designing the thickness of overlays.

VARIABLES

The extent and type of distress that a pavement undergoes depends upon the traffic it carries and its structural strength. These three variables are discussed below.

Distress, in the AASHTO Road Tests, is defined by the term "serviceability" (S). The serviceability of a new pavement decreases with an increase in traffic. The rate of decrease depends upon the structural strength of the pavement; the higher the structural strength, the lower the rate of decrease. Traffic is defined in terms of accumulated 18-kip equivalent single axle loads (18-kip). The structural strength is defined by the design thickness index (D), which is defined as

$$D = a_1h_1 + a_2h_2 + a_3h_3, \tag{1}$$

where a_1, a_2, and a_3 are strength coefficients for the respective layers and h_1, h_2, and h_3 are the thicknesses of the surface course, base course, and subbase course, respectively. Serviceability is measured by pavement roughness, cracking, patching, and rutting.

RELATIONSHIP BETWEEN S, 18-KIP, AND D

Before Overlay

The AASHTO Road Tests report gives raw data on 270 pavements, including the cross section, total traffic, and axle loads for the five values of S=3.5,3.0,2.5,2.0, and 1.5 for each pavement. These raw data were utilized to determine the design thickness index, D, of each pavement, and its accumulated traffic in 18-kip (8,160 kg.) equivalents, as discussed in the following paragraphs.

The Thickness Index

The AASHTO Road Test results give strength coefficient values of the materials used in the pavement sections as 0.44 for an asphaltic concrete surface course, 0.14 for an untreated stone base, and 0.11 for untreated material in the subbase. Since all of the 270 pavements tested at the AASHTO Road Tests and considered in this investigation consisted of these three materials only, for the purpose of this investigation equation 1 could be written as

$$D = (0.44\ h_1 + 0.14\ h_2 + 0.11\ h_3). \tag{2}$$

Accumulated Traffic

The axle load equivalency values given by the AASHTO Road Test Results were used to determine the equivalent 18-kip (8,160 kg) for a given axle load. The accumulated 18-kip equivalents for each of the five S values on each project were then determined by multiplying the accumulated axle load repetitions by the axle load in terms of the 18-kip (8,160 kg) equivalent.

Linear multiregression analyses of the thickness indices and 18-kips (8, 160 kg) for each of the five S values were carried out separately by using the model equation

$$\text{Log 18-kip} = A + B \text{ (thickness index)}, \qquad (3)$$

where

A = the intercept of the thickness index axis for a given serviceability, and

B = slope of the linear curve for 18-kip versus thickness index for a given S value.

The equations so developed are as follows:

For S = 3.5 (270 data points) (4)

$$\text{Log (18-kip)} = 1.140 + 1.128\ D$$

(Correlation Coefficient, R = 0.88).

For S = 3.0 (258 data points) (5)

$$\text{Log (18-kip)} = 1.702 + 1.063\ D$$

(R = 0.93).

For S = 2.5 (239 data points) (6)

$$\text{Log (18-kip)} = 1.810 + 1.080\ D$$

(R = 0.95).

For S = 2.0 (230 data points) (7)

$$\text{Log (18-kip)} = 1.814 + 1.106\ D$$

(R = 0.95).

For S = 1.5 (with 216 data points) (8)

$$\text{Log (18-kip)} = 1.834 + 1.116\,D$$

(R = 0.95).

In equations 4 through 8 the values of B in model equation 3* for the five S values are almost identical. The maximum value is 1.128, the minimum is 1.063, and the average is 1.1. The value of the constant B was, therefore, taken as 1.1, and the values of A in model equation 3 were redetermined. The equation so determined and the values of A so obtained follow.

$$\text{Log 18-kip} = A + 1.1\,(\text{thickness index}), \qquad (9)$$

and

A = 1.27 for S = 3.5 (R = 0.88, SE = 0.69),

= 1.63 for S = 3.0 (R = 0.93, SE = 0.47),

= 1.79 for S = 2.5 (R = 0.95, SE = 0.38),

= 1.87 for S = 2.0 (R = 0.95, SE = 0.36), and

= 1.92 for S = 1.5 (R = 0.95, SE = 0.36).

The correlation coefficients and standard errors of estimate shown demonstrate an excellent relationship exists for S, 18-kip, and D.

Based on equation 9, Figures 1 and 2 have been drawn to show the relationship between S, 18-kip (8,160 kg), and D throughout the life of a flexible pavement. In these two figures the values of S were extrapolated. This was done by plotting A versus S as given in equation 9 and as shown in Figure 3. By means of Figure 3 the values of A could be obtained for any value of S.

After Overlay

The AASHTO Road Test Results give raw data on 99 overlay projects. From these data the following were obtained: (a) The values of S before the overlay, immediately after the overlay, and at the end of the overlay service; and (b) the

*Log 18-kip = A + B (thickness index).

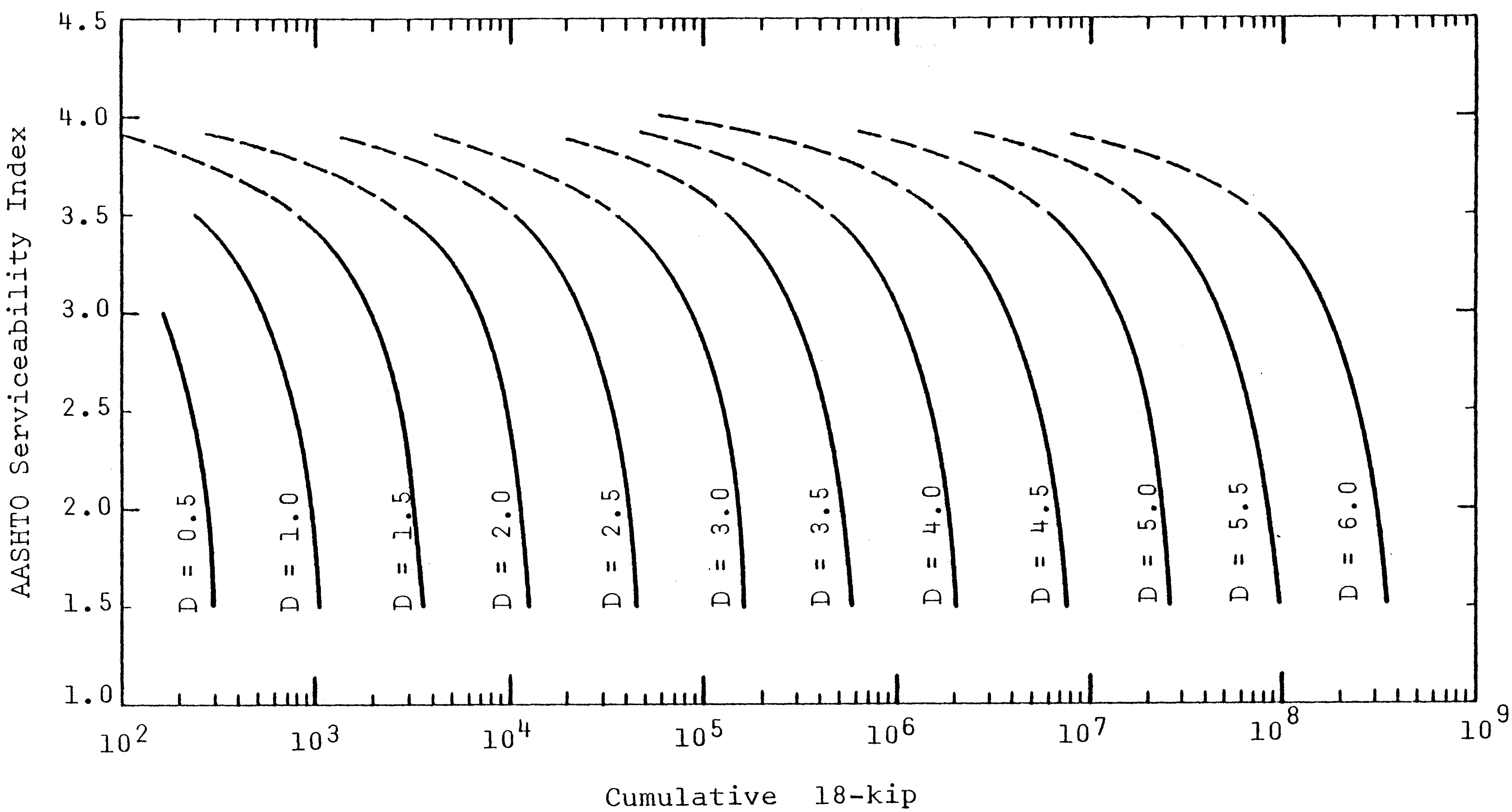


Figure 1. Relationship between culumative traffic and AASHTO serviceability for pavements having varying thickness indices. (Conversion unit: 18-kip = 8,160 kg)

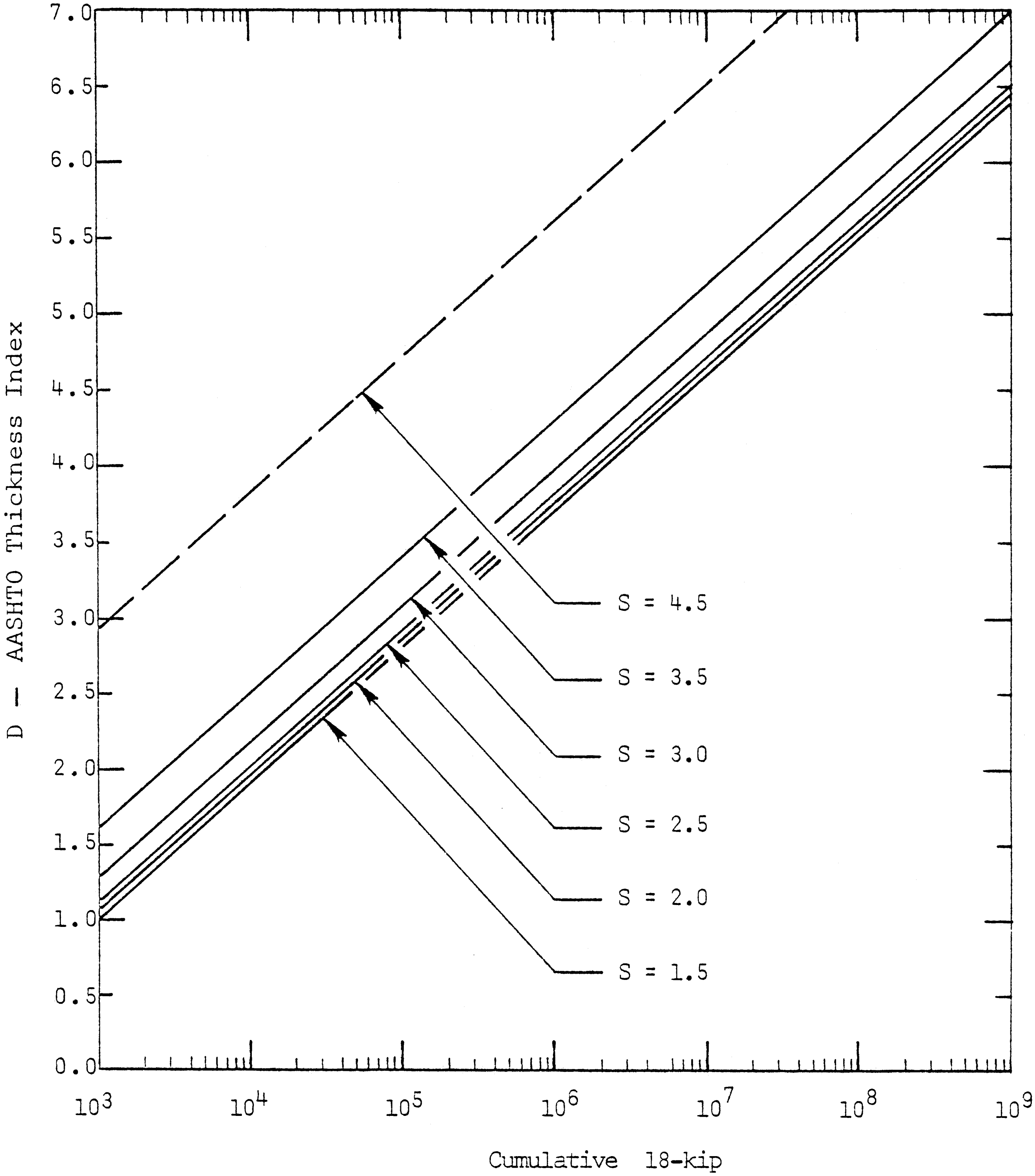
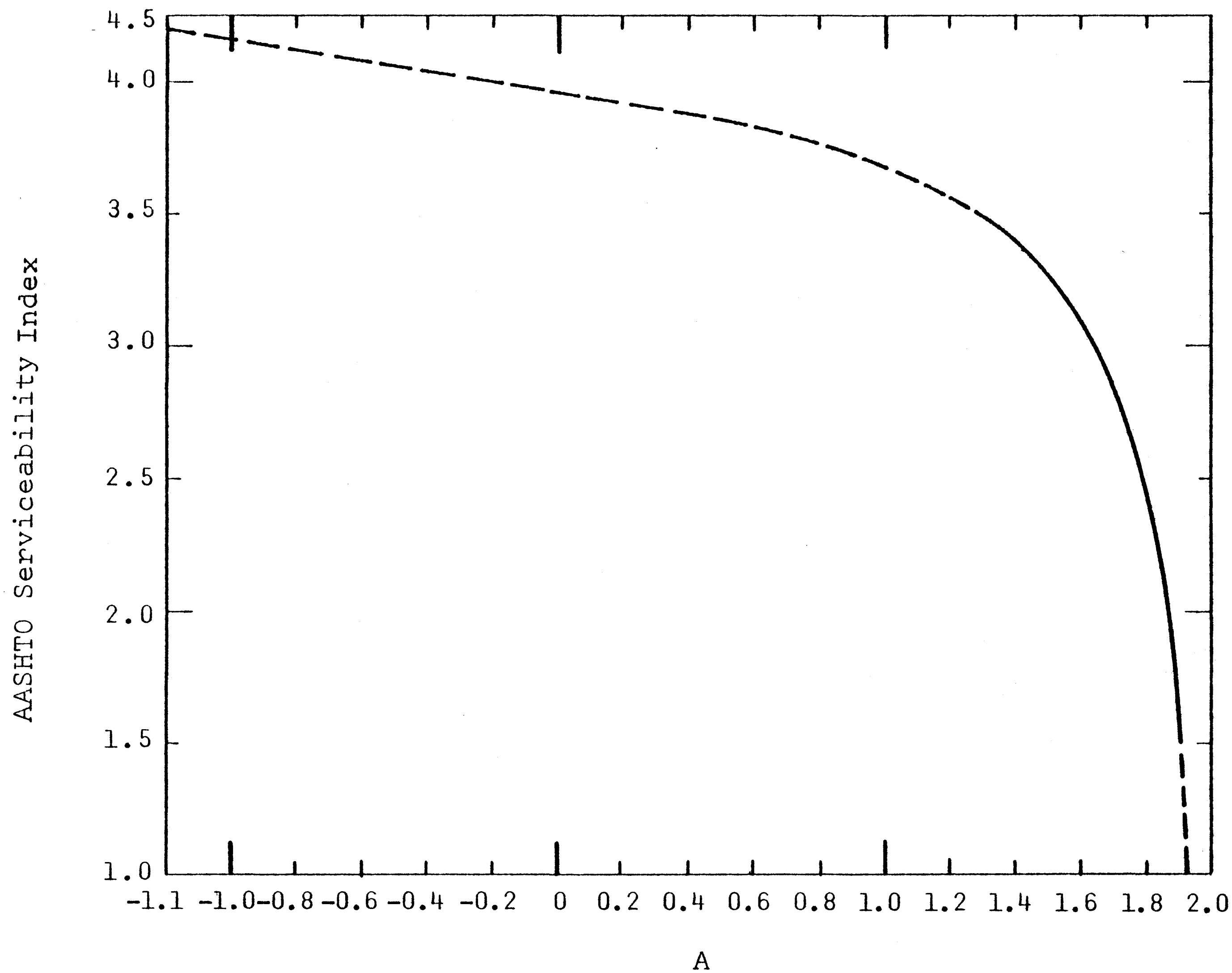


Figure 2. Relationships between D, S, and cumulative 18-kip. (Conversion unit: 18-kip = 8,160 kg)



S	A
1.0-	1.92
1	1.92
1.25	1.91
1.50	1.90
1.70	1.89
1.80	1.88
2.0	1.87
2.1	1.85
2.2	1.84
2.3	1.83
2.4	1.81
2.5	1.78
2.6	1.76
2.7	1.74
2.8	1.71
2.9	1.68
3.0	1.64
3.1	1.59
3.2	1.54
3.3	1.47
3.4	1.39
3.5	1.27
3.6	1.14
3.7	0.97
3.8	0.70
3.9	0.32
4.0	-0.2

Figure 3. A versus serviceability index.
(Conversion unit: 18-kip = 8,160 kg)

18-kip (8,160 kg) before the overlay and at the end of the service life of the overlay. The 18-kip immediately after the overlay is equal to the 18-kip immediately before the overlay. The three data points so obtained for each project could be plotted in Figure 1 and extrapolated parallel to the curves given there. By this means the values of S, 18-kip, and D for the pavement before and after the overlay could be determined. An example of this is shown in Figure 4.

A study of these data for each project given in Appendix 1 shows that all pavements behave in a manner shown by the solid line in Figure 4. This figure is, in fact, an example of the mean values of pavements on loop 5 as given in Appendix 1. This example shows that the pavement deteriorated to an S value of 1.2 prior to the overlay. Since the overlay covered all the observed types of distress, the S values increased without a change in traffic. After an overlaid pavement is open to traffic, the rate of decrease in the S value with an increase in traffic is constant. The duration of this trend depends upon the thickness of the overlay. After some time the reduction in S accelerates in the same manner as for a new pavement, and the curve of S versus traffic follows the general trend shown for new pavements before the overlay. This behavior of the overlaid pavement is shown in Figure 4.

In practice the serviceability of the pavement and the 18-kip (8,160 kg) carried by the pavement before the overlay are known. If the additional thickness index contributed by the overlay could be determined, the pavement behavior in terms of S versus 18-kip after the overlay could be predicted, as shown in Figure 4. The thickness index of the overlay can be determined if the strength coefficient of the overlay is known. The method of determining the strength coefficient is given in the following section.

DETERMINATION OF THE STRENGTH COEFFICIENT OF AN OVERLAY

In determining the strength coefficient of an overlay the raw data on the 99 AASHTO overlay projects were used. The data on each of the 99 projects needed for this investigation are shown in Appendix 1 in their original form or after conversion. The information in Appendix 1 shows the following.

1. The pavements overlaid had a minimum thickness index of 1.28, a maximum of 4.82, and an average of 3.35. The actual thicknesses of the pavements ranged from 5 inches (12.7 cm) to 21 inches (53 cm). Thus, the strength coefficient values determined in this investigation covered a broad range of pavement strengths.

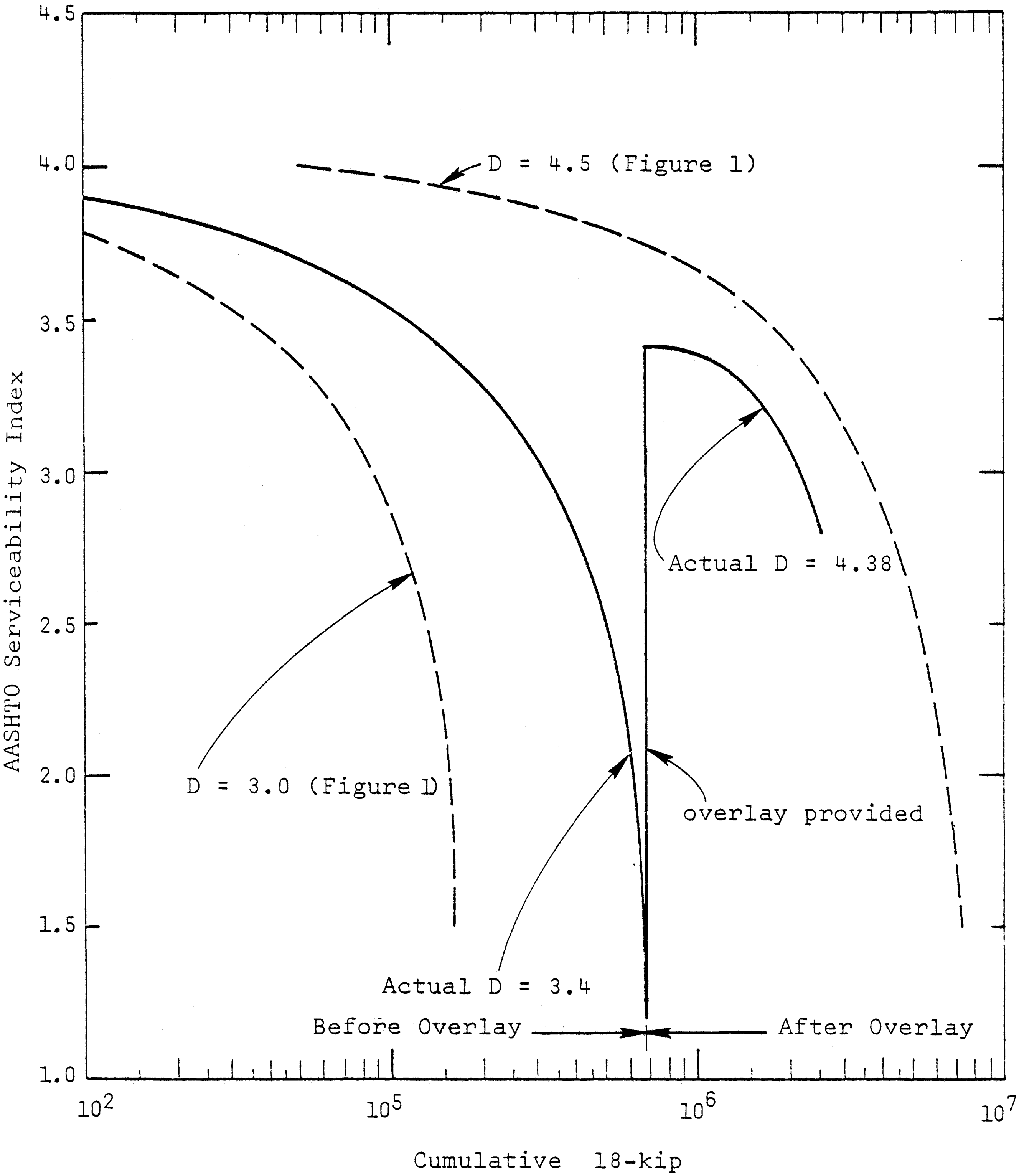


Figure 4. Example of pavement and overlay behavior (Loop 5 - AASHTO Road Test).

2. All the pavements had reached an S value of about 1.5 or below, with an average of 1.2, before they were overlaid. Usually, pavements — especially those heavily trafficked — are overlaid when the S value is 2.5 or above. The overlay data based on low terminal S values will not affect the results of this investigation and could be applied to pavements with high terminal S values because, as shown in Figure 1, the traffic carried at S = 2.5 is not a great deal more than the traffic carried at S = 1.5 or below.

3. The overlay thickness varied from 2 inches (5 cm) for very low type pavements to 3 1/2 inches (8.9 cm) — 4 inches (10 cm) in one case only — with an average of 3 inches (7.6 cm). The results of this study must therefore be assumed to be applicable for overlay thicknesses greater than 2 inches (5 cm) until further data are available for verification.

Method of Determining the Strength Coefficient

The strength coefficient of an overlay could be obtained as

$$D_a = D_b + h.a_o, \tag{10}$$

where D_b and D_a are the actual thickness indices before and after the overlay, h is the thickness of the overlay in inches or centimetres, and a_o is the strength coefficient for one inch or one centimetre of an overlay.

The value of D_b before the overlay may not be exactly the same as the design value obtained by equation 2. This difference may be due to various factors like subgrade support, material variations, construction techniques, etc. Thus, in the example shown in Figure 4 for the mean of values of pavements on loop 5 (Appendix 1), the mean design thickness index of the pavements by use of equation 2 was 3.48. When plotted, the data of S versus 18-kip showed that the actual value of D_b was 3.40. It is, therefore, necessary that the actual value of D_b be determined for the design of overlays.

The actual value of D_b could be obtained from the data on S and 18-kip as given by (a) equation 9 combined with Figure 3, or (b) Figure 1, or (c) Figure 2. The use of these three methods is shown by taking an example of the mean of the values of loop 5 wherein the mean values of S and 18-kip before the overlay are 1.2 and 674,000 18-kip (6,180 kg). From Figure 3 the value of A for S = 1.2 is 1.92. Hence, D_b in equation 9 =

$$\frac{\log 674{,}000 - 1.92}{1.1} = 3.6.$$

From Figure 1 the value of D_b as shown on an enlarged scale in Figure 4 is 3.4. From Figure 2 the value of D_b as shown on an enlarged scale in Figure 5 is 3.48.

In a similar way the value of D_a in equation 10 can be determined by use of Figure 1 or 2. This is shown by the example of the mean of the values of loop 5 in Appendix 1, wherein the mean values of S and 18-kip (8,160 kg) after the service life of the overlay are 2.79 and 2,370,000 18-kip (6,180 kg). The value of D_a from Figure 1 as shown on an enlarged scale in Figure 4 is 4.38, and that from Figure 2 as shown on the enlarged scale in Figure 5 is 4.34.

Using the average values of D_b and D_a obtained from Figures 4 and 5, we get D_b = 3.44 and D_a = 4.36. The mean thickness of an overlay on loop 5 is 3 inches (7.5 cm). Thus the mean strength coefficient of an overlay obtained from equation 10 =

$$\frac{4.36 - 3.44}{3} = 0.31.$$

In this investigation the strength coefficient values for the 99 overlay projects were determined and are given in Appendix 1. The average value of the strength coefficients of these 99 overlays is 0.30. The statistical curve as obtained for the strength coefficients of the overlays is shown in Figure 6. This curve indicates that the population is not normally distributed. If the mean value of 0.30 is adopted as the strength coefficient of the overlay, 50% of the design projects will be satisfied. To cover a greater percentage of designed projects, a value of 0.22 is recommended. This value, as shown in Figure 6, will cover 62% of the design projects for AASHTO pavements which were reduced to a terminal S value of 2.5 or below before an overlay was provided. For roads and highways for which overlays are provided at higher terminal indices, a strength coefficient of 0.22 should satisfy a much larger percentage of the design projects. The value of 0.22 is exactly half the value of the strength coefficient of asphaltic concrete for new pavements. It is, therefore, recommended that the strength coefficient for an overlay for the purpose of design be taken as half the strength coefficient of asphaltic concrete.

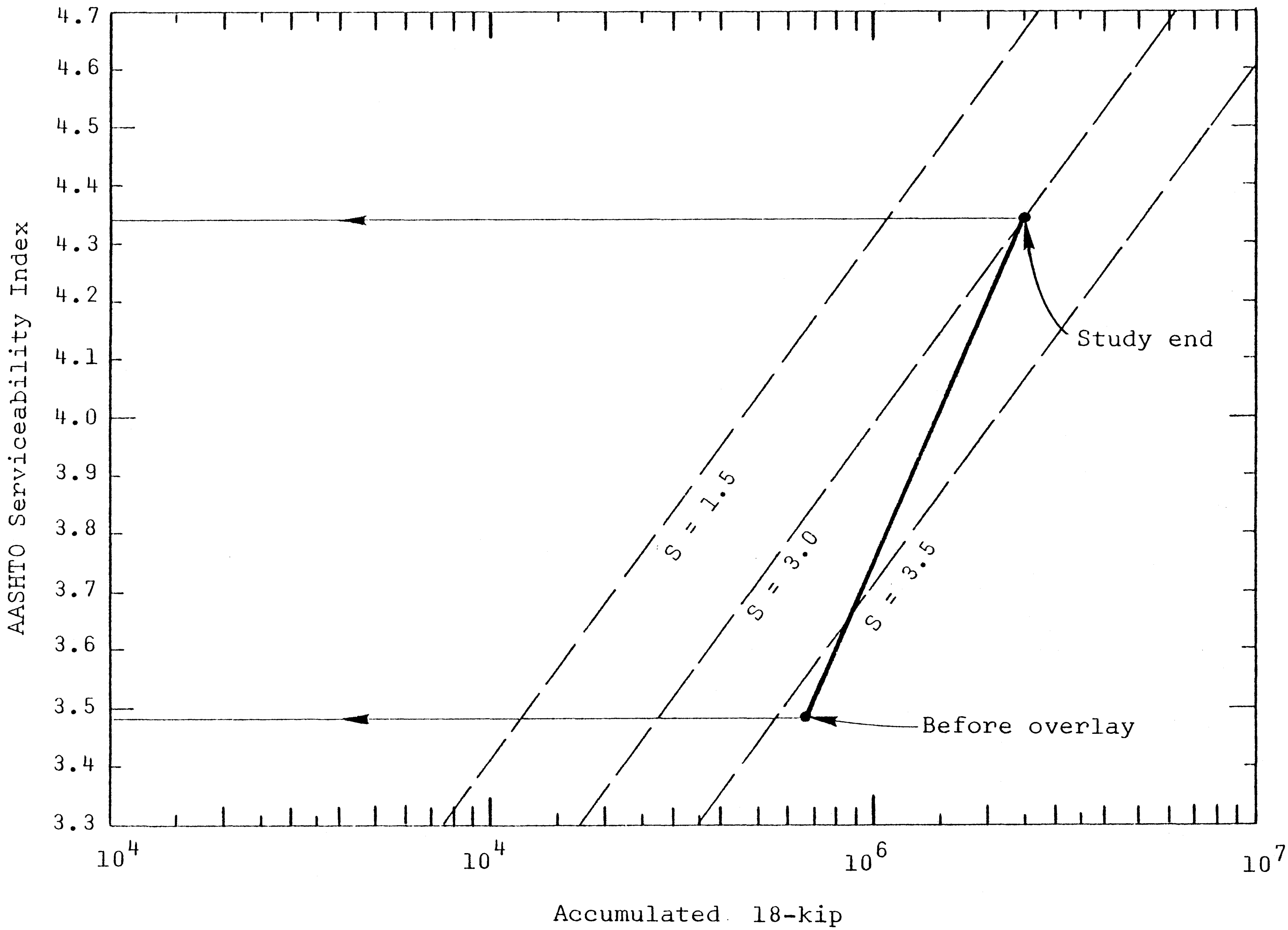


Figure 5. Method of determining thickness index given accumulated 18-kip and serviceability index.(Example: Loop 5 - AASHTO)

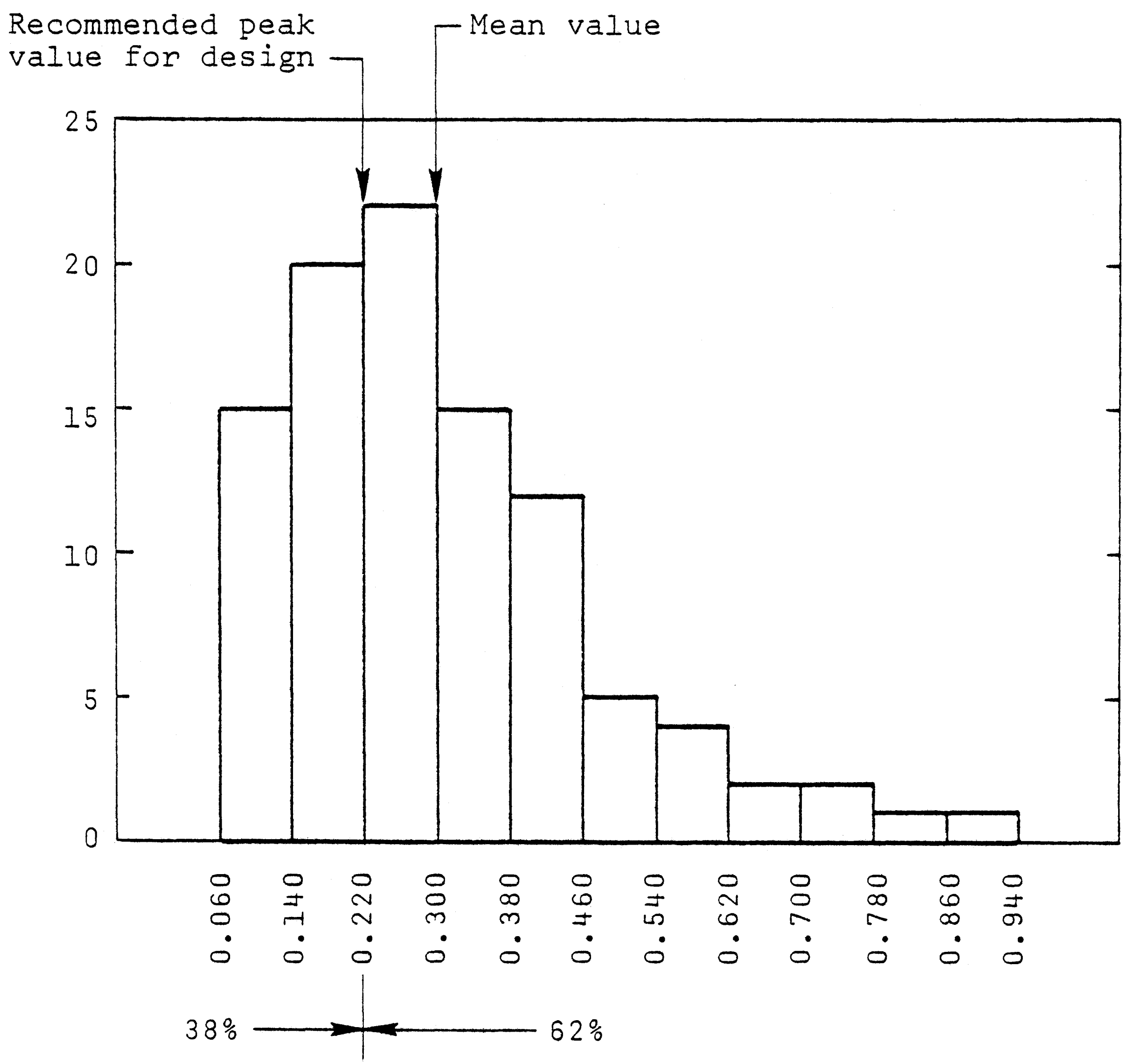


Figure 6. Statistical curve for thickness equivalency value of overlays on AASHTO overlay test pavements.

Taking the strength coefficient of an asphaltic concrete overlay as half the value for new construction can be justified as follows. With age and traffic, the pavement becomes fatigued and weak. When an underlying layer becomes weaker than the overlying one, the thickness equivalency of the overlying layer decreases. This is illustrated by the practice in Virginia of taking the thickness equivalency of cement treated aggregate directly over the raw subgrade as 0.6 times the thickness equivalency when placed over a strong subbase or base course.

THICKNESS OF AN OVERLAY

Based on equation 9 the traffic carried by an overlaid pavement could be obtained as

Traffic after the overlay = Antilog (log 18-kip of total traffic before and after the overlay) minus Antilog (log 18-kip of traffic before the overlay)

$$= \text{Antilog } (Aa + 1.1\,Da) - \text{Antilog } (Ab - 1.1\,Db), \qquad (11)$$

where Ab and Aa are the same as the values of A in equation 9* for an S value before the overlay and at the end of the overlay service, respectively, and Db and Da are the values of D before and after the overlay, respectively.

In the AASHTO road tests, the S values before the overlay and at the end of the service life of the overlay were not the same. In practice these values are the same, depending upon the road classification; i.e. Aa = Ab. In such a case equation 11 reduces to

Traffic after the overlay = traffic before the overlay x [Antilog (0.11 x overlay thickness x strength coefficient of overlay) - 1], or (12)

$$\frac{\text{Traffic after the overlay}}{\text{Traffic before the overlay}} = [\text{Antilog } (0.11 \times 0.22 \times \text{overlay thickness}) - 1], \text{ or} \qquad (13)$$

*Log 18-kip = A + 1.1 (thickness index).

$$\text{Percentage increase in traffic after the overlay} = [\text{Antilog}\ (0.0242 \times \text{overlay thickness}) - 1] \times 100. \qquad (14)$$

Based on equation (14), Figure 7 has been drawn. It shows the percentage increase in the 18-kip equivalent versus the overlay thickness and can be used in determining the required thickness of an overlay. This figure shows that the traffic capacities for overlay thicknesses of 1, 2, and 3 inches (2.5, 5.1, and 7.6 cm) are respectively 78%, 217%, and 464% of the traffic before the overlay.

If these percentage increases in traffic are examined carefully, it is seen that the percentage increase in traffic would be the same if the overlay were applied in several thin layers rather than in one thick layer. Thus, one thick layer of, say, 3 inches (7.6 cm) would carry the same traffic as three layers of 1-inch (2.5 cm) as shown in Table 1.

Deflection studies in Virginia carried out before and after the application of asphaltic concrete overlays have shown that overlay thicknesses of 1-inch (2.5 cm) and above do contribute to an increase in the structural strength of the pavement. It is, therefore, recommended that overlays provided for increasing the structural strength of the pavements be limited to a minimum of 1-inch (2.5 cm). The method described under the subhead below is recommended for the design of overlay thickness.

Table 1

Example of Overlay Thickness Versus Traffic

Pavement section	Total traffic before overlay	Traffic due to the overlay	Total traffic due to overlays only
No overlay	-	0	0
First 1 inch overlay	1	78%	0 + 78 = 78%
Second 1 inch overlay	1 + 0.78 = 1.78	1.78 x 78 = 139%	78 + 139 = 217%
Third 1 inch overlay	1 + 2.17 = 3.17	3.17 x 78 = 247%	217 + 247 = 464%

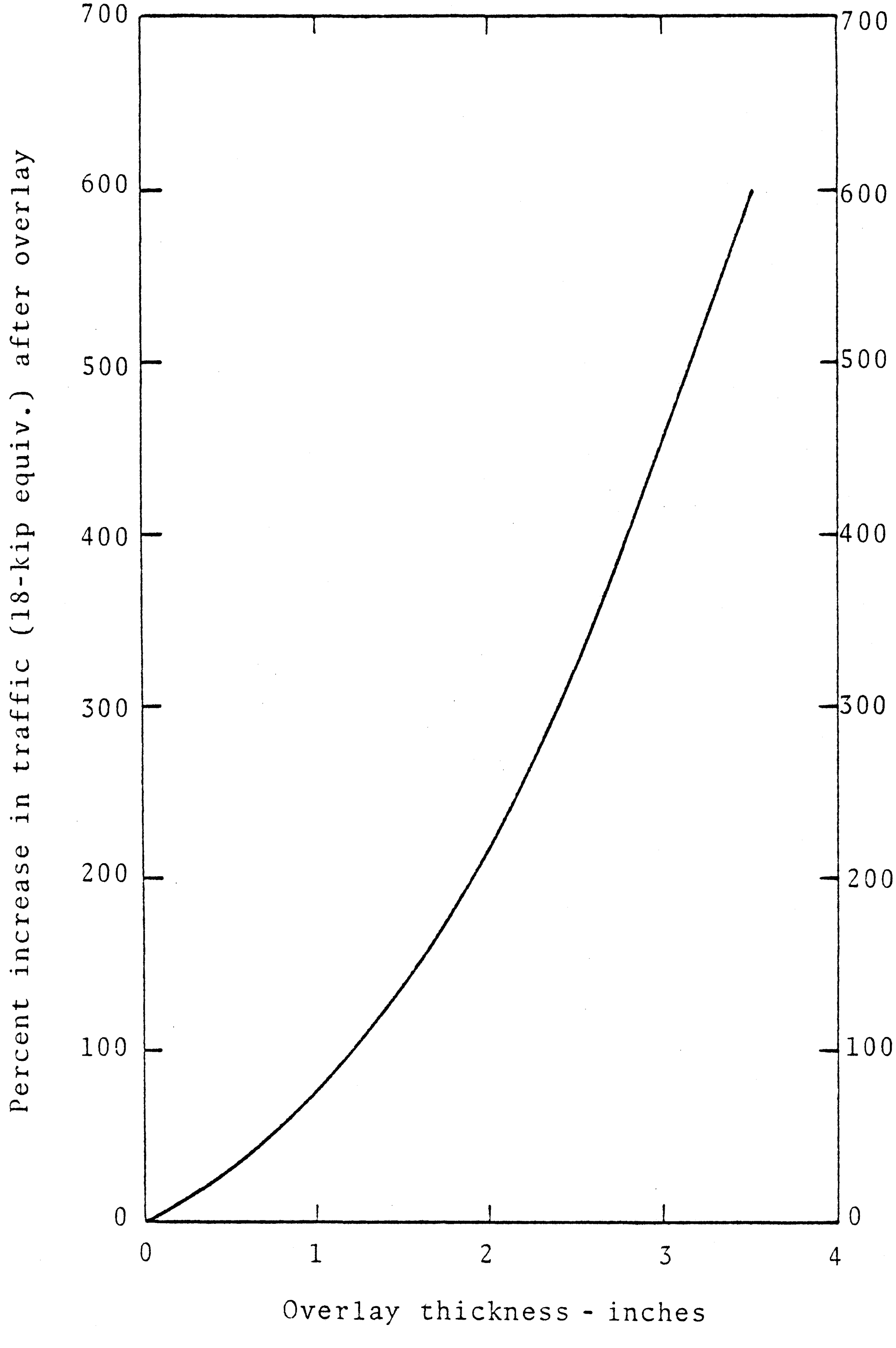


Figure 7. Overlay thickness versus traffic carrying capacity. (Conversion units: 18-kip = 8,160 kg
1 inch = 2.5 cm)

Design of Overlay Thickness

The design of the overlay thickness is dependent upon the durability of the asphaltic concrete mix as influenced by the age, hardening, and stripping of asphalt, along with other factors. An overlay made from a well-designed mix properly placed could perform satisfactorily for 10 to 15 years without surface rejuvenation. For determining the thickness of an overlay, the use of a 12-year service life for the mix is recommended. The procedure for determining the overly thickness is as follows.

1. Determine the accumulated traffic in terms of the 18-kip (8,160 kg) equivalents that the pavement has carried from the date of construction to the date of the proposed overlay, irrespective of any previous overlays.

2. Determine the accumulated traffic in terms of the 18-kip (8,160 kg) equivalents the pavement will carry in the 12 years following the overlay.

3. From Figure 7, determine the thickness of the overlay from a given percentage increase in traffic after the overlay, taking the percentage increase as

$$\frac{\text{18-kip (8,160 kg) after the overlay}}{\text{18-kip (8,160 kg) before the overlay}} \times 100.$$

For example, an interstate highway pavement that was built in 1967 and had an S value of 3.45 in 1977 would qualify for an overlay. The accumulated traffic up to 1977 was 0.45 million 18-kip (8,160 kg) equivalents. The ADT in 1977 was 140 18-kip (8,160 kg) equivalents. Assuming a yearly increase in traffic of 5%, the accumulated traffic at the end of 12 years would be

$$140 \times 365\,[1 + (1 + .05) + (1 + .05)^2 + \ldots (1 + .05)^{11}]$$

$$= 51{,}100 \times 15.92$$

$$= 0.81 \text{ million 18-kip (8,160 kg) equivalents.}$$

The percentage increase in traffic after the overlay would be

$$\frac{0.81}{0.45} \times 100,$$

or 180%. From Figure 7 the designed thickness of the overlay is determined to be 1.75 inches (4.5 cm).

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CONCLUSIONS

1. A simplified design method based on visual inspections could provide uniformity in decisions regarding the stages at which pavements would be overlaid in an economical manner.

2. The strength coefficient of an asphaltic overlay is less than the strength coefficient of asphaltic concrete for new pavements. It is recommended that in the design of overlays, the strength coefficient for an asphaltic overlay should be taken as half (0.22) the strength coefficient of asphaltic concrete for new pavements (0.44).

3. The method for designing an overlay developed in this investigation could be used for determining the thickness of an overlay.

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Appendix 1

Data on AASHTO Overlay Projects

Loop	AASHTO Design D	Overlay Thickness in.	Before Overlay			After Overlay				Strength Coeff. of Overlay	
			18 kip 1000 S	S	Actual D	S	At end of Service: 18 kip 1000 S	S	Actual D	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2	1.72	2	5	1.0	1.6	2.5	5	2.35	1.98	0.190	
	1.74	2	5	1.1	1.6	2.4	5	2.15	1.96	0.180	
	1.28	2	1	6.0	0.95	2.7	10	2.45	2.03	0.540	
	1.30	2	3	1.7	1.44	2.23	9	2.00	2.02	0.290	
	1.74	2	8	2.2	1.87	3.17	3	3.20	2.32	0.225	
Mean	1.56	2	4.4	1.2	1.49	2.60	6.4	2.43	2.06	0.285	0.149
3	2.60	3	117	0.9	2.84	3.33	130	3.35	3.65	0.270	
	3.06	3.5	103	1.6	2.81	3.35	69	3.55	3.73	0.263	
	3.06	3.5	119	0.8	2.85	3.10	124	2.75	3.37	0.148	
	3.04	3	182	1.0	3.02	3.73	111	3.65	4.20	0.393	
	2.62	3	40	1.7	2.46	3.97	271	3.80	4.65	0.730	
	2.60	4	89	1.5	2.76	2.97	73	2.55	3.12	0.120	
	2.60	3	36	2.1	2.46	3.30	56	2.00	2.81	0.117	
	2.64	3.5	24	1.3	2.23	3.50	167	3.30	3.50	0.362	
	3.04	3.5	171	1.7	3.03	3.77	118	3.80	4.60	0.449	
	2.16	3	18	1.1	2.10	3.80	117	3.45	3.48	0.460	
	2.16	3	21	0.5	2.17	2.90	20	2.00	2.50	0.110	
	2.18	3	17	1.2	2.08	2.20	12	2.00	2.36	0.093	
Mean	2.65	3.25	78	1.3	2.57	3.33	106	3.02	3.50	0.293	0.194
4	2.64	3	157	1.6	2.98	3.87	1,044	3.90	5.45	0.823	
	2.64	3	127	1.5	2.89	3.97	846	3.50	4.30	0.470	
	2.64	3	86	1.2	2.73	3.70	1,111	2.70	3.95	0.407	
	2.64	3	117	0.7	2.82	3.40	846	3.10	4.00	0.393	
	2.62	3	86	1.4	2.78	3.85	76	2.00	3.04	0.087	

Appendix 1

Data on AASHTO Overlay Projects

Loop	AASHTO Design D	Overlay Thickness in.	Before Overlay			After Overlay	At end of Service			Strength Coeff. of Overlay	
			18 kip 1000 S	S	Actual D	S	18 kip 1000 S	S	Actual D	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
4	3.08	3	162	1.1	3.50	3.43	1,026	3.45	4.35	0.283	
cont.	3.08	3	252	0.5	3.14	2.73	831	2.30	3.83	0.230	
	3.06	3	162	1.4	3.00	2.90	803	2.85	3.90	0.300	
	3.94	3	571	1.5	3.48	3.35	479	2.35	3.82	0.113	
	3.04	3	133	1.3	2.87	3.37	831	2.25	3.78	0.303	
	3.06	3	152	1.1	2.95	3.77	1,026	3.25	4.20	0.416	
	3.06	3	151	1.4	2.95	3.97	813	3.25	4.12	0.390	
	3.48	3	541	0.5	3.45	3.67	324	3.50	4.25	0.267	
	3.08	3	408	0.0	3.32	3.67	407	3.15	4.00	0.227	
	3.48	3.5	645	1.1	3.51	3.83	430	2.90	3.97	0.131	
	3.48	3.5	550	2.1	3.53	3.70	348	3.55	4.38	0.243	
	3.06	3	530	1.1	3.45	3.15	550	2.80	3.95	0.167	
	3.06	3	495	2.2	3.52	3.50	388	3.20	4.05	0.177	
	3.52	3	775	1.1	3.60	3.35	416	3.15	4.14	0.180	
	3.04	3	116	1.3	2.85	3.30	648	2.00	3.62	0.257	
	3.04	3.5	386	0.0	3.30	3.40	407	3.35	4.10	0.229	
	3.48	3	734	1.9	3.62	3.00	430	2.65	3.93	0.103	
	3.50	3.5	557	1.2	3.48	3.37	457	2.50	3.81	0.094	
Mean	3.12	3.09	343	1.2	3.21	3.49	632	2.94	4.04	0.273	0.163
5	3.04	3	214	0.6	3.07	3.23	2,894	3.65	5.15	0.693	
	3.04	3	183	1.4	3.03	2.97	2,413	2.85	4.30	0.423	
	3.06	3	281	1.2	3.18	3.20	2,894	2.35	4.26	0.360	
	3.06	3	341	1.6	3.30	3.27	2,297	2.85	4.30	0.333	
	3.04	3	147	0.9	2.94	3.83	292	2.00	3.43	0.163	

Appendix 1

Data on AASHTO Overlay Projects

Loop	AASHTO Design D	Overlay Thickness in.	Before Overlay			After Overlay				Strength Coeff. of Overlay	
							At end of Service				
			18 kip 1000 S	S	Actual D	S	18 kip 1000 S	S	Actual D	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
5	3.04	3	132	1.4	2.94	3.10	271	2.00	3.40	0.153	
cont.	3.50	3	375	0.4	3.32	3.80	2,798	2.60	4.31	0.330	
	3.50	3	385	1.5	3.36	3.80	2,208	3.65	5.08	0.573	
	3.48	3	362	0.9	3.28	3.00	2,849	2.00	4.21	0.310	
	3.48	3	337	1.7	3.31	3.17	2,297	2.54	4.22	0.303	
	3.92	3	1,667	0.1	3.88	3.40	1,224	2.45	4.24	0.120	
	3.92	3	975	1.4	3.68	3.10	1,053	2.85	4.20	0.173	
	3.06	3	161	1.5	2.98	3.60	330	2.00	3.48	0.167	
	3.06	3	170	1.1	2.96	3.75	167	1.55	3.31	0.117	
	3.46	3	364	1.4	3.30	3.50	2,848	3.60	5.02	0.573	
	3.46	3	334	1.7	3.31	2.90	240	2.00	3.54	0.077	
	3.90	3	1,654	1.4	3.87	3.50	735	3.60	4.95	0.360	
	3.50	3	378	1.6	3.35	3.63	2,797	3.85	5.72	0.790	
	3.50	3	304	1.7	3.26	3.30	2,296	2.55	4.23	0.323	
	3.48	3	370	1.3	3.30	4.07	2,798	3.95	5.93	0.877	
	3.48	3	942	1.1	3.66	3.55	1,053	2.50	4.10	0.147	
	3.48	3	378	1.5	3.33	4.00	2,798	3.10	4.50	0.390	
	3.92	3	2,001	0.9	3.95	3.53	895	2.15	4.20	0.083	
	3.46	3	231	1.0	3.11	3.00	2,894	2.55	4.27	0.387	
	3.46	3	319	1.6	3.28	3.37	2,257	2.20	4.16	0.293	
	3.90	3	1,852	0.8	3.93	3.30	1,192	3.30	4.61	0.227	
	3.90	3	1,544	0.6	3.85	2.97	882	2.95	4.30	0.150	
	3.90	3.5	1,492	1.5	3.88	3.30	1,283	3.15	4.50	0.207	
	3.90	3	1,334	1.2	3.80	3.33	946	3.45	4.60	0.267	
	3.48	3	994	1.0	3.68	3.67	1,005	3.60	4.85	0.390	
Mean	3.48	3	674	1.2	3.40	3.40	1,696	2.79	4.38	0.325	0.203

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Data on AASHTO Overlay Projects

Loop	AASHTO Design D	Overlay Thickness in.	Before Overlay			After Overlay				Strength Coeff. of Overlay	
							At end of Service				
			18 kip 1000 S	S	Actual D	S	18 kip 1000 S	S	Actual D	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
6	4.36	3	3,374	1.1	4.15	3.90	1,992	3.90	6.02	0.623	
	4.82	3	6,865	1.2	4.46	3.67	3,921	3.55	5.37	0.303	
	3.92	3	1,300	1.0	3.78	2.93	10,396	2.50	4.80	0.340	
	3.92	3	710	1.4	3.57	2.90	5,188	2.60	4.52	0.317	
	3.94	3	1,320	1.3	3.80	3.57	10,396	3.40	5.22	0.473	
	4.78	3	6,757	1.0	4.44	3.35	4,068	3.00	4.92	0.160	
	3.94	3	1,856	1.6	3.96	2.97	7,736	2.85	4.82	0.287	
	3.94	3	2,569	0.4	4.05	3.47	2,494	3.70	5.46	0.470	
	3.50	3	3,765	1.5	4.25	2.97	7,912	1.75	4.70	0.150	
	3.50	3.5	2,435	1.0	4.02	3.30	2,798	3.15	4.74	0.206	
	3.48	3	841	0.9	3.62	3.4	10,865	2.00	4.72	0.367	
	4.36	3	3,320	1.7	4.20	3.83	2,137	3.85	5.92	0.573	
	4.36	2.5	7,090	1.5	4.46	3.30	4,205	3.00	4.92	0.184	
	4.36	3.5	2,723	1.6	4.11	2.97	2,271	2.95	4.58	0.134	
	4.34	3.5	5,711	1.6	4.40	3.40	4,909	3.15	5.02	0.177	
	4.34	3	3,434	1.4	4.18	3.50	2,137	3.65	5.40	0.407	
	4.38	3	4,792	0.7	4.30	2.50	4,909	2.65	4.78	0.160	
	4.38	3	3,712	1.3	4.24	3.97	1,992	3.85	5.90	0.553	
	3.94	3	1,789	1.7	3.95	2.50	9,594	2.20	4.74	0.263	
	3.94	3.5	3,374	1.5	4.19	4.07	2,271	4.25	-	-	
	3.90	3	811	0.5	3.6	3.80	10,865	3.70	5.80	0.733	
	3.90	3	2,072	1.9	4.04	3.47	4,517	3.35	4.92	0.293	
	3.92	3	870	1.1	3.64	3.40	1,467	2.00	4.08	0.147	
	3.92	3	661	1.2	3.54	2.93	984	2.00	3.75	0.137	
	4.36	3	1,418	1.1	3.84	3.50	10,122	2.10	4.73	0.297	

Appendix 1

Data on AASHTO Overlay Projects

			Before Overlay			After Overlay				Strength Coeff. of Overlay	
							At end of Service				
Loop	AASHTO Design D	Overlay Thickness in.	18 kip 1000 S	S	Actual D	S	18 kip 1000 S	S	Actual D	Mean	Std. Dev.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
6	4.36	3	1,520	0.1	3.85	3.67	4,100	2.90	4.63	0.260	
cont.	3.94	3	1,105	1.3	3.73	3.85	10,650	2.55	4.82	0.363	
	3.94	3	701	1.0	3.55	2.87	5,188	2.05	4.46	0.303	
	4.38	3	1,496	1.6	3.88	3.47	8,890	2.10	4.70	0.273	
Mean	4.11	3.05	2,703	1.2	3.99	3.49	5,403	2.92	4.95	0.320	0.159
Average of Means	3.35	3	760	1.2	2.93	3.26	2,338	2.82	3.79	0.30	0.174

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