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THICKNESS DESIGN

—Full-Depth Asphalt Pavement Structures for Highways and Streets

ENGINEERING · RESEARCH · EDUCATION · THE ASPHALT INSTITUTE

THE ASPHALT INSTITUTE

Manual Series No. 1 (MS-1)

REVISED EIGHTH EDITION *AUGUST 1970*

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—FULL-DEPTH ASPHALT PAVEMENT STRUCTURES FOR HIGHWAYS AND STREETS

Printed in USA

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CONVERSION FACTORS

The units of measurement used in this manual may be converted to metric units by the following factors:

To convert from	*to*	*multiply by*
foot	**meter**	**0.3048**
inch	**centimeter**	**2.5400**
inch	**meter**	**0.0254**
mile	**kilometer**	**1.6093**
miles/hour	**kilometers/hour**	**1.6093**
pound	**kilogram**	**0.4536**

FOREWORD

Thickness Design—Full-Depth Asphalt Pavement Structures for Highways and Streets (MS-1) is published for engineers who determine thickness requirements for asphalt pavement structures. It serves also as a useful text for instruction of students in highway engineering.

This manual presents methods for evaluating the factors that should be considered in the overall thickness design of the asphalt pavement structure. It includes such important topics as traffic evaluation, subgrade soil evaluation, total thickness and layer thickness determination, compaction, drainage, and environmental effects.

An adequate and economical design for a pavement structure is just as important as one for any other engineering structure. An underdesigned pavement will fail just as surely, though perhaps not as spectacularly, as other types of structures, and the engineer's responsibility for the failure is just as real. On the other hand, a wasteful overdesign, or selection of materials that are not the most economical and suitable for the design, is contrary to the standards of the engineering profession. The purpose of this manual, then, is to serve as a guide in the design of pavement structures that match the environmental and service requirements.

Previous editions of this manual contained thickness design procedures for Full-Depth asphalt pavement structures as well as pavement structures with untreated granular bases. The main body of this edition incorporates only design procedures for *Full-Depth* asphalt pavement structures built with asphalt concrete similar to Asphalt Institute Type IV mixes. Appendix A, however, contains general guidelines for designs using asphalt bases other than asphalt concrete and Appendix B contains guidelines for designs with granular bases.

For many reasons explained in this manual, The Asphalt Institute strongly recommends the use of Full-Depth asphalt construction.

The procedures herein are based on analyses of data from the AASHO Road Test, the WASHO Road Test, British Road Tests, experience of state and federal agencies and other sources. While they are considered as reliable, they do not represent the final word. Work is under way to develop more rational design methods. As knowledge increases in this field, this manual will be revised to reflect the latest and most up-to-date techniques.

Other Asphalt Institute manuals dealing with subgrade evaluation and mix design are referred to in this publication. Information about them may be obtained from any of the engineering offices of The Asphalt Institute listed in the back of this manual. The men who staff these offices will welcome the opportunity to serve you.

THE ASPHALT INSTITUTE
ASPHALT INSTITUTE BUILDING
COLLEGE PARK, MARYLAND 20740
DECEMBER 1969

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Chapter I

INTRODUCTION

1.01 ASPHALT PAVEMENT STRUCTURE—An asphalt pavement structure is composed of an asphalt surface course and one or more asphalt base courses supported by the native soil (subgrade). Sometimes, layers termed "subbase" or "improved subgrade," or both, are also included in the structure.

These structures may be designed and built to support the heaviest traffic volumes and loads. With increasing depth, wheel loads are spread over larger areas, thus reducing the loading intensity until the subgrade will support the load without damage.

This is illustrated in Figure I-1(a). The wheel load, W, is transmitted to the pavement surface through the tire, as an approximately uniform vertical pressure, P_o. The pavement structure then spreads the load stresses, thus reducing their intensity until, at the surface of the

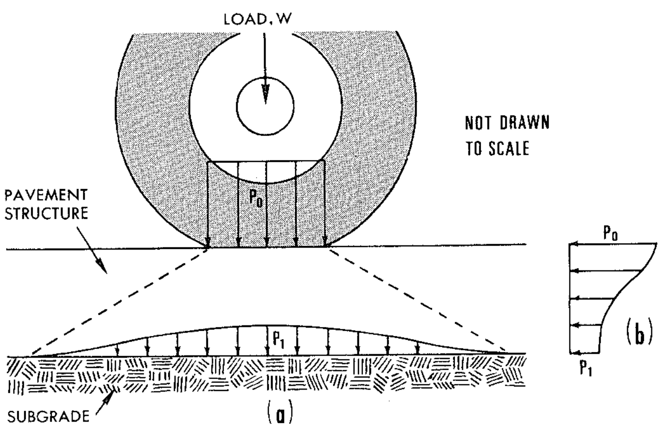


Figure I-1—Spread of wheel-load through pavement structure

subgrade, the vertical pressure has a maximum intensity of P_1. Figure I-1(b) illustrates the general manner in which the maximum vertical pressure intensity decreases with depth, from P_o to P_1. By proper selection of pavement materials and with an appropriate depth and strength of structure, P_1 will be small enough to be easily supported by the subgrade.

1.02 DEFINITION OF TERMS—In most cases, terminology of special significance will be explained at appropriate points in the text. However, for convenient reference, a Glossary is contained in Appendix G.

1.03 ADVANTAGES OF ASPHALT BASES—Asphalt bases are composed of mineral aggregates bonded together by asphalt. They have many advantages. One of the more important of these is the ability to resist pavement stresses.

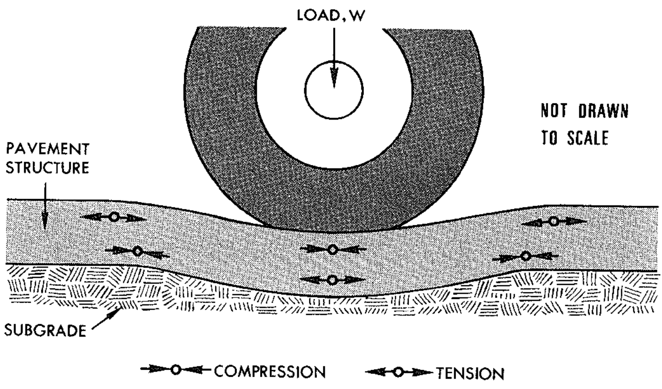


Figure 1-2—Pavement deflection results in tensile and compressive stresses in pavement structure

The wheel load, W, deflects the pavement structure and causes both tensile and compressive stresses. See Figure I-2. Asphalt-bonded aggregates resist these stresses far better than unbonded aggregates, which have no tensile strength. Therefore, asphalt bases spread the wheel load over broader areas than unbonded aggregate bases and less pavement structure thickness is required. This applies to all loading conditions.

Other important advantages of asphalt bases:

1. With proper construction, they will result in pavements of improved riding quality.
2. Aggregates that are not suitable for asphalt surface courses often may be used in asphalt base courses.
3. They afford an excellent means for stage construction.
4. Construction delays caused by inclement weather are minimized.
5. They may be used by haul traffic before the surface course is placed, thus expediting construction.

1.04 ADVANTAGES OF FULL-DEPTH® ASPHALT PAVEMENTS—A Full-Depth asphalt pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. In addition to those outlined above for asphalt bases, Full-Depth asphalt pavements have the following advantages:

1. They have no permeable granular layers to entrap water and impair performance.
2. Subsurface drainage is not normally required.
3. The need for base drainage through the shoulder is eliminated, allowing a substantial reduction in the quantity of high-quality granular materials.
4. Time required for construction is reduced.
5. When placed in deep lifts (4 inches or more), construction seasons may be extended.
6. There is less interference with utilities in city street construction because they are thinner than pavement structures with untreated granular layers.

7. They provide and retain uniformity in the pavement structure.
8. They are unaffected by frost or moisture.
9. There is little or no reduction in subgrade strength, and sometimes it may actually increase. According to limited current studies, moisture contents do not build up in subgrades under Full-Depth asphalt pavement structures as in those under pavements with granular bases. Thus the subgrade retains or increases its strength.

Chapter II

DESIGN CONSIDERATIONS

2.01 FULL-DEPTH ASPHALT PAVEMENTS—The main body of this manual presents a thickness design procedure for pavement structures to be built entirely of dense-graded asphalt concrete, similar to Asphalt Institute Type IV mixes.

Appendix A brings together such information as is presently available on the substitution of other types of asphalt bases for the dense-graded asphalt concrete type. Investigations are under way by The Asphalt Institute and others to extend and enhance design information for these other types of asphalt bases. These investigations encompass comprehensive field, laboratory and theoretical studies. As documented information becomes available it will be incorporated into this manual.

The Asphalt Institute strongly recommends the use of Full-Depth asphalt pavements. As pointed out in Chapter I, untreated aggregate bases cannot withstand tensile stresses and thus they perform in an inferior manner when compared with asphalt bases. In addition, there is substantial evidence that untreated granular bases frequently act as moisture accumulators and reservoirs which hold water continually in contact with the subgrade. This gradually decreases the strength of the subgrade and, in turn, lowers the load-carrying capability of the roadway. Nevertheless, Appendix B is included to give some general guidelines on converting thickness designs for Full-Depth asphalt pavement structures to ones for pavement structures using granular bases, in case such information is desired.

2.02 OUTLINE OF PROCEDURE—Principal factors to be evaluated for the structural design of a Full-Depth asphalt pavement are:

1. Traffic conditions throughout the design period.

2. Subgrade and available construction materials.
3. Environmental factors which may affect pavement behavior or service.
4. Miscellaneous design requirements.

Each of these factors is discussed in the following text. Methods to establish the structural design of the pavement are given in Chapter V.

2.03 DRAINAGE—One of the advantages of Full-Depth asphalt pavements, previously noted, is that subsurface drainage normally is not required. Only where high ground water tables require interceptor drains, where water may accumulate at the low point of vertical curves, or where active springs or seeps occur beneath the pavement must consideration be given to subsurface drainage. The design of subsurface drains to overcome these conditions is covered in considerable detail in *Drainage of Asphalt Pavement Structures*, Manual Series No. 15 (MS-15), The Asphalt Institute.

2.04 COMPACTION—Sufficient compaction to prevent additional consolidation of materials within the pavement structure, and the upper zone of the subgrade, is highly important for satisfactory pavement performance. Under heavily loaded vehicles, inadequate compaction usually is followed by further consolidation of the materials in wheel paths. This results in irregular pavement surfaces that ride poorly and that may pond water on flat grades. Inadequate compaction also fails to develop the full design strength of materials within the structure. The result may be early failure of the roadway. Compaction requirements are specified in Chapter IV.

2.05 ENVIRONMENTAL EFFECTS—Asphalt pavement structures are built to serve extreme ranges of environmental conditions—from the tropics to arctic regions and from arid deserts to rain forests. The various combinations of environmental factors make it impractical to establish precise methods of evaluation, but procedures presented in this manual will result in pavement designs that will give proper service under the more adverse conditions. In some environments, however, local or regional experience may justify some modifications in designs determined by these procedures. Asphalt Institute engineers can provide advice on these matters in the areas they serve.

2.06 STAGE CONSTRUCTION—There are many types of installation where stage construction of the pavement should be considered. One of these is streets in new housing developments. Here, the asphalt base may be built to accommodate construction traffic and an asphalt surface added as the final phase of construction. Another example is roads where traffic volume is expected to increase substantially some time after initial construction. A distinct advantage of stage construction is that any consolidation of roadway materials under traffic that may occur can be corrected when the final surface is placed. This assures superior surface smoothness over a much longer period of time. Design procedures for planned stage construction are contained in Chapter VI.

NOTES

Chapter III

TRAFFIC ANALYSIS

3.01 TRAFFIC—Traffic on highways and streets varies both in number of vehicles and in the magnitude of loadings. Among the various political subdivisions, legal axle load limits may vary for different classes of roads. Likewise, maximum gross load limits and minimum wheel spacings usually are governed by statutes. Furthermore, traffic patterns are constantly changing as a result of land-use developments. Current and future traffic conditions therefore cannot be established precisely.

Nevertheless, the cumulative effects of traffic loads are very important factors in the structural design of a pavement. Both the initial traffic conditions, and the manner in which they may be expected to change, must be evaluated. Because of the infinite variability of these traffic conditions, their cumulative effects must be expressed in some *common denominator* for practical use in a pavement design method. Procedures outlined in this manual employ a *Design Traffic Number* (DTN) as the common denominator. Determination of this factor is fully discussed later in this chapter.

3.02 TRAFFIC ESTIMATES—Estimating the initial and future traffic volumes and loadings for precise design requires substantial study and analysis. Such a comprehensive treatment of the subject is beyond the scope of this manual. However, selected references to authoritative publications are given at the end of this chapter.

Help on traffic estimates for pavement thickness design may come from several sources. Assistance may be obtained from consulting engineers specializing in this field. The planning departments of the state highway departments and municipalities also may supply valuable information. In addition, a traffic survey of existing roadways, similar to the roadway being planned, will be helpful.

3.03 SPECIAL TERMS—Special terms used in this manual in relation to traffic analysis are:

1. *Design Lane:* the lane on which the greatest number of equivalent 18,000-pound single-axle loads is expected. Normally, this will be either lane of a two-lane roadway or the outside lane of multi-lane highways.

2. *Design Period:* the number of years from the initial application of traffic until the first major resurfacing or overlay is anticipated. This term should not be confused with *pavement life.* By adding asphalt overlays as required, pavement life may be extended indefinitely, or until geometric considerations or other factors may make the pavement obsolete.

3. *Design Traffic Number* (DTN): the average daily number of equivalent 18,000-pound single-axle loads estimated for the design lane during the design period. (NOTE: The thickness design charts, Figures V-1 and V-2, are based on a 20-year design period and DTN for the design period must be adjusted for their appropriate use. Refer to Article 3.04.)

4. *Equivalent 18,000-Pound Single-Axle Load:* the effect on pavement performance of any combination of axle loads of varying magnitude, equated to the number of 18,000-pound single-axle loads required to produce an equivalent effect. Extensive studies have provided factors for converting various axle loads to an equivalent number of 18,000-pound single-axle loads. These factors are given in Appendix C.

5. *Initial Daily Traffic* (IDT): the average daily number of vehicles expected to use the roadway, in both directions, during the first year.

6. *Initial Traffic Number* (ITN): the average daily number of equivalent 18,000-pound single-axle load applications expected on the design lane during the first year.

7. *Traffic Classification:*

Light:	Traffic conditions resulting in a Design Traffic Number (DTN) less than ten (10).
Medium:	Traffic conditions resulting in a Design Traffic Number (DTN) between ten (10) and one hundred (100).
Heavy:	Traffic conditions resulting in a Design Traffic Number (DTN) above one hundred (100).

NOTE: Mix design criteria and other requirements vary for these traffic classifications. Refer to *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*, Manual Series No. 2 (MS-2), and *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types*, Specification Series No. 1 (SS-1), The Asphalt Institute.

3.04 DETERMINING THE DESIGN TRAFFIC NUMBER (DTN)—A simplified and approximate method for determining the DTN is outlined below. A somewhat more comprehensive method is given in Appendix C.

1. Estimate the average daily number of vehicles expected during the first year following the opening of the finished roadway to traffic. This is called the Initial Daily Traffic (IDT).

2. Estimate the percent heavy trucks, A, in the traffic stream from traffic count and classification data. However, when such data are lacking, estimates may be made from information given in Table III-1.

TABLE III-1—ESTIMATED RANGES IN PERCENT TRUCKS AND AVERAGE GROSS WEIGHT IN THE UNITED STATES

Description of Highway or Street	Percent[1] Heavy Trucks	Average[1] Gross Weight (1000 Pound)
City Streets (local)	5 or less	15-25
Urban Highways		
Primary	5[2] - 15	20-30
Interstate	5 - 10	35-45
Local Rural Roads	15 or less	15-25
Interurban Highways		
Primary	5 - 20	30-40
Interstate	10 - 25	35-45

[1] Average United States conditions only. Other countries and local United States conditions, depending on land use and industry, may require special considerations.
[2] Sometimes less.

3. Determine the percent heavy trucks,* B, in the design lane. This may be estimated from Table III-2. Normally most trucks operate in the outermost traffic lanes, and may be considered equally divided in both directions. There are exceptions to this, however, for special circumstances where heavy truck-haul traffic will be in one direction, such as mining areas, with empty trucks using the return lanes. On multilane highways, it has been found that more than 80 percent of the heavily loaded trucks usually are in the outside lanes.

*Heavy trucks are heavy commercial vehicles, normally 2-axle 6-tire vehicles or larger. Pickup and light panel trucks are excluded.

TABLE III-2—PERCENTAGE OF TOTAL TRUCK TRAFFIC IN DESIGN LANE

Number of Traffic Lanes (Two Directions)	Percentage of Trucks in Design Lane
2	50
4	45 (35-48)[1]
6 or more	40 (25-48)[1]

[1] Probable range.

4. Estimate the average daily number of heavy trucks expected on the design lane (one direction only) as follows:

$$\text{Number of heavy trucks} = (\text{IDT}) \times \frac{A}{100} \times \frac{B}{100}$$

where IDT, A, and B are as described in steps 1, 2, and 3, above.

5. Estimate the average gross weight of the heavy trucks from weight study data. When such data are lacking, estimates may be made from information given in Table III-1.

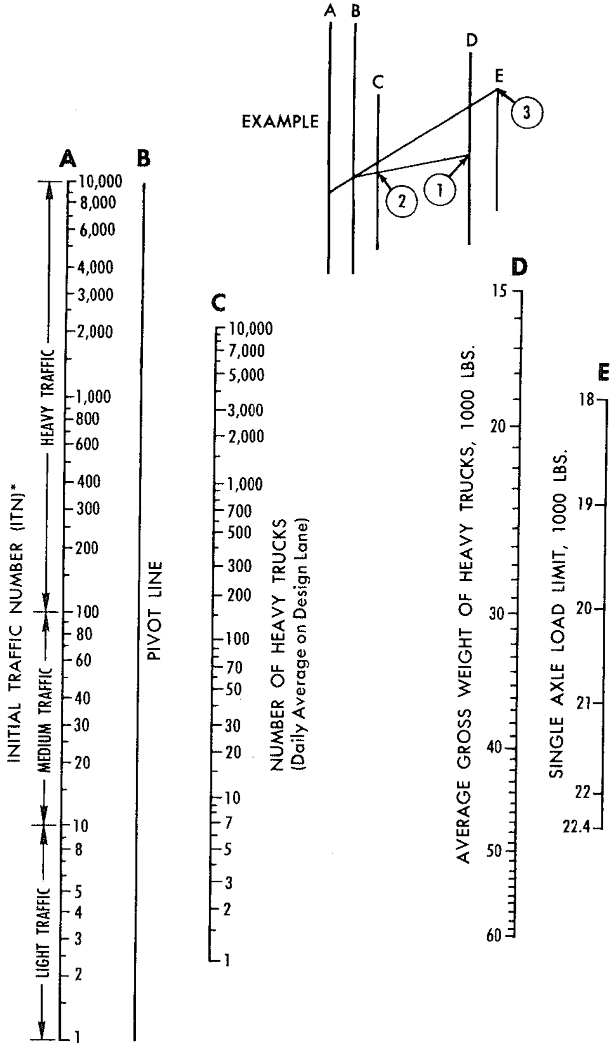
6. Determine the legal single-axle load limit established by state or local statutes.

7. With the above information, establish the Initial Traffic Number (ITN) using the Traffic Analysis Chart, Figure III-1, as follows:

   (a) Enter the chart with the average Gross Weight (step 5) at the proper point on line D.

   (b) Locate the number of heavy trucks, daily average on the design lane (step 4) at the proper point on line C.

   (c) Connect the points on lines D and C with a straight line and extend it to line B. Where this line intersects line B is the pivot point.



* ITN value may require correction where the IDT of automobiles and light trucks is relatively high. See Figure III-2

Additional copies of this nomograph are available at the nearest Asphalt Institute office.

Figure III-1—Traffic analysis chart

(d) Locate the proper single-axle load limit point on line E.

(e) Connect the single-axle load limit point on line E with the pivot point on line B with a straight line and extend it to line A.

(f) Read the Initial Traffic Number (ITN) on line A where the extended line E-B intersects it.

8. When the resultant ITN is 10 or less, and when a relatively large number of automobiles and light trucks are expected to use the roadway, a correction of ITN is required. The correction is made by the use of Figure III-2, as follows:

   (a) Enter Figure III-2 on the horizontal scale at a point representing the Daily Volume of Automobile and Light Trucks in the Design Lane.

   (b) Move vertically to the curve representing the Initial Traffic Number (ITN) based on heavy trucks, determined previously.

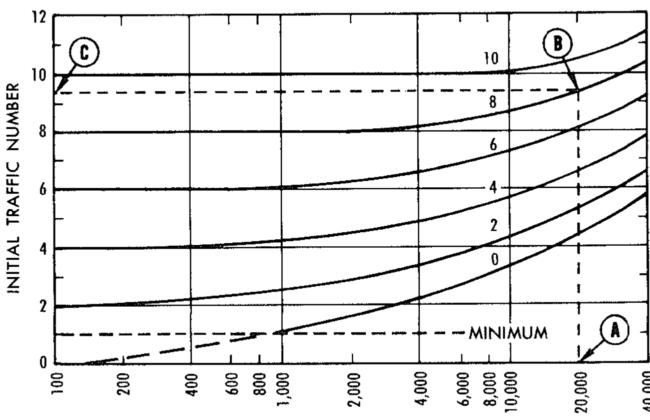


Figure III-2—Chart for adjusting Initial Traffic Number (ITN) for daily volume of automobiles and light trucks

(c) Read the corrected ITN on the Initial Traffic Number scale.

An example of this correction is illustrated on Figure III-2, assuming the following:

Daily Volume of Automobiles and Light Trucks in Design Lane = 20,000 vehicles

ITN (based on heavy trucks) = 8.

Enter the chart at Daily Volume = 20,000 (Point A) and move vertically to ITN 8 line (Point B). The corrected ITN is 9.5 (Point C).

9. Establish the Design Period. For new construction, the Design Period normally will be 20 years.
10. Estimate the Annual Growth Rate of traffic. Currently, traffic in the United States increases, on an average, about 3 to 5 percent per year. In other countries, especially in Europe, the annual growth rate may be more than 5 percent.
11. For the selected Design Period and Annual Growth Rate, select the Initial Traffic Number (ITN) Adjustment Factor from Table III-3.
12. Multiply the ITN (step 7 or 8 above) by the Adjustment Factor (step 11 above) to obtain DTN_{20} for use in the Thickness Design Charts in Chapter V.

NOTE: The Thickness Design Charts (Figures V-1 and V-2) are based on a 20-year design period. For a Design Period of less, or more, than 20 years, an adjustment must be made to reflect the fewer, or additional, equivalent 18,000-pound single-axle loads. This adjustment is made by multiplying the ITN by the proper factor from Table III-3. The DTN obtained, then, is the average daily number of equivalent 18,000-pound single-axle load applications for the selected Design Period adjusted to an equivalent DTN for a 20-year Design Period.

TABLE III-3—INITIAL TRAFFIC NUMBER (ITN) ADJUSTMENT FACTORS

Design Period, Years, (n)	Annual Growth Rate, percent (r) 2	4	6	8	10
1	0.05	0.05	0.05	0.05	0.05
2	0.10	0.10	0.10	0.10	0.10
4	0.21	0.21	0.22	0.22	0.23
6	0.32	0.33	0.35	0.37	0.39
8	0.43	0.46	0.50	0.53	0.57
10	0.55	0.60	0.66	0.72	0.80
12	0.67	0.75	0.84	0.95	1.07
14	0.80	0.92	1.05	1.21	1.40
16	0.93	1.09	1.28	1.52	1.80
18	1.07	1.28	1.55	1.87	2.28
20	1.21	1.49	1.84	2.29	2.86
25	1.60	2.08	2.74	3.66	4.92
30	2.03	2.80	3.95	5.66	8.22
35	2.50	3.68	5.57	8.62	13.55

$$\text{Factor} = \frac{(1 + r)^n - 1}{20\, r}$$

NOTE: Truck growth rate, which includes both number and weight of trucks, may increase faster than overall traffic growth rate, particularly on roads with large volumes of heavy trucks. Growth rates for these roads should be determined from truck weight study data, if possible.

Example 1—Assume a proposed six-lane interstate interurban highway will have an estimated ADT = 38,000. The annual growth rate of traffic is expected to be 4 percent. The legal single-axle load limit is 18,000 pounds and the average gross weight is expected to be 40,000 pounds. The heavy trucks in the traffic stream are expected to be 11 percent of the total traffic volume. The heavy trucks in the design lane are estimated to be 40 percent of the total number of heavy trucks. Find the DTN for a 20-year Design Period.

1. IDT = 38,000 vehicles per day.
2. Percent heavy trucks in both directions, A = 11.
3. Percent heavy trucks in design lane, B = 40.

4. Number of heavy trucks in design lane =

$$38{,}000 \times \frac{11}{100} \times \frac{40}{100} = 1672$$

(See Tables III-1 and III-2. Plot on line C, Figure III-1).

5. Draw line through points C and D and project to line B.
6. Single-axle load limit = 18,000 pounds. Plot on line E, Figure III-1.
7. Draw line through points on lines B and E and project to line A.
8. Read on line A, Figure III-1, an Initial Traffic Number (ITN) = 1400.
9. ITN more than 10, no correction for automobiles and light trucks necessary.
10. Design Period = 20 years.
11. Annual Growth Rate = 4 percent.
12. Initial Traffic Adjustment Factor = 1.49 (see Table III-3).
13. $DTN_{20} = 1400 \times 1.49 = 2086$ or, rounding off, 2100.

Additional design examples are in Appendix E.

3.05 BIBLIOGRAPHY FOR TRAFFIC ESTIMATION—Listed below are selected publications that contain helpful information on procedures for making traffic estimates.

1. *Traffic Engineering Handbook,* Institute of Traffic Engineers, Washington, D. C., 1965
2. *Highway Capacity Manual,* Special Report 87, Highway Research Board, National Academy of Sciences, Washington, D. C., 1965
3. *A Policy on Geometric Design of Rural Highways,* ("The Blue Book"), American Association of State Highway Officials, Washington, D. C., 1965
4. *Traffic Assignment Manual,* Bureau of Public Roads, U.S. Department of Commerce (now Federal Highway Administration), Washington, D.C., 1964

Chapter IV

MATERIALS EVALUATION AND REQUIREMENTS

4.01 MATERIALS TESTING—All materials that are considered for use in an asphalt pavement structure should be tested and evaluated to establish an appropriate basis for economical design and construction. Such tests and evaluations also will furnish information for establishing proper compaction controls and other construction requirements.

Enough soil borings should be made in the proposed roadway and in potential borrow areas to identify the different soil types likely to be encountered. Sufficient quantities of each soil type should be taken for testing and evaluation. Soil profiles should be prepared. *Soils Manual,* Manual Series No. 10 (MS-10), The Asphalt Institute, includes recommendations and other pertinent information on the soil survey. However, to avoid biased results, random sampling techniques should be used to select sampling locations. Refer to Appendix F for such a method.

A. Subgrade

4.02 DEFINITION—Subgrade is defined as the uppermost material placed in an embankment or unmoved from cuts in the normal grading of the roadbed. It is the foundation for the asphalt pavement structure. Subgrade soil sometimes is called "basement soil" or "foundation soil."

4.03 EVALUATION METHODS—The thickness design nomographs in this manual call for subgrade strength values determined by standardized tests as described in

Soils Manual, Manual Series No. 10 (MS-10), The Asphalt Institute. These are:

1. California Bearing Ratio (CBR)
2. Resistance (R) Value
3. Bearing Value Determination (Plate Bearing Test).

Although they are standardized tests, changes in details have been made in many areas to suit local practice. Such changes frequently bring about test results that are different than those obtained from the standard test methods.

Evaluation methods employing these mechanical strength tests are by far the most reliable for design purposes. These tests, performed on subgrade soils in the laboratory or in place, may be supplemented by soil classification tests, if desired. Enough tests should be made to evaluate fully each different soil on the project.

Mechanical strength tests should always be used to evaluate subgrade soils for design of pavements for medium and heavy traffic conditions (see Article 3.03, Item 7). Such tests are preferred for light traffic conditions as well, but soil classification systems can be used to estimate subgrade strength if done by an experienced soils engineer. Figure IV-1 is a guide for estimating CBR values from AASHO and Unified soil classifications.

4.04 ENVIRONMENTAL EFFECTS—In strength evaluation of untreated subgrade materials, factors that may adversely affect the load supporting properties of the material must be considered. The three most critical factors are moisture, soil expansion, and frost effects. CBR and R-value methods both take into account the critical effects of strength loss due to saturation and swelling of the soils. But effects of these factors must be estimated for the Plate Bearing Test because it is made in place.

Frost action can be evaluated on the basis of either frost heave or weakening during the frost melting period. The design method in this manual takes into account reduced supporting capacity of the subgrade during the frost melt period. It results in a pavement structure that is adequate during the frost melt period but will have a load

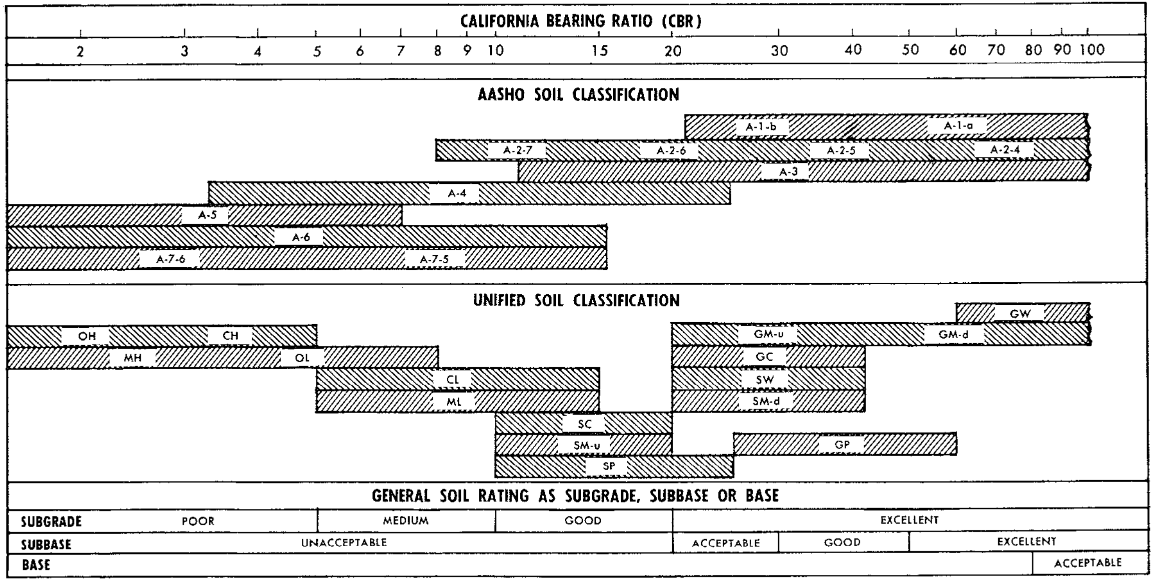


Figure IV-1—Approximate correlation of soil ratings for use in design of light traffic pavements

carrying capacity in excess of that required during other periods of the year. Abrupt changes in subgrade conditions and local areas where soils are highly susceptible to frost heaving and frost boils should be removed and replaced, or reworked to unify the upper portion of the subgrade.

4.05 SELECTION OF DESIGN STRENGTH VALUE—After the strength values are determined the Design Subgrade Strength Value is fixed. The Design Subgrade Strength Value is defined as the subgrade strength value that 90 percent of all test values in the section are equal to or greater than. It is determined in the following manner:

1. Arrange all test values in numerical order.

2. For each different test value, beginning with the lowest one, compute the percentage of the total number of values that is equal to, or greater than that value.

3. Plot the results on cross section paper: abscissa = subgrade strength value; ordinate = percent of subgrade strength values equal to or greater than.
   Draw a smooth best-fit curve through the plotted points.

4. Read from the curve the subgrade strength value at 90 percent. This is the Design Subgrade Strength Value.

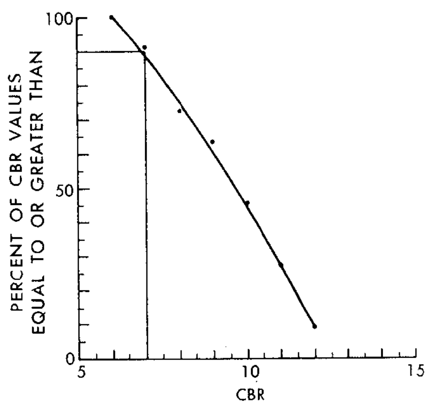
Example—Given: Eleven CBR test values (9, 6, 12, 7, 8, 7, 10, 9, 10, 11, and 11) from a roadway section.

1. CBR = 6, 7, 7, 8, 9, 9, 10, 10, 11, 11, and 12

2. Percent of CBR values equal to or greater than each different value.

CBR	Number equal to or greater than	Percent equal to or greater than
6	11	(11/11)100 = 100
7		
7	10	(10/11)100 = 90.9
8	8	(8/11)100 = 72.7
9		
9	7	(7/11)100 = 63.6
10		
10	5	(5/11)100 = 45.4
11		
11	3	(3/11)100 = 27.3
12	1	(1/11)100 = 9.1

3.



4. Design Subgrade Strength Value, CBR = 7

If a sample from a test location has a value so low that it indicates a weak area, additional samples should be obtained and tested to determine the extent of the area. Such locations may require local increases in thickness to provide uniform support for the entire length of the section to be treated. Test values representing these locations are omitted from calculations to obtain the design strength value.

4.06 IMPROVED SUBGRADE—An improved subgrade is any course or courses of improved material between the native subgrade soil and the pavement structure. It may be a treated in-place material, or an imported material.

Improved subgrade normally is not required in the design and construction of a Full-Depth asphalt pavement structure. It should be considered only when a subgrade that will not support construction equipment is encountered. In such cases it is used as a working platform for construction of the pavement courses and does not affect the design thickness of the pavement structure. A study at the construction site usually is required to establish the best solution for such problems.

4.07 COMPACTION REQUIREMENTS—Compaction normally increases the supporting power of each layer of the pavement structure. Unless each of the various layers is amply compacted during construction, additional consolidation may occur under traffic. This will result in loss of surface smoothness and possible failure of the pavement structure. *Asphalt Paving Manual,* Manual Series No. 8 (MS-8), The Asphalt Institute, covers compaction in detail.

Compaction tests are made in the laboratory on each of the materials to be used in construction to determine the practical maximum density that may be obtained. For subgrade and improved subgrade materials, these laboratory compacted densities should be determined by means of AASHO Method of Test T 180, "Moisture-Density Relations of Soils Using a 10-pound Rammer and an 18-inch Drop." The following compaction criteria are recommended for subgrades and improved subgrades in the construction of asphalt pavement structures:

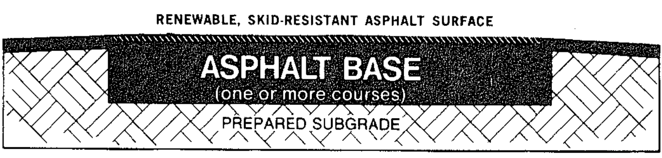
1. *Cohesive Subgrades.* A minimum of 95 percent of AASHO Designation T 180, Method D, density for the top six inches.
2. *Cohesionless Subgrades.* A minimum of 100 percent of AASHO Designation T 180, Method D, density for the top six inches.

Below a depth of six inches all fill areas should be compacted to a minimum of 90 percent of AASHO Designation T 180, Method D density. The water content for compaction of cohesive soils should be determined by tests and should be selected to provide the highest remolded strength consistent with expansion considerations. Generally, nonexpansive cohesive soils should be compacted one or two percent on the dry side of laboratory optimum moisture for best results.

In non-uniform soil deposits, where differential heaving is likely to occur, it may be necessary to rework and recompact the subgrade to provide more uniform subgrade conditions.

B. Full-Depth Asphalt Pavement Structure

4.08 DEFINITION—A Full-Depth asphalt pavement structure is an asphalt pavement in which asphalt-aggregate mixtures are employed for *all* courses above the subgrade or improved subgrade. A Full-Depth asphalt pavement is laid directly on the prepared subgrade. The mathematical symbol T_A denotes Full-Depth or Total Asphalt.



Thickness design procedures given in the main body of this manual are for pavement structures composed entirely of asphalt concrete mixtures similar to Asphalt Institute Type IV mixes. Appendices A and B provide some general guidelines for the design of pavements with other base types.

4.09 REQUIREMENTS FOR ASPHALT PAVEMENT STRUCTURE—Mix design and construction requirements for asphalt concrete surface and base courses are fully covered in the following Asphalt Institute publications:

1. *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types,* Manual Series No. 2 (MS-2)

2. *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types,* Specification Series No. 1 (SS-1)

3. *Thin Hot-Mix Wearing Courses* (an Advisory), MISC-68-3.

4.10 SHOULDERS—Full-Depth asphalt concrete shoulders contribute high lateral support to the pavement structure. They can be built as an integral part of the pavement structure and, because they are not subjected to a large volume of traffic, they usually are relatively thin.

As moisture does not affect asphalt concrete adversely, lateral drains normally are not required when Full-Depth asphalt construction is used. However, lateral drains may be needed to bleed off water in cut sections, low points, and at appropriate intervals in long grades.

It is recommended that a Design Traffic Number of 1 be used for shoulder thickness design. (See Chapter V.)

Chapter V

THICKNESS DESIGN OF PAVEMENT STRUCTURE

5.01 FULL-DEPTH ASPHALT PAVEMENT—This chapter presents a method for determining the total thickness of asphalt concrete pavement structure, T_A, required above the subgrade or improved subgrade to support the anticipated traffic. The basis of the method is the high strength and bearing capacity of high-quality hot-mix asphalt concrete meeting requirements for Asphalt Institute Type IV mixes. The thicknesses derived, therefore, assume the use of these mixes, or ones similar to them. A thin hot-mix asphalt surface, either coarser- or finer-graded than Type IV mixes, may be added if required for increased friction or other special requirements.

Tentative recommendations are made in Appendix A for thickness design using some other types of asphalt-bound bases.

5.02 THICKNESS DESIGN CHARTS—Figures V-1 and V-2 are used to determine the total thickness of hot-mix asphalt concrete pavement, T_A, required for given traffic and subgrade conditions. Figure V-1 is used when the subgrade strength is measured by means of the California Bearing Ratio (CBR) Test* or Plate Bearing Test*. Figure V-2 is used when subgrade strength is measured by the R-value, derived from the Stabilometer Test*.

The Design Traffic Number (DTN) employed in Figures V-1 and V-2 is determined by the procedure presented in Chapter III.

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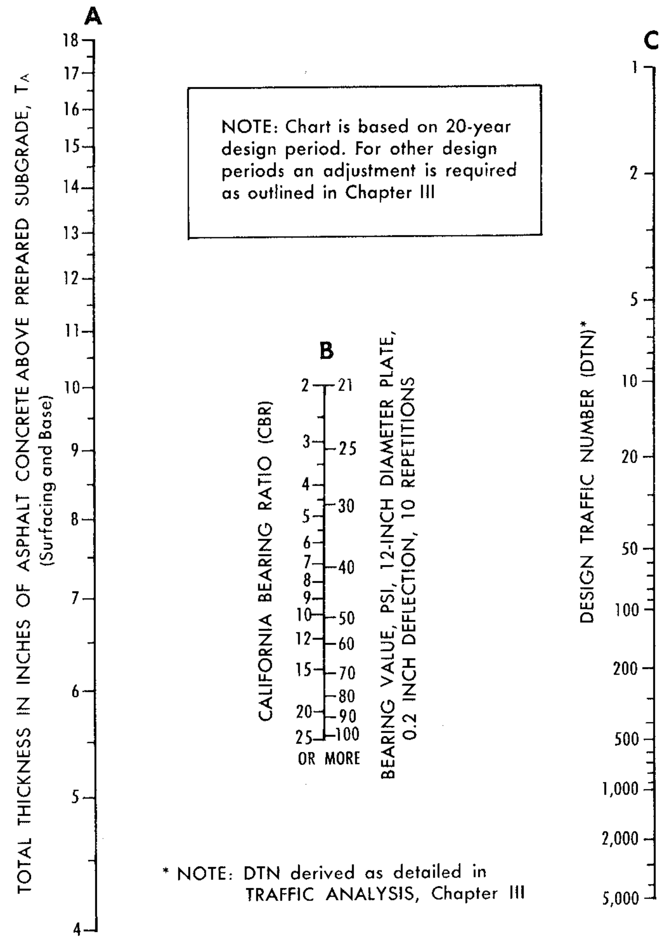
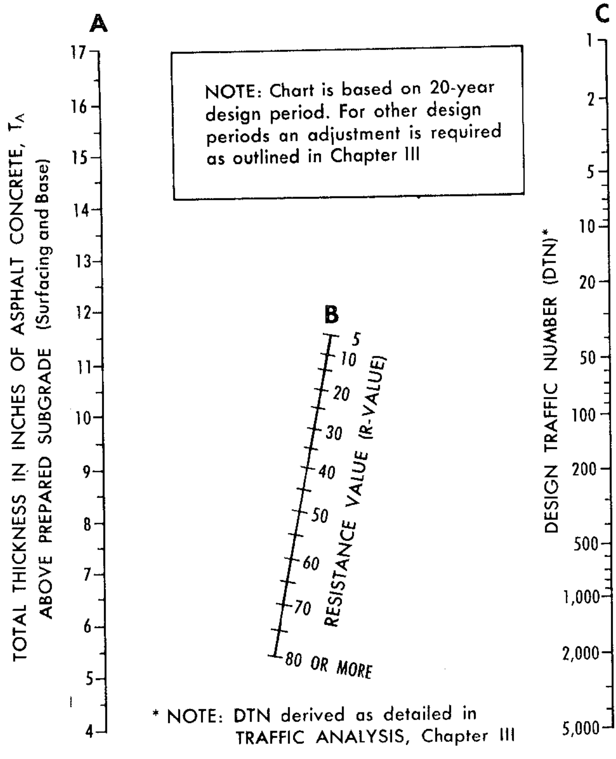
*See *Soils Manual,* Manual Series No. 10 (MS-10), The Asphalt Institute, for details of test.



Additional copies of this nomograph are available at the nearest Asphalt Institute office.

Figure V-1—Thickness design chart for asphalt pavement structures using subgrade soil CBR or Plate-Bearing values



Additional copies of this nomograph are available at the nearest Asphalt Institute office.

Figure V-2—Thickness Design Chart for asphalt pavement structures using Subgrade Soil Resistance Value

5.03 DETERMINING TOTAL STRUCTURE THICKNESS—The use of the thickness design charts is illustrated by the following example:

Assume—

CBR of subgrade = 7

Design Traffic Number (DTN) = 2100

1. Locate CBR value of 7 on Scale B
2. Locate DTN value of 2100 on Scale C
3. Draw line connecting CBR value and DTN value and extend to Scale A
4. Read value of 10.4 inches on Scale A and round to the next highest ½ inch, or 10.5 inches.

Thus, a total asphalt pavement structure thickness, T_A, of 10.5 inches is required for the assumed conditions of CBR and DTN. T_A may be determined similarly from Figures V-1 or V-2 for Plate Bearing or R-value subgrade support values, respectively. Thicknesses determined by these charts should be rounded off to the next highest one-half (½) inch.

The following minimum thicknesses of total asphalt pavement structure, T_A, are recommended:

Design Traffic Number (DTN)	Minimum T_A, Inches
Less than 10	4
10-100	5
100-1000	6
More than 1000	7

5.04 THICKNESS OF SURFACE COURSE—As this thickness design procedure calls for the use of asphalt paving mixtures similar to Asphalt Institute Type IV mixes,* there is no need for a different surface course mix for structural strength. However, a different surface course mix may be needed to provide desirable surface properties for skid resistance, hydroplaning prevention, light reflection, or other such characteristics. Usually, these surfaces are one-half inch to one inch thick and are added to the total design thickness of the pavement structure.

*Refer to *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types,* Specification Series No. 1 (SS-1), The Asphalt Institute.

Chapter VI

PLANNED STAGE CONSTRUCTION

6.01 TWO APPROACHES TO STAGE CONSTRUCTION—Planned Stage Construction is the construction of roads and streets by applying successive layers of asphalt concrete according to design and a predetermined time schedule.

Two approaches to Planned Stage Construction are described in this chapter. In each, the pavement is to be built in two stages. One approach is to use the normal design period of 20 years and then, for Stage 1, reduce the design thickness by 1 or 2 inches of asphalt concrete.

The other is to use a relatively short design period for Stage 1 thickness design, say five years or less, and then provide for Stage 2 construction at the end of that period.

Unforeseen changes in traffic or other conditions may shorten, or lengthen, the predicted design period for Stage 1. With either approach, therefore, performance of the pavement structure should be evaluated each two years to determine when Stage 2 will actually be needed.

6.02 ADVANTAGES OF PLANNED STAGE CONSTRUCTION—The advantages of Planned Stage Construction include improved pavement performance; more accurate analysis of traffic; and, possibly, more effective use of funds.

Improved performance is gained through locating and repairing weak spots that may develop between the first and second stages. Since corrections can be made prior to placing the second stage, a smoother riding pavement and better performance will result.

For the initial pavement design, traffic volume must be estimated, so deferring the final stage makes it possible to secure data on traffic actually using the highway. Thus corrections to the design may be made for Stage 2, either increasing or decreasing the original design, as required.

Both of these advantages should result in a more effective use of funds.

6.03 DESIGN PROCEDURE—*Planned Stage Construction by Reducing Full Design*—In the first step of Planned Stage Construction by Reducing Full Design, determine the pavement structure thickness for a 20-year design period using procedures described in Chapters III, IV, and V. Next, reduce the 20-year design thickness by one or more inches of asphalt concrete. This will be the total thickness of asphalt concrete, T_A, for Stage 1 construction.

Then, estimate the number of years of service between Stage 1 and Stage 2 by determining the design period for the Stage 1 structural section. This is done by the following steps:

1. Enter the thickness design chart, Figure V-1 or V-2, at the total thickness of asphalt concrete for Stage 1, Scale A.
2. Locate the design subgrade strength value on Scale B.
3. Extend a straight line from the point on Scale A through the point on Scale B to the Design Traffic Number (DTN), Scale C.
4. Read the DTN on Scale C.
5. Divide the DTN thus obtained by the Initial Traffic Number (ITN) to determine the Initial Traffic Number Adjustment Factor.
6. Locate the Initial Traffic Number Adjustment Factor in Table III-3 in the proper Annual Growth Rate column and read, or interpolate, the Design Period. This is the estimated number of years of service between Stages 1 and 2.

Example: A Design Traffic Number (DTN) of 2100 (see *Example,* Article 3.04) and a design subgrade strength value of CBR 7 (see *Example,* Article 4.05) result in a 20-year asphalt pavement structure design thickness, T_A, of 10.5 inches (see Article 5.03). If 1.5 inches of total thickness is withheld for the Stage 1 design, the number of years before it must be added (Stage 2) to complete the 20-year design thickness must be estimated.

1. Enter Figure V-1, Scale A, at 9.0 inches (10.5 in.- 1.5 in.).

2. Locate CBR 7 on Scale B.

3. Extend a straight line from 9.0 inches, Scale A, through CBR 7, Scale B, to Scale C.

4. Read DTN = 450 on Scale C.

5. Divide DTN = 450 by ITN = 1400 (see Example, Article 3.04) to determine Initial Traffic Number Adjustment Factor

$$\frac{450}{1400} = 0.32.$$

6. Annual Growth Rate = 4 percent (Example, Article 3.04). From Table III-3, interpolating, the Design Period = 5.8 years. Therefore, the estimated length of service between Stages 1 and 2 is approximately 6 years.

Planned Stage Construction for a Given Time Period— Often it is desirable to construct a pavement for an estimated design period of only a few years, anticipating that the second stage can be more adequately designed as traffic patterns become established. This approach to stage construction design is particularly valuable for city streets or low-volume rural roads where little information on present or future traffic is available.

1. Select the length of time for Stage 1, usually less than 5 years.

2. Estimate the Initial Daily Traffic (IDT) and the percent and average gross weight of heavy trucks. Then determine the Design Traffic Number (DTN) for a 20-year design period and for Stage 1 design period, Chapter III.

3. Determine the design subgrade strength value, Chapter IV.

4. Determine the thickness of asphalt pavement structure, T_A, needed for the design conditions for a 20-year design period and for Stage 1 design period, Chapter V.

Example: A section of interurban highway is to be built by planned stage construction. Initial Daily Traffic (IDT) is estimated to be 2,500 vehicles, of which 10 percent are heavy trucks of 35,000 pounds average gross weight. The legal single-axle load limit is 18,000 pounds. Annual Growth Rate is estimated to be 4 percent.

1. Stage 1 design period selected to be 3 years.

2. DTN_{20} = 104 and DTN_3 = 11 (Chapter III).

3. Design subgrade strength value, R-value = 45 (Chapter IV).

4. Total thickness of asphalt concrete pavement structure, T_A, for 20-year design period = 8.0 inches

   Total thickness of asphalt concrete pavement structure, T_A, for 3-year design period = 5.5 inches

5. Stage 2 estimated thickness then is (8.0 in.-5.5 in.) = 2.5 inches

Appendix A

ASPHALT BASES OTHER THAN ASPHALT CONCRETE

A.01 TENTATIVE PROCEDURES—Only limited data are currently available for establishing thickness requirements for asphalt bases other than asphalt concrete. These data are from a few field test sections, accelerated test track studies, and comprehensive laboratory studies. Procedures given in this appendix should therefore be considered tentative. They will be modified and refined as additional studies are completed. In the interim, they should be helpful in designing pavement thicknesses when these other types of asphalt base are to be used.

A.02 HOT-MIX SAND ASPHALT BASES—The main body of this manual details a thickness design procedure for pavements to be built with mixtures similar to Asphalt Institute Type IV mixes. Many times, however, aggregates are available with gradings that are similar to Asphalt Institute Mix Types VI, VII, or VIII—many deposits of natural sands, for example. These materials, when hot mixed with asphalt cement, provide economical and durable asphalt bases. Recommendations on gradation, design, and other properties of these mixes, as well as construction methods, are given in *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types*, Specification Series No. 1 (SS-1), The Asphalt Institute. Appendix C of SS-1 should be used, except that (1) the recommended value for sand equivalent is 40 for Heavy traffic category and 35 for Medium and Light traffic categories; (2) the grading limits and asphalt content range should be similar to Asphalt Institute Mix Types VI, VII, or VIII; (3) the mixture should meet the suggested criteria on page 74 of SS-1; and (4) the job-mix formula tolerances should be the same as for Specification PM-1.

The tentative method for thickness design of asphalt pavement structures using hot-mix sand asphalt bases follows:

1. Determine the required total thickness of asphalt concrete pavement structure, T_A, according to the procedures set forth in the main body of this manual.

2. Establish the thickness of pavement surface, T_s, to be built with asphalt concrete meeting requirements in *Construction Specifications for Asphalt Concrete,* (SS-1). The recommended minimum thickness of pavement surface is:
   Light Traffic, DTN less than 10.......... 2 inches
   Medium Traffic, DTN 10 to 100........ 3 inches
   Heavy Traffic, DTN above 100............ 4 inches

3. Subtract the thickness of asphalt concrete pavement surface, T_s, (step 2) from the total thickness of asphalt concrete pavement structure, T_A, (step 1) to determine the required effective thickness of asphalt concrete base, T_e

4. Multiply the difference found in step 3 by a factor of 1.3 to obtain the required thickness of the hot-mix sand asphalt base, T_b

   EXAMPLE—

   (1) Assume a road in the Heavy Traffic classification that will require a total thickness of asphalt concrete pavement structure, T_A, of 11.0 inches. Further, assume that a pit-run sand is economically available that will result in an asphalt paving mix meeting the criteria specified above.

   (2) According to the recommended minimums in step 2, above, the thickness of asphalt concrete pavement surface, T_s, should be not less than 4 inches.

(3) Subtract the 4-inch thickness of asphalt concrete pavement surface, T_s, from the 11-inch total thickness of asphalt concrete pavement structure, T_A. The required thickness of asphalt concrete base, T_e, then, is 7 inches.

(4) Multiply the required thickness of asphalt concrete base ($T_e = 7$ inches) by a factor of 1.3. The required thickness of hot-mix sand asphalt base, T_b, is 9.1 inches, or 9.5 inches when rounded to the next highest one-half inch.

A.03 LIQUID AND EMULSIFIED ASPHALT BASES—Liquid asphalts of the Rapid-Curing (RC), Medium-Curing (MC) and Slow-Curing (SC) types are often used to prepare durable and economical asphalt bases. Likewise, mixing grade emulsified asphalts are highly satisfactory for this purpose. Good construction practice is essential. All such mixes require aerating to reduce moisture and volatile contents to the required amounts for maximum compaction and these design procedures presume the attainment of maximum compaction. Proper aeration is reached when volatile content is reduced to about 50 percent and the moisture content does not exceed two percent by weight of the total mixture (two to five percent by weight for emulsified asphalt mixtures).

These bases may be either plant mixed or road mixed. However, road-mixed bases for pavements designed by the procedure described in this appendix require construction by machines equipped with pugmill-type mixers that provide uniformity in mixing and positive controls for mix proportioning.

Recommendations for plant-mix pavements using these liquid and emulsified asphalts may be found in *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types*, Specification Series No. 1 (SS-1), The Asphalt Institute. Recommendations for road-mix pavements prepared by pugmill-type travel plants are contained in *Asphalt Mixed-in-Place (Road-Mix) Manual,* Manual Series No. 14 (MS-14), The Asphalt Institute. For mixes conforming with these recommendations the tentative method for thickness design of asphalt pavement structures using liquid and emulsified asphalt bases follows:

1. Determine the required total thickness of asphalt concrete pavement structure, T_A, according to the procedure set forth in the main body of this manual.
2. Establish the thickness of pavement surface, T_s, to be built with asphalt concrete meeting requirements in *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types,* (SS-1). The recommended minimum thickness of pavement surface is:
   Over base mixes with aggregate gradings similar to Type IV mixes.

   Light Traffic, DTN less than 10.......... 2 inches
   Medium Traffic, DTN 10 to 100.......... 3 inches
   Heavy Traffic, DTN above 100.......... 4 inches

   Over other base mixes
   Light Traffic, DTN less than 10.......... 3 inches
   Medium Traffic, DTN 10 to 100........ 4 inches
   Heavy Traffic, DTN above 100.......... 5 inches
3. Subtract the thickness of asphalt concrete pavement surface, T_s, (step 2) from the total thickness of asphalt concrete pavement structure, T_A, (step 1) to obtain the required effective thickness of asphalt concrete base, T_e.
4. Multiply the difference found in step 3 by a factor of 1.4 to obtain the required thickness of liquid or emulsified asphalt base, T_b.

EXAMPLE—

(1) Assume a road in the Medium Traffic classification that will require a total thickness of asphalt concrete pavement structure, T_A, of 10.0 inches. Further, assume that a pit-run aggre-

gate is economically available for preparing a plant-mixed base with emulsified asphalt, conforming with recommendations in *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types* (SS-1).

(2) According to the recommended minimums in step 2, above, the thickness of asphalt concrete pavement surface, T_s, should be not less than 4 inches.

(3) Subtract the 4-inch thickness of asphalt concrete pavement surface, T_s, from the 10-inch total thickness of asphalt concrete pavement structure, T_A. The required thickness of asphalt concrete base, T_e, then, is 6 inches.

(4) Multiply the required thickness of asphalt concrete base (T_e = 6 inches) by a factor of 1.4. The required thickness of road-mixed emulsified asphalt base, T_b, is 8.4 inches or 8.5 inches when rounded to the next highest one-half inch.

Appendix B

UNTREATED GRANULAR BASES

B.01 UNTREATED GRANULAR BASES — Full-Depth asphalt pavements placed directly on the prepared subgrade offer many advantages over those that include untreated granular layers as part of the pavement structure. Conditions may sometimes exist, however, that call for consideration of a pavement section with an untreated granular base replacing a portion of the Full-Depth asphalt pavement.

The AASHO Road Test and other pavement studies have demonstrated that untreated granular layers require substantially thicker pavement sections than Full-Depth asphalt pavements. The principal reasons for these differences are given in Chapters I and II.

The relative thickness requirements for the two types of pavement structure vary, depending upon subgrade classification, magnitude of wheel loads, amount of traffic, and other factors. The extent to which each of the variables affects relative thickness requirements has not yet been fully evaluated. However, enough is known to set up general guidelines for converting Full-Depth asphalt pavement thickness designs obtained by procedures in this manual to thickness designs for asphalt pavement structures with untreated granular bases.

B.02 MINIMUM THICKNESS OF ASPHALT PAVEMENT LAYER—Only a limited portion of a Full-Depth asphalt pavement may ordinarily be converted to untreated granular base. The maximum thickness that may be converted depends on the minimum thickness of asphalt pavement layer required above it to support the anticipated traffic. The chart in Figure B-1 may be used as a guide for establishing this minimum thickness. The chart takes into consideration the amount and weight of traffic loadings, expressed as DTN, and the strength properties of untreated granular base.

B.03 THICKNESS OF GRANULAR BASE—To determine the *maximum* thickness of asphalt layer for which granular base may be substituted, subtract the *minimum* required thickness of asphalt pavement layer (from Figure B-1) from the Full-Depth asphalt pavement thickness, T_A. Lesser thicknesses of asphalt layer may be converted to granular base, if desired.

Analytical studies of extensive data available from road tests, laboratory experiments, and theoretical analyses show that there is no simple, constant factor for converting a given thickness of asphalt layer into a thickness of untreated granular base that will provide equivalent load-supporting capacity. This conversion is a variable that depends principally on the amount of traffic, the magnitude of the wheel loads, and the strength properties of the untreated granular base and

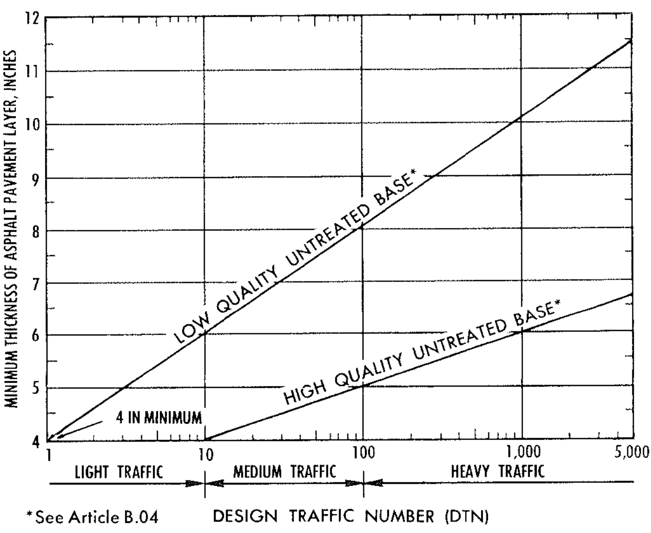


Figure B-1—Minimum thickness of asphalt pavement layers over untreated granular bases

subgrade. Until there are further developments in this area, The Asphalt Institute recommends the use of a *Substitution Ratio* (S_r) for making an approximate thickness conversion from asphalt layer to untreated granular base. Specifically, it is recommended that:

1. 2.0 inches of high-quality untreated granular base material, as defined in Article B.04, be required for each 1.0 inch of asphalt layer for which it may be substituted. In this case, $S_r = 2.0$.

2. 2.7 inches of low-quality untreated base material, as defined in Article B.04, be required for each 1.0 inch of asphalt layer for which it may be substituted. In this case, $S_r = 2.7$.

B.04 UNTREATED BASE QUALITY REQUIREMENTS—High-quality and low-quality untreated base materials are prescribed as follows:

Test	Test Requirements Low-Quality	High-Quality
CBR, minimum	20	100
or		
R-value, minimum	55	80
Liquid Limit, maximum	25	25
Plasticity Index, maximum	6	NP
Sand Equivalent, minimum	25	50
Passing No. 200 sieve, maximum	12	7

B.05 EXAMPLE OF CONVERSION TO GRANULAR BASE—Assume these conditions for the design of a highway:

1. DTN = 80
2. CBR of subgrade = 4

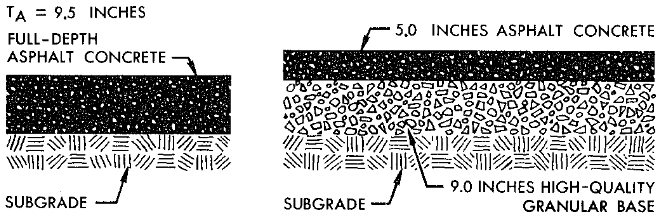
Using the procedure in the main body of this manual, the total thickness of asphalt concrete pavement, T_A, would be 9.5 inches. Assume further that granular base material of high quality is available and that consideration will be given to substituting as much of this untreated material as possible in the lower portion of the pavement structure. Figure B-1 indicates that, for these conditions, about 5 inches is the least thickness of asphalt pavement layer that should be used. The thickness of asphalt layer that may be converted to untreated granular base therefore is:

9.5 inches − 5.0 inches = 4.5 inches.

Article B.03 recommends a Substitution Ratio, S_r, of 2.0 for high-quality untreated granular base material. Therefore, the thickness of granular base to be substituted for 4.5 inches of asphalt layer is:

4.5 inches × 2.0 = 9.0 inches

Alternate thickness designs would then be:



B.06 ADDITIONAL INFORMATION—For more detailed information on local practices for the design of asphalt pavements with granular base, contact the nearest Asphalt Institute office.

Appendix C

DETAILED PROCEDURE FOR TRAFFIC ANALYSIS

C.01 DETAILED TRAFFIC ANALYSIS—Chapter III describes a condensed procedure for using traffic estimates to establish the Initial Traffic Number (ITN) which, in turn, is used to derive the Design Traffic Number (DTN), one of the principal factors in determining pavement thickness requirements.

This appendix describes a more precise procedure for determining the ITN when suitable traffic data are available. This procedure requires the use of detailed traffic survey data, including loadometer studies, to establish the ITN. Such data are accumulated by and may be obtained from state highway departments and other agencies.

C.02 DEFINITIONS — Terms applicable to traffic analysis, as used in this manual, are defined in Appendix G, Glossary.

C.03 TRAFFIC DATA—Obviously, no traffic data are available which are directly applicable to a new pavement facility. The designer must therefore depend upon traffic studies of similar facilities, and community or regional planning studies, to provide the information needed for a detailed traffic analysis (see Chapter III).

State highway departments and many cities and counties accumulate a variety of traffic data which are useful in making traffic analyses of existing and proposed pavement facilities. State highway departments annually report such data in standard format to the Federal Highway Administration. Tables W-1, W-2 and W-4 of these reports, titled "Loadometer and Truck Weight Studies," contain data appropriate for use in traffic analysis procedures outlined in this manual.

C.04 TRAFFIC GROWTH—Pavements must be designed to serve adequately traffic needs over a period of years. Traffic growth must therefore be anticipated in determining structural requirements of the pavement. Traffic growth for comparable facilities, as well as community and regional planning programs, provide a basis for the estimate. The current traffic growth rate in the United States is about 3 to 5 percent annually. In other countries, especially in Europe, the annual growth rate may be more than 5 percent.

C.05 DESIGN PERIOD—A pavement may be designed to support the cumulative effects of traffic for any period of time. The selected period, in years, for which the pavement is to be designed is termed the *Design Period.* At the end of the Design Period, it may be expected that the pavement may require an asphalt overlay to restore high-level riding quality. Design Period, however, should not be confused with pavement life. Asphalt overlays as required not only restore riding qualities but give the asphalt pavement an indefinite life. It will become obsolete only through required changes in grade, alignment or other such factors.

Thickness design curves given in Chapter V of this manual are based on a Design Period of 20 years. If a different Design Period is to be used, these thickness design curves may be used *provided* the Design Traffic Number (DTN) is properly adjusted. The procedure for making this adjustment is explained in Chapter III.

C.06 HIGHWAY CAPACITY—Consideration must be given to the number of traffic lanes required to accommodate the traffic volume, both initially and throughout the Design Period. Any of the selected publications listed in Article 3.05, BIBLIOGRAPHY FOR TRAFFIC ESTIMATION, Chapter III, may be used as a guide for determining the required number of pavement lanes.

C.07 CUMULATIVE EFFECTS OF TRAFFIC—Both the number of vehicles and the weight on each wheel of each vehicle affect the structural requirements of the pavement facility. These occur in an infinite number of combinations and cannot be precisely established. For pavement design purposes, the cumulative effects of these factors must be reduced to some "common denominator." This procedure uses *Equivalent 18,000-pound Single-Axle Loads* as the "common denominator."

C.08 LOAD EQUIVALENCY FACTOR AND TRUCK FACTOR—A *Load Equivalency Factor* is used to convert a single- or tandem-axle load of given magnitude to an *Equivalent 18,000-pound Single-Axle Load.* Such factors for various axle loads have been established by extensive research. The *Truck Factor,* the average number of *Equivalent 18,000-pound Single-Axle Loads* per truck, is used in computing the Initial Traffic Number (ITN).

Load Equivalency Factors for single-axle loads of 10,000 pounds and above and for tandem-axle loads of 17,000 pounds and above can be found in Figure C-1. Where significant volumes of heavily loaded trucks are anticipated, the effects of automobile and light truck loadings on thickness design requirements are of little or no significance and often may be disregarded for design purposes. Conditions under which light axle loads may be disregarded for design purposes are discussed later.

Figure C-2 shows how to determine the *Truck Factor* from loadometer data. For convenience, axle loads are grouped as shown in Column (1). The Load Equivalency Factor, Column (2), for the *average axle* load of each group is determined from Figure C-1. The *Axles Per Day, Per 1000 Trucks and Combinations,* Column (3), may be obtained from Column 34, Table W-4, of the previously noted report titled "Loadometer and Truck Weight Study," or from other sources. The number of *Equivalent 18,000-pound Single-Axle Loads, per 1000 trucks and combinations,* is then shown in Column

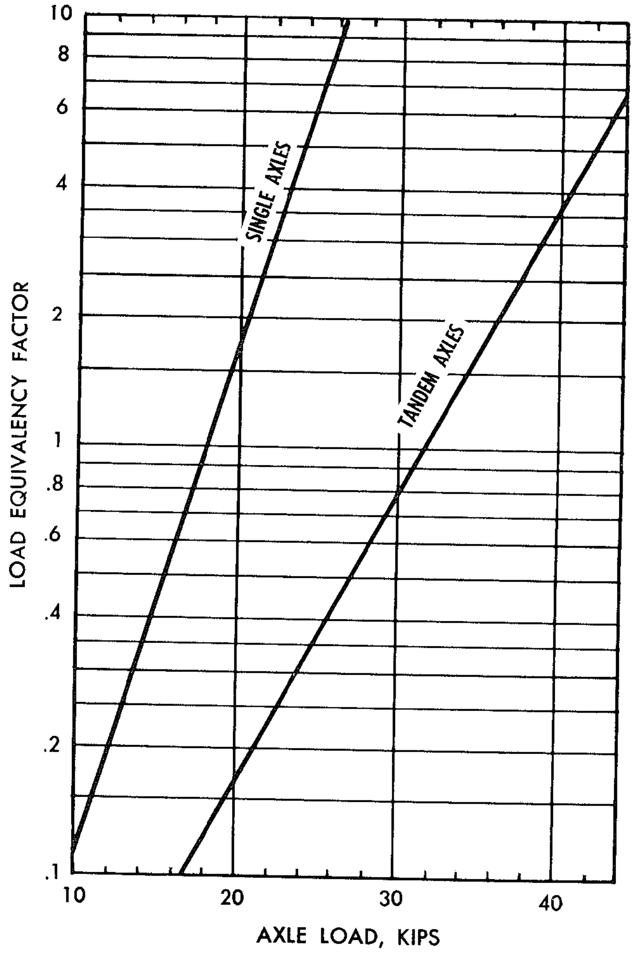


Figure C-1—Load equivalency factors for loads equal to or greater than 10,000 pounds

(1) Axle Load Group (1000-lb.)	(2) Load Equivalency Factor	(3) Axles Per Day Per 1000* Trucks and Combinations	(4) Equivalent 18,000-lb. Single-Axle Loads Per 1000 Trucks and Combinations
		SINGLE AXLES	
Under 8	......	1135.4	......
8-12	0.11	487.3	53.6
12-16	0.34	282.7	96.1
16-18	0.76	118.6	90.1
18-20	1.31	31.9	41.8
20-22	2.26	2.6	5.9
22-24	3.91	6.5	25.4
24-26	6.74		
		Subtotal =	312.9
		TANDEM AXLES	
Under 14	......	189.3	......
14-20	0.11	141.6	15.6
20-26	0.27	168.4	45.5
26-30	0.57	99.4	56.7
30-32	0.92	2.6	2.4
32-34	1.25		
34-36	1.70		
36-38	2.33		
38-40	3.15		
40-42	4.36		
42-44	5.88		
44-46	8.15		
		Subtotal	= 120.2
		Total Single Plus Tandem Axles	= 433.1

Truck Factor $= \frac{433.1}{1000} = 0.43$**

(see Glossary, Appendix G)

* Data from Table W-4 of state highway department "Loadometer and Truck Weight Study" reports, or from other sources.

** If this factor is determined to be less than 0.05, a Truck Factor of 0.05 should be assumed for design purposes.

Figure C-2—Sample calculation of equivalent 18,000-pound single-axle loads and truck factor

(4). These data are the product of data in columns (2) and (3).

Note that while trucks having single-axle loads less than 8,000 pounds, and tandem-axle loads less than 14,000 pounds, are both included in the truck count, no Load Equivalency Factor is indicated for them. The Load Equivalency Factor for these lighter loads is so small that their effects on pavement thickness design requirements may be disregarded except as noted later. The designer should keep in mind, however, that truck counts normally include these lighter loads.

If the *Truck Factor,* computed as shown in Figure C-2, is less than 0.05, Truck Factor of 0.05 should be used as a practical minimum value.

C.09 DESIGN LANE — For two-lane streets and highways, the *Design Lane* may be either lane of the pavement facility. Under some conditions, more trucks may be anticipated in one direction than in the other. The lane with the greatest number of trucks then becomes the Design Lane for two-lane pavements.

The outside lane of multi-lane pavements normally carries the highest volume of trucks. As with two-lane highways, there may be circumstances which result in more truck traffic in one direction than in the other.

In the absence of specific data, Table III-2 may be used for determining the relative proportion of trucks to be expected for the Design Lane.

C.10 DETERMINING THE INITIAL TRAFFIC NUMBER (ITN)—An Initial Traffic Number (ITN) for the anticipated volume of trucks is determined as follows:

1. Estimate the daily number of all trucks in both directions expected to use the pavement during the first year of service (Article C.03).

2. Calculate the Load Equivalency Factor per truck, or Truck Factor (Article C.08).

3. Determine the decimal equivalent of the percentage of trucks using the Design Lane (Article C.09).
4. The Initial Traffic Number (ITN), based on truck traffic only, is the product of all factors in Steps 1 through 3, above.

If the Initial Traffic Number (ITN) established in Step 4 is 10 or more (Medium or Heavy Traffic) the relative effects of light axle loads on pavement thickness design requirements will be negligible and may be disregarded. If the Initial Traffic Number (ITN) is less than 10 (Light Traffic) it must be adjusted to compensate for the effects of the light axle loads on thickness design requirements.

C.11 ADJUSTING THE INITIAL TRAFFIC NUMBER (ITN) FOR LIGHT TRAFFIC CONDITIONS— This procedure is described in Chapter III of this manual.

Appendix D

ANNUAL COST OF HIGHWAYS

D.01 BACKGROUND OF PROCEDURE—This discussion is based on a paper by R. H. Baldock* in which he examined existing methods available for determining the annual cost of highways. He found that all of these methods are similar in that each considers a highway to be a capital investment of public or private funds and each presents a procedure for determining annual costs which includes many factors in addition to construction cost. Mr. Baldock proposed an additional procedure which more conclusively describes the total costs involved.

This procedure for evaluation of highways includes all factors affecting the annual cost with respect to a reasonable period of analysis. To avoid obsolescence due to major technological changes affecting transportation, an analysis period of 40 years was selected. The entire investment is amortized during this period although the highway will almost undoubtedly continue to serve as a portion of the original or some lesser system. This procedure follows the general accounting practice usually applied to capital investments.

Two methods are proposed for analysis of annual cost. The first involves *all* costs pertaining to the complete highway and is used to evaluate the whole facility. The second analyzes only those costs pertaining to the traveled way or mainline section, including pavement structure, shoulders, and when appropriate, structural drainage features. Only the latter method is needed to evaluate and compare alternative pavement designs to determine the

*R. H. Baldock, "Determination of the Annual Cost of Highways," Highway Research Board Record 12, Highway Research Board, Washington, D. C., 1963. (The late Mr. Baldock, Consulting Engineer-Economist, formerly was State Highway Engineer of the Oregon State Highway Commission.)

most appropriate design for a specific highway.

D.02 BASIC FACTORS REQUIRED FOR DETERMINING ANNUAL COST—The basic factors involved in computing the annual cost per mile of highway are as follows:

(1) **First Cost (Per Mile)**

First cost should include construction and right-of-way. Construction costs should be divided between the pavement structure and shoulders, and all other construction expenses. This division makes it easier to compare the annual costs of alternative pavement designs.

(2) **Maintenance Cost (Per Mile)**

The total per mile maintenance cost should be divided into pavement structure and shoulder maintenance expense and the expense of all other maintenance. The sum of these represents maintenance in determining total annual cost per mile but only the former is used in comparing alternative designs.

(3) **Operation Cost (Per Mile)**

Operation costs should include the expense, other than maintaining the capital investment, of providing service to the road user. This includes snow removal, sanding, signs, signals, striping and marking, and similar services. Many states charge some of the above items to maintenance and for determining annual highway costs the separation of these items is not necessary.

(4) **Administration and Overhead Costs (Per Mile)**

The administration and overhead costs, including field surveys and office design, are considerable and must be charged. It is suggested that they be prorated over the miles on the system on the basis of first cost of construction.

(5) **Cost of Resurfacing and Resurfacing Frequency (Per Mile)**

Resurfacing costs are estimated on the basis of past experience. Pavement structural design presented in this manual is based upon resurfacing after 20 years of service life. This period should be used for resurfacing frequency.

(6) **Salvage Value (Per Mile)**

This procedure amortizes the entire investment in a highway over the analysis period of 40 years. For this reason, the salvage value at the end of the analysis life of the project may be considered as having a zero value and does not enter into the computation.

(7) **Interest Rate**

Money has a definite rental value and interest on the investment in a highway must be charged to enable economic evaluation of the project. If constructed with borrowed funds, interest payments accrue to the security holder. If, on the other hand, the project is funded from the owners' revenues, interest is in the nature of a fixed charge against the project to compensate for the loss of earning power of the funds "frozen" therein. In the case of public funds derived from taxes, these funds, if not so captured, could have been invested by the public to yield a safe and reasonable return and, therefore, the interest charge represents a cost.

Economists have used interest rates varying from 5 to 10 percent in studies of highway economics. It is recommended that the interest rate used in determination of the annual highway cost be 6 percent annually.

(8) **Annual Costs of Traveled Way or Mainline Pavement Only (Per Mile)**

When economic studies are made to determine the most appropriate of the several alternative pavement designs being considered, intial construction and maintenance costs of the traveled way, or mainline section, only should be used. Right-of-way, Administration and Overhead, Operation, and other costs may be disregarded because they apply equally to all alternatives.

D.03 DETERMINING ANNUAL COST OF HIGHWAYS—Two formulas are presented in Mr. Baldock's paper for determining the annual cost of highways. Formula No. 1 includes all costs of building, maintaining, operating and administrating the highway. This formula is used to calculate the total annual cost.

(1) FORMULA NO. 1

Formula No. 1 calculates the total annual cost as follows:

$$C = CRF_n \left[A + E_1\, PWFn_1 + E_2\, PWFn_1 - \left(1 - \frac{Y}{X}\right)(E_1 \text{ or } E_2)\, PWF_n \right] + M + O + D$$

where:

C = the complete annual cost per mile of highway

CRF = the Capital Recovery Factor = $\dfrac{r\,(1 + r)^n}{(1 + r)^n - 1}$

PWF = Present Worth Factor, for a single payment = $\dfrac{1}{(1 + r)^{n_1}}$

r = the interest rate (6 percent)

n = the analysis period (40 years)

n_1 = the number of years after construction that future work is performed (Note by The Asphalt Institute: n_1 will have different values in the same analysis depending upon whether it is used with E_1 or E_2.)

A = total construction and right-of-way costs per mile

E_1 = first resurfacing costs per mile

E_2 = second resurfacing costs per mile

Y = number of years between the last resurfacing and the end of analysis period

X = estimated service life, in years, of last resurfacing

M = total annual maintenance cost per mile

O = annual operation cost per mile

D = annual administration and overhead cost per mile

(2) FORMULA NO. 2

Formula No. 2 includes only costs necessary to compare alternate pavement designs. This one calculates the annual cost per mile of the traveled way, or mainline section.

$$C_1 = CRF_n \left[A_1 + E_1\, PWFn_1 + E_2\, PWFn_1 - \left(1 - \frac{Y}{X}\right)(E_1 \text{ or } E_2)\, PWF_n \right] + M_1$$

where:

C_1 = annual cost of traveled way, or mainline section, per mile

A_1 = initial construction cost of traveled way, or mainline section per mile

M_1 = annual maintenance cost of traveled way, or mainline section per mile

All other terms are defined under Formula No. 1.

D.04 EXAMPLES — DETERMINING ANNUAL COST—

EXAMPLE 1—

Annual Cost of Traveled Way—Complete Construction

All Asphalt Concrete Section

Cost Elements

Analysis period, n		40 years
Interest rate, r		6.0 percent
Initial Cost, A		\$70,710
Resurfacing, E		\$11,705
Estimated Life of Resurfacing, X		20 years
Annual Maintenance Cost, M_1		\$190
Time Between Last Resurfacing and End of Analysis Period, Y		20 years
Capital Recovery Factor, CRFn	— 40 yrs	0.06646
Present Worth Factor, PWFn	— 40 yrs	0.09722
Present Worth Factor, $PWFn_1$	— 20 yrs.	0.31180

C_1 = 0.06646 [70,710 + (11,705) (0.31180) + 0 − 0] + 190

C_1 = 0.06646 [70,710 + 3650] + 190

C_1 = 0.06646 [74,360] + 190

C_1 = 4,942 + 190

C_1 = \$5,132 Annual Cost per mile

EXAMPLE 2—

Annual Cost of Traveled Way—Stage Construction
All Asphalt Concrete Section

Cost Elements

Analysis Period, n		40 years
Interest Rate, r		6.0 percent
Initial Cost, A_1 (1½ inch A.C. withheld for future)		$61,980
Second Stage Cost, E_1 (Place 1½ inch at 5th year)		$8,810
Resurfacing, E_2 (Place 2" at 25th year)		$11,705
Estimated Life of Second Stage and Resurfacing		20 years
Annual Maintenance Cost, M_1		$190
Time Between Last Resurfacing and End of Analysis Period, Y		15 years
Capital Recovery Factor, CRFn	— 40 yrs.	0.06646
Present Worth Factor, PWFn	— 40 yrs.	0.09722
Present Worth Factor, $PWFn_1$	— 5 yrs.	0.74726
Present Worth Factor, $PWFn_1$	— 25 yrs.	0.23300

$$C_1 = 0.06646\ [61{,}980 + (8{,}810)(0.74726) + (11{,}705)(0.23300) - (1 - \frac{15}{20})(11{,}705)(0.09722)] + 190$$

$$C_1 = 0.06646\ [61{,}980 + 6{,}583 + 2{,}727 - 284] + 190$$
$$C_1 = 0.06646\ [71{,}006] + 190$$
$$C_1 = 4{,}719 + 190$$
C_1 = \$4,909 Annual Cost per Mile

Appendix E

TYPICAL DESIGN EXAMPLES

E.01 GENERAL—Given below are typical design examples to illustrate the use of design techniques given in this manual.

1. Example 1 illustrates the design techniques in Chapters III, IV and V.
2. Examples 2 and 3 use the pavement thickness obtained in Example 1 and illustrate stage design techniques in Chapter VI.
3. Example 4 uses the data and results of Example 1 to illustrate the incorporation of asphalt bases other than asphalt concrete as described in Appendix A.
4. Example 5 illustrates the design techniques in Chapters III, IV and V, but using detailed traffic analysis data described in Appendix C.

E.02 EXAMPLE 1—

1. *General*

Assume that a design is needed for a four-lane interurban Interstate highway with a moderately heavy column of truck traffic.

2. *Traffic Analysis* (Chapter III)

The Initial Daily Traffic (IDT) is estimated to be 10,800 vehicles, 19 percent of which are heavy trucks. Average weight of the trucks is 42,000 pounds and 45 percent of the truck traffic is in the outside, or design, lane. The legal single-axle load limit is 18,000 pounds. An Annual Growth Rate of 4 percent is expected during the 25-year Design Period. Using the procedure presented in Chapter III, the ITN is found to be 760. Using an ITN adjustment factor of 2.08 for the estimated Annual Growth Rate and Design Period, a DTN of 1580 is obtained for use in the Thickness Design Chart.

3. *Subgrade Evaluation* (Chapter IV)

The design subgrade strength value is CBR 10.

4. *Thickness Design Pavement Structure* (Chapter V)

The total required thickness of asphalt concrete, T_A, from Figure V-1, in Chapter V, is 9 inches when rounded off to the next highest one-half inch.

E.03 EXAMPLE 2—

1. *General*

The pavement in Example 1 is assumed to be built as a Planned Stage Construction Project (refer to Chapter VI). It is desired that the pavement initially will be placed 7½ inches thick with the remaining 1½ inches added at a later date.

2. *Stage 1 Design Period*

For T_A of 7½ inches and a CBR of 10 the Thickness Design Chart, Figure V-1 in Chapter V, is used to obtain a DTN of 280. This value is then divided by the ITN value of 760 to obtain the ITN adjustment factor of 0.37. Using Table III-3 in Chapter III for an Annual Growth Rate of 4 percent, the adjustment factor indicates the Design Period for Stage 1 is between 6 and 7 years.

3. *Adding Stage 2*

The additional 1½ inches should be added after six years of service as the Stage 2 portion of the project unless pavement performance evaluation indicates that it is needed sooner.

E.04 EXAMPLE 3—

1. *General*

The pavement in Example 1 is assumed to be built as a Planned Stage Construction project (refer to

Chapter VI). It is desired that the second stage be added in about five years.

2. *Traffic Analysis for Stage 1*

The ITN obtained in Example 1 is multiplied by the ITN adjustment factor of 0.27 obtained from Table III-3 in Chapter III for a 5-year Design Period and 4 percent Annual Growth Rate. The DTN obtained for use in the Thickness Design Chart will be 205 (say 210).

3. *Thickness Design of Stage 1*

The total thickness of asphalt concrete, T_A, required for Stage 1 is found by using the DTN of 210 and CBR of 10 in the Thickness Design Chart, Figure V-1, in Chapter V. The required T_A for Stage 1 is 7.5 inches to the next highest ½ inch.

4. *Thickness Design of Stage 2*

The required thickness of asphalt concrete for the Stage 2 design is 9 inches (see Example 1). Since 7.5 iches is placed for Stage 1, an additional 1.5-inch layer of asphalt concrete will be added for Stage 2.

After Stage 1 has been built another traffic analysis should be performed prior to adding Stage 2 to see if the traffic is as predicted. If there is any significant change, the added thickness for Stage 2 may be adjusted as required.

E.05 EXAMPLE 4—

1. *General*

Assume that a design is needed for a two-lane interurban highway that is to have a hot-mixed sand asphalt base.

2. *Traffic Classification*

The Design Traffic Number for use in the Thickness Design Chart is 160. This is classified as heavy traffic.

3. *Subgrade Evaluation* (Chapter IV)

The design subgrade strength value is CBR 8.

4. *Thickness Design of Pavement Structure* (Chapter V)

The total required thickness of asphalt concrete, T_A, is 8 inches, when rounded off to the next highest ½ inch.

5. *Layer Thickness*

The following steps from Appendix A are used to determine the layer thicknesses of the different components of the asphalt pavement for T_A = 8 inches.

(a) Asphalt concrete surface, T_S, for heavy traffic on hot-mix sand asphalt base = 4 inches.

(b) Required thickness, T_B, of asphalt concrete base = 8 inches − 4 inches = 4 inches.

(c) Factor for hot-mix sand asphalt base = 1.3

(d) Thickness of hot-mix sand asphalt base = 4 inches × 1.3 = 5.2 inches, or 5.5 inches, when rounded off to the next highest ½ inch.

6. *Total Pavement Thickness*

Asphalt concrete surface	=	4 inches
Hot-mix sand asphalt base	=	5.5 inches
Total thickness	=	9.5 inches

E.06 EXAMPLE 5—

1. *General*

Assume that a design is required for a four-lane interurban highway for which loadometer data are available. The loadometer data, from a state with 22,400 pounds legal axle load limit, are shown in Figure C-2. They will be used with the traffic analysis procedures of Chapter III to compute the Initial Traffic Number.

2. *Traffic Analysis*

This highway is estimated to have an Initial Daily Traffic Volume of 8,000 vehicles per day. Buses and trucks of all types, including panel and pickups, make up 15 percent of the total traffic volume. The computation of the Truck Factor is shown in Figure C-2. The assumed Annual Growth Rate is 3 percent and a Design Period of 20 years is established.

The following steps, from Appendix C and Chapter III, are used to compute the Design Traffic Number for use in the Thickness Design Charts.

(a) Daily number of all trucks and buses in both directions = 8000 × 0.15 = 1200

(b) Truck Factor as calculated in Figure C-2 = 0.43

(c) Proportion of all trucks and buses using the Design Lane, from Table III-2 = 0.45

(d) Initial Traffic Number, computed from trucks and buses only, is the product of steps a, b and c = 1200 × 0.43 × 0.45 = 232

(e) Initial Traffic Number adjustment factor, from Table III-3 = 1.35

(f) Design Traffic Number for use in Thickness Design Chart, Figure V-2, = 232 × 1.35 = 313

3. *Subgrade Evaluation*

The design subgrade strength value is Resistance Value (R-Value) = 16.

4. *Thickness Design of Pavement Structure*

From Figure V-2 in Chapter V of the thickness, T_A, of asphalt concrete pavement is 12.5 inches when rounded off to the next highest one-half inch.

NOTES

Appendix F

PROCEDURE FOR SELECTING SAMPLING LOCATIONS BY RANDOM SAMPLING TECHNIQUE

F.01 PROCEDURE FOR SELECTING SAMPLING LOCATIONS—Table F-1 contains random numbers for the general sampling procedure. To use this table for selecting locations for collecting samples the following steps are necessary:

1. Break down the project into sections whose boundaries are defined by changes in major soil types.

2. Determine the number of sampling locations within a section by selecting the maximum *average* longitudinal distance desired between samples and dividing the length of the section by the maximum average longitudinal distance.

3. Select a column of random numbers in Table F-1 by placing 28 one-inch-square pieces of cardboard, numbered 1 through 28, into a container (such as a bowl), shaking them to get them thoroughly mixed, and drawing out one.

4. Go to the column of random numbers identified with the number drawn from the container. In sub-column A, locate all numbers equal to and less than the number of sampling locations per section desired.

5. Multiply the total length of the section by the decimal values in sub-column B, found opposite the numbers located in sub-column A. Add the result to the station number at the beginning of the section to obtain the station of the sampling location.

6. Multiply the total width of the proposed pavement in the section by the decimal values in sub-column C, found opposite the numbers located in sub-column A, then subtract one-half the total width of the proposed pavement from the result to obtain the offset distance from the centerline to the sampling location. A positive (+) number will be the distance to the *right* of centerline and a negative (−) number will be the distance to the *left* of centerline.

EXAMPLE—

A new roadway location is 12,000 feet long begining at Station 150 + 00. It passes through two major soil areas, the boundary between them being at Station 205 + 00. The proposed pavement is to be 24 feet wide.

1. For sampling purposes, the project should be divided into two sections whose boundaries are

Section 1: Station 150+00 to Station 205+00 (5,500 feet)

Section 2: Station 205+00 to Station 270+00 (6,500 feet)

2. Samples of the subgrade soil at *average* intervals of 500 feet are desired. The number of sampling locations in each section, then, are

$$\text{Section 1: } \frac{5{,}500 \text{ feet}}{500 \text{ feet}} = 11 \text{ locations}$$

$$\text{Section 2: } \frac{6{,}500 \text{ feet}}{500 \text{ feet}} = 13 \text{ locations}$$

3. The numbers 26 and 12, drawn from a container, identify the columns of random numbers in Table F-1 to use for the two sections.

4. For Section 1 the numbers selected from Column 26 are

Col. A	Col. B	Col. C
11	.956	.142
10	.216	.565
9	.665	.354
8	.471	.708
7	.278	.357
6	.421	.807
5	.138	.228
4	.088	.686
3	.512	.329
2	.233	.610
1	.033	.886

For Section 2 the numbers selected from column 12 are

Col. A	Col. B	Col. C
13	.432	.556
12	.305	.616
11	.744	.948
10	.254	.834
9	.935	.582
8	.416	.372
7	.733	.838
6	.284	.628
5	.695	.111
4	.153	.163
3	.542	.352
2	.489	.827
1	.320	.212

5. Section 1: Length of section = 5,500 feet

Length of Section ×	Col. B =	Distance from Beginning of Section +	Station at Beginning of Section =	Station Number of Sampling Location
5,500	.956	5,258	150 + 00	202 + 58
5,500	.216	1,188	150 + 00	161 + 88
5,500	.665	3,658	150 + 00	186 + 58
5,500	.471	2,590	150 + 00	175 + 90
5,500	.278	1,529	150 + 00	165 + 29
5,500	.421	2,316	150 + 00	173 + 16
5,500	.138	759	150 + 00	157 + 59
5,500	.088	484	150 + 00	154 + 84
5,500	.512	2,816	150 + 00	178 + 16
5,500	.233	1,282	150 + 00	162 + 82
5,500	.033	182	150 + 00	151 + 82

Section 2: Length of section = 6,500 feet

Length of Section	×	Col. B	=	Distance from Beginning of Section	+	Station at Beginning of Section	=	Station Number of Sampling Location
6,500		.432		2,808		205 + 00		233 + 08
6,500		.305		1,982		205 + 00		224 + 82
6,500		.744		4,836		205 + 00		253 + 36
6,500		.254		1,651		205 + 00		221 + 51
6,500		.935		6,078		205 + 00		265 + 78
6,500		.416		2,704		205 + 00		232 + 04
6,500		.733		4,764		205 + 00		252 + 64
6,500		.284		1,846		205 + 00		223 + 46
6,500		.695		4,518		205 + 00		250 + 18
6,500		.153		994		205 + 00		214 + 94
6,500		.542		3,523		205 + 00		240 + 23
6,500		.489		3,178		205 + 00		236 + 78
6,500		.320		2,080		205 + 00		225 + 80

6. Section 1: Total width of proposed pavement = 24 feet

Width of Pavement	×	Col. C	=	Distance from Left Edge of Proposed Pavement	−	½ Width of Pavement	=	Offset Distance from Centerline to Sampling Location
24		.142		3.4		12		−8.6
24		.565		13.6		12		1.6
24		.354		8.5		12		−3.5
24		.708		17.0		12		5.0
24		.357		8.6		12		−3.4
24		.807		19.4		12		7.4
24		.228		5.5		12		−6.5
24		.686		16.5		12		4.5
24		.329		7.9		12		−4.1
24		.610		14.6		12		2.6
24		.886		21.3		12		9.3

Section 2: Total width of proposed pavement = 24 feet

Width of Pavement	×	Col. C	=	Distance from Left Edge of Proposed Pavement	−	½ Width of Pavement	=	Offset Distance from Centerline to Sampling Location
24		.556		13.3		12		1.3
24		.616		14.8		12		2.8
24		.948		22.8		12		10.8
24		.834		20.0		12		8.0
24		.582		14.0		12		2.0
24		.372		8.9		12		−3.1
24		.838		20.1		12		8.1
24		.628		15.1		12		3.1
24		.111		2.7		12		−9.3
24		.163		3.9		12		−8.1
24		.352		8.4		12		−3.6
24		.827		19.8		12		7.8
24		.212		5.1		12		−6.9

7. Sampling locations (see Figure F-1)

	Station Number	Distance from Centerline to Sampling Location	
		Left	Right
Section 1	151 + 82		9.3
	154 + 84		4.5
	157 + 59	6.5	
	161 + 88		1.6
	162 + 82		2.6
	165 + 29	3.4	
	173 + 16		7.4
	175 + 90		5.0
	178 + 16	4.1	
	186 + 58	3.5	
	202 + 58	8.6	
Section 2	214 + 94	8.1	
	221 + 51		8.0
	223 + 46		3.1
	224 + 82		2.8
	225 + 80	6.9	
	232 + 04	3.1	
	233 + 08		1.3
	236 + 78		7.8
	240 + 23	3.6	
	250 + 18	9.3	
	252 + 64		8.1
	253 + 36		10.8
	265 + 78		2.0

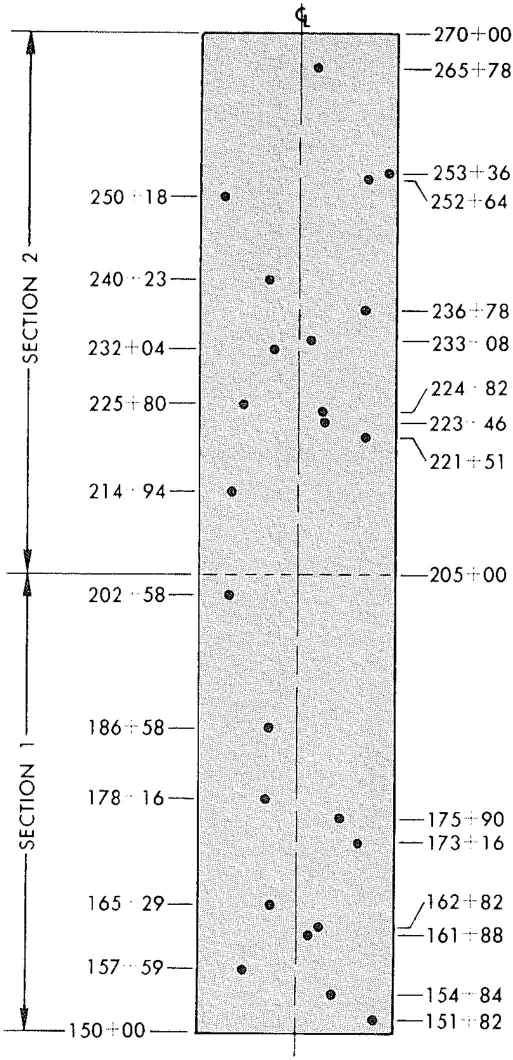


Figure F-1—Sampling locations (example)

TABLE F-1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE

Col. No. 1			Col. No. 2			Col. No. 3			Col. No. 4			Col. No. 5			Col. No. 6			Col. No. 7		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
15	.033	.576	05	.048	.879	21	.013	.220	18	.089	.716	17	.024	.863	30	.030	.901	12	.029	.386
21	.101	.300	17	.074	.156	30	.036	.853	10	.102	.330	24	.060	.032	21	.096	.198	18	.112	.284
23	.129	.916	18	.102	.191	10	.052	.746	14	.111	.925	26	.074	.639	10	.100	.161	20	.114	.848
30	.158	.434	06	.105	.257	25	.061	.954	28	.127	.840	07	.167	.512	29	.133	.388	03	.121	.656
24	.177	.397	28	.179	.447	29	.062	.507	24	.132	.271	28	.194	.776	24	.138	.062	13	.178	.640
11	.202	.271	26	.187	.844	18	.087	.887	19	.285	.899	03	.219	.166	20	.168	.564	22	.209	.421
16	.204	.012	04	.188	.482	24	.105	.849	01	.326	.037	29	.264	.284	22	.232	.953	16	.221	.311
08	.208	.418	02	.208	.577	07	.139	.159	30	.334	.938	11	.282	.262	14	.259	.217	29	.235	.356
19	.211	.798	03	.214	.402	01	.175	.641	22	.405	.295	14	.379	.994	01	.275	.195	28	.264	.941
29	.233	.070	07	.245	.080	23	.196	.873	05	.421	.282	13	.394	.405	06	.277	.475	11	.287	.199
07	.260	.073	15	.248	.831	26	.240	.981	13	.451	.212	06	.410	.157	02	.296	.497	02	.336	.992
17	.262	.308	29	.261	.087	14	.255	.374	02	.461	.023	15	.438	.700	26	.311	.144	15	.393	.488
25	.271	.180	30	.302	.883	06	.310	.043	06	.487	.539	22	.453	.635	05	.351	.141	19	.437	.655
06	.302	.672	21	.318	.088	11	.316	.653	08	.497	.396	21	.472	.824	17	.370	.811	24	.466	.773
01	.409	.406	11	.376	.936	13	.324	.585	25	.503	.893	05	.488	.118	09	.388	.484	14	.531	.014
13	.507	.693	14	.430	.814	12	.351	.275	15	.594	.603	01	.525	.222	04	.410	.073	09	.562	.678
02	.575	.654	27	.438	.676	20	.371	.535	27	.620	.894	12	.561	.980	25	.471	.530	06	.601	.675
18	.591	.318	08	.467	.205	08	.409	.495	21	.629	.841	08	.652	.508	13	.486	.779	10	.612	.859
20	.610	.821	09	.474	.138	16	.445	.740	17	.691	.583	18	.668	.271	15	.515	.867	26	.673	.112
12	.631	.597	10	.492	.474	03	.494	.929	09	.708	.689	30	.736	.634	23	.567	.798	23	.738	.770
27	.651	.281	13	.499	.892	27	.543	.387	07	.709	.012	02	.763	.253	11	.618	.502	21	.753	.614
04	.661	.953	19	.511	.520	17	.625	.171	11	.714	.049	23	.804	.140	28	.636	.148	30	.758	.851
22	.692	.089	23	.591	.770	02	.699	.073	23	.720	.695	25	.828	.425	27	.650	.741	27	.765	.563
05	.779	.346	20	.604	.730	19	.702	.934	03	.748	.413	10	.843	.627	16	.711	.508	07	.780	.534
09	.787	.173	24	.654	.330	22	.816	.802	20	.781	.603	16	.858	.849	19	.778	.812	04	.818	.187
10	.818	.837	12	.728	.523	04	.838	.166	26	.830	.384	04	.903	.327	07	.804	.675	17	.837	.353
14	.895	.631	16	.753	.344	15	.904	.116	04	.843	.002	09	.912	.382	08	.806	.952	05	.854	.818
26	.912	.376	01	.806	.134	28	.969	.742	12	.884	.582	27	.935	.162	18	.841	.414	01	.867	.133
28	.920	.163	22	.878	.884	09	.974	.046	29	.926	.700	20	.970	.582	12	.918	.114	08	.915	.538
03	.945	.140	25	.939	.162	05	.977	.494	16	.951	.601	19	.975	.327	03	.992	.399	25	.975	.584

(Continued) TABLE F—1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE

Col. No. 8			Col. No. 9			Col. No. 10			Col. No. 11			Col. No. 12			Col. No. 13			Col. No. 14		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
09	.042	.071	14	.061	.935	26	.038	.023	27	.074	.779	16	.073	.987	03	.033	.091	26	.035	.175
17	.141	.411	02	.065	.097	30	.066	.371	06	.084	.396	23	.078	.056	07	.047	.391	17	.089	.363
02	.143	.221	03	.094	.228	27	.073	.876	24	.098	.524	17	.096	.076	28	.064	.113	10	.149	.681
05	.162	.899	16	.122	.945	09	.095	.568	10	.133	.919	04	.153	.163	12	.066	.360	28	.238	.075
03	.285	.016	18	.158	.430	05	.180	.741	15	.187	.079	10	.254	.834	26	.076	.552	13	.244	.767
28	.291	.034	25	.193	.469	12	.200	.851	17	.227	.767	06	.284	.628	30	.087	.101	24	.262	.366
08	.369	.557	24	.224	.572	13	.259	.327	20	.236	.571	12	.305	.616	02	.127	.187	08	.264	.651
01	.436	.386	10	.225	.223	21	.264	.681	01	.245	.988	25	.319	.901	06	.144	.068	18	.285	.311
20	.450	.289	09	.233	.838	17	.283	.645	04	.317	.291	01	.320	.212	25	.202	.674	02	.340	.131
18	.455	.789	20	.290	.120	23	.363	.063	29	.350	.911	08	.416	.372	01	.247	.025	29	.353	.478
23	.488	.715	01	.297	.242	20	.364	.366	26	.380	.104	13	.432	.556	23	.253	.323	06	.359	.270
14	.496	.276	11	.337	.760	16	.395	.363	28	.425	.864	02	.489	.827	24	.320	.651	20	.387	.248
15	.503	.342	19	.389	.064	02	.423	.540	22	.487	.526	29	.503	.787	10	.328	.365	14	.392	.694
04	.515	.693	13	.411	.474	08	.432	.736	05	.552	.511	15	.518	.717	27	.338	.412	03	.408	.077
16	.532	.112	20	.447	.893	10	.476	.468	14	.564	.357	28	.524	.998	13	.356	.991	27	.440	.280
22	.557	.357	22	.478	.321	03	.508	.774	11	.572	.306	03	.542	.352	16	.401	.792	22	.461	.830
11	.559	.620	29	.481	.993	01	.601	.417	21	.594	.197	19	.585	.462	17	.423	.117	16	.527	.003
12	.650	.216	27	.562	.403	22	.687	.917	09	.607	.524	05	.695	.111	21	.481	.838	30	.531	.486
21	.672	.320	04	.566	.179	29	.697	.862	19	.650	.572	07	.733	.838	08	.560	.401	25	.678	.360
13	.709	.273	08	.603	.758	11	.701	.605	18	.664	.101	11	.744	.948	19	.564	.190	21	.725	.014
07	.745	.687	15	.632	.927	07	.728	.498	25	.674	.428	18	.793	.748	05	.571	.054	05	.797	.595
30	.780	.285	06	.707	.107	14	.745	.679	02	.697	.674	27	.802	.967	18	.587	.584	15	.801	.927
19	.845	.097	28	.737	.161	24	.819	.444	03	.767	.928	21	.826	.487	15	.604	.145	12	.836	.294
26	.846	.366	17	.846	.130	15	.840	.823	16	.809	.529	24	.835	.832	11	.641	.298	04	.854	.982
29	.861	.307	07	.874	.491	25	.863	.568	30	.838	.294	26	.855	.142	22	.672	.156	11	.884	.928
25	.906	.874	05	.880	.828	06	.878	.215	13	.845	.470	14	.861	.462	20	.674	.887	19	.886	.832
24	.919	.809	23	.931	.659	18	.930	.601	08	.855	.524	20	.874	.625	14	.752	.881	07	.929	.932
10	.952	.555	26	.960	.365	04	.954	.827	07	.867	.718	30	.929	.056	09	.774	.560	09	.932	.206
06	.961	.504	21	.978	.194	28	.963	.004	12	.881	.722	09	.935	.582	29	.921	.752	01	.970	.692
27	.969	.811	12	.982	.183	19	.988	.020	23	.937	.872	22	.947	.797	04	.959	.099	23	.973	.082

(Continued) **TABLE F—1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE**

Col. No. 15			Col. No. 16			Col. No. 17			Col. No. 18			Col. No. 19			Col. No. 20			Col. No. 21		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
15	.023	.979	19	.062	.588	13	.045	.004	25	.027	.290	12	.052	.075	20	.030	.881	01	.010	.946
11	.118	.465	25	.080	.218	18	.086	.878	06	.057	.571	30	.075	.493	12	.034	.291	10	.014	.939
07	.134	.172	09	.131	.295	26	.126	.990	26	.059	.026	28	.120	.341	22	.043	.893	09	.032	.346
01	.139	.230	18	.136	.381	12	.128	.661	07	.105	.176	27	.145	.689	28	.143	.073	06	.093	.180
16	.145	.122	05	.147	.864	30	.146	.337	18	.107	.358	02	.209	.957	03	.150	.937	15	.151	.012
20	.165	.520	12	.158	.365	05	.169	.470	22	.128	.827	26	.272	.818	04	.154	.867	16	.185	.455
06	.185	.481	28	.214	.184	21	.244	.433	23	.156	.440	22	.299	.317	19	.158	.359	07	.227	.277
09	.211	.316	14	.215	.757	23	.270	.849	15	.171	.157	18	.306	.475	29	.304	.615	02	.304	.400
14	.248	.348	13	.224	.846	25	.274	.407	08	.220	.097	20	.311	.653	06	.369	.633	30	.316	.074
25	.249	.890	15	.227	.809	10	.290	.925	20	.252	.066	15	.348	.156	18	.390	.536	18	.328	.799
13	.252	.577	11	.280	.898	01	.323	.490	04	.268	.576	16	.381	.710	17	.403	.392	20	.352	.288
30	.273	.088	01	.331	.925	24	.352	.291	14	.275	.302	01	.411	.607	23	.404	.182	26	.371	.216
18	.277	.689	10	.399	.992	15	.361	.155	11	.297	.589	13	.417	.715	01	.415	.457	19	.448	.754
22	.372	.958	30	.417	.787	29	.374	.882	01	.358	.305	21	.472	.484	07	.437	.696	13	.487	.598
10	.461	.075	08	.439	.921	08	.432	.139	09	.412	.089	04	.478	.885	24	.446	.546	12	.546	.640
28	.519	.536	20	.472	.484	04	.467	.266	16	.429	.834	25	.479	.080	26	.485	.768	24	.550	.038
17	.520	.090	24	.498	.712	22	.508	.880	10	.491	.203	11	.566	.104	15	.511	.313	03	.604	.780
03	.523	.519	04	.516	.396	27	.632	.191	28	.542	.306	10	.576	.659	10	.517	.290	22	.621	.930
26	.573	.502	03	.548	.688	16	.661	.836	12	.563	.091	29	.665	.397	30	.556	.853	21	.629	.154
19	.634	.206	23	.597	.508	19	.675	.629	02	.593	.321	19	.739	.298	25	.561	.837	11	.634	.908
24	.635	.810	21	.681	.114	14	.680	.890	30	.692	.198	14	.749	.759	09	.574	.599	05	.696	.459
21	.679	.841	02	.739	.298	28	.714	.508	19	.705	.445	08	.756	.919	13	.613	.762	23	.710	.078
27	.712	.366	29	.792	.038	06	.719	.441	24	.709	.717	07	.798	.183	11	.698	.783	29	.726	.585
05	.780	.497	22	.829	.324	09	.735	.040	13	.820	.739	23	.834	.647	14	.715	.179	17	.749	.916
23	.861	.106	17	.834	.647	17	.741	.906	05	.848	.866	06	.837	.978	16	.770	.128	04	.802	.186
12	.865	.377	16	.909	.608	11	.747	.205	27	.867	.633	03	.849	.964	08	.815	.385	14	.835	.319
29	.882	.635	06	.914	.420	20	.850	.047	03	.883	.333	24	.851	.109	05	.872	.490	08	.870	.546
08	.902	.020	27	.958	.856	02	.859	.356	17	.900	.443	05	.859	.935	21	.885	.999	28	.871	.539
04	.951	.482	26	.981	.976	07	.870	.612	21	.914	.483	17	.863	.220	02	.958	.177	25	.971	.369
02	.977	.172	07	.983	.624	03	.916	.463	29	.950	.753	09	.863	.147	27	.961	.980	27	.984	.252

(Continued) TABLE F—1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE

Col. No. 22			Col. No. 23			Col. No. 24			Col. No. 25			Col. No. 26			Col. No. 27			Col. No. 28		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
12	.051	.032	26	.051	.187	08	.015	.521	02	.039	.005	16	.026	.102	21	.050	.952	29	.042	.039
11	.068	.980	03	.053	.256	16	.068	.994	16	.061	.599	01	.033	.886	17	.085	.403	07	.105	.293
17	.089	.309	29	.100	.159	11	.118	.400	26	.068	.054	04	.088	.686	10	.141	.624	25	.115	.420
01	.091	.371	13	.102	.465	21	.124	.565	11	.073	.812	22	.090	.602	05	.154	.157	09	.126	.612
10	.100	.709	24	.110	.316	18	.153	.158	07	.123	.649	13	.114	.614	06	.164	.841	1,0	.205	.144
30	.121	.744	18	.114	.300	17	.190	.159	05	.126	.658	20	.136	.576	07	.197	.013	03	.210	.054
02	.166	.056	11	.123	.208	26	.192	.676	14	.161	.189	05	.138	.228	16	.215	.363	23	.234	.533
23	.179	.529	09	.138	.182	01	.237	.030	18	.166	.040	10	.216	.565	08	.222	.520	13	.266	.799
21	.187	.051	06	.194	.115	12	.283	.077	28	.248	.171	02	.233	.610	13	.269	.477	20	.305	.603
22	.205	.543	22	.234	.480	03	.286	.318	06	.255	.117	07	.278	.357	02	.288	.012	05	.372	.223
28	.230	.688	20	.274	.107	10	.317	.734	15	.261	.928	30	.405	.273	25	.333	.633	26	.385	.111
19	.243	.001	21	.331	.292	05	.337	.844	10	.301	.811	06	.421	.807	28	.348	.710	30	.422	.315
27	.267	.990	08	.346	.085	25	.441	.336	24	.363	.025	12	.426	.583	20	.362	.961	17	.453	.783
15	.283	.440	27	.382	.979	27	.469	.786	22	.378	.792	08	.471	.708	14	.511	.989	02	.460	.916
16	.352	.089	07	.387	.865	24	.473	.237	27	.379	.959	18	.473	.738	26	.540	.903	27	.461	.841
03	.377	.648	28	.411	.776	20	.475	.761	19	.420	.557	19	.510	.207	27	.587	.643	14	.483	.095
06	.397	.769	16	.444	.999	06	.557	.001	21	.467	.943	03	.512	.329	12	.603	.745	12	.507	.375
09	.409	.428	04	.515	.993	07	.610	.238	17	.494	.225	15	.640	.329	29	.619	.895	28	.509	.748
14	.465	.406	17	.518	.827	09	.617	.041	09	.620	.081	09	.665	.354	23	.623	.333	21	.583	.804
13	.499	.651	05	.539	.620	13	.641	.648	30	.623	.106	14	.680	.884	22	.624	.076	22	.587	.993
04	.539	.972	02	.623	.271	22	.664	.291	03	.625	.777	26	.703	.622	18	.670	.904	16	.689	.339
18	.560	.747	30	.637	.374	04	.668	.856	08	.651	.790	29	.739	.394	11	.711	.253	06	.727	.298
26	.575	.892	14	.714	.364	19	.717	.232	12	.715	.599	25	.759	.386	01	.790	.392	04	.731	.814
29	.756	.712	15	.730	.107	02	.776	.504	23	.782	.093	24	.803	.602	04	.813	.611	08	.807	.983
20	.760	.920	19	.771	.552	29	.777	.548	20	.810	.371	27	.842	.491	19	.843	.732	15	.833	.757
05	.847	.925	23	.780	.662	14	.823	.223	01	.841	.726	21	.870	.435	03	.844	.511	19	.896	.464
25	.872	.891	10	.924	.888	23	.848	.264	29	.862	.009	28	.906	.367	30	.858	.299	18	.916	.384
24	.874	.135	12	.929	.204	30	.892	.817	25	.891	.873	23	.948	.367	09	.929	.199	01	.948	.610
08	.911	.215	01	.937	.714	28	.943	.190	04	.917	.264	11	.956	.142	24	.931	.263	11	.976	.799
07	.946	.065	25	.974	.398	15	.975	.962	13	.958	.990	17	.993	.989	15	.939	.947	24	.978	.633

Appendix G

GLOSSARY

G.01 ANNUAL COSTS OF HIGHWAYS—The average cost per year of a pavement structure computed by considering the highway as a capital investment of public funds using an interest rate to account for the time value of money.

G.02 ASPHALT BASE COURSE—A foundation course consisting of mineral aggregate, bound together with asphaltic material.

G.03 ASPHALT CONCRETE—High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high quality aggregate, thoroughly compacted into a uniform, dense mass. Typified by Asphalt Institute Type IV Mixes (See *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types,* Specification Series No. 1 [SS-1], The Asphalt Institute).

G.04 ASPHALT PAVEMENT STRUCTURE—All courses of asphalt-aggregate mixtures placed above the subgrade or improved subgrade.

G.05 ASPHALT SURFACE COURSE—The top course of an asphalt pavement, sometimes called asphalt wearing course.

G.06 CITY STREET—A street whose traffic is predominantly local in character.

G.07 DESIGN LANE—The lane on which the greatest number of equivalent 18,000-pound single-axle loads is expected. Normally this will be either lane of a two-lane roadway or the outside lane of multilane highways.

G.08 DESIGN PERIOD—The number of years from the initial application of traffic until the first major resurfacing is anticipated. This term should not be confused with *pavement life.* By adding asphalt overlays as required, pavement life may be extended indefinitely, or until geometric considerations or other factors may make the pavement obsolete.

G.09 DESIGN SUBGRADE STRENGTH VALUE—The subgrade strength value that is equal to or less than approximately 90 percent of all test values in the section.

G.10 DESIGN THICKNESS, T_A—The total thickness of asphalt concrete determined from the thickness design chart as adequate for a given Design Traffic Number and subgrade strength value.

G.11 DESIGN TRAFFIC NUMBER (DTN)—The average daily number of equivalent 18,000-pound single-axle loads estimated for the Design Lane, during the Design Period. (Note: Thickness design charts, Figures V-1 and V-2, are based on a 20-year design period and DTN must be adjusted for their appropriate use. Refer to Chapter III for adjustment procedure.)

G.12 EQUIVALENT 18,000-POUND SINGLE-AXLE LOAD—The effect on pavement performance of any combination of axle loads of varying magnitude equated to the number of 18,000-pound single-axle loads required to produce an equivalent effect.

G.13 FULL-DEPTH ASPHALT PAVEMENT—A term registered by The Asphalt Institute with the U. S. Patent Office. The term Full Depth (also called "Mark") certifies that the pavement is one in which asphalt-aggregate mixtures are employed for *all* courses above the subgrade or improved subgrade. A FULL-DEPTH asphalt pavement is laid directly on the prepared subgrade.

G.14 HIGHWAY CAPACITY—The practical capacity of a street or highway in terms of the maximum number of vehicles of all types for which the highway should be geometrically designed.

G.15 IMPROVED SUBGRADE—Any course or courses of select or improved material between the native subgrade soil and the pavement structure.

G.16 INITIAL DAILY TRAFFIC (IDT)—The average daily number of vehicles expected to use the roadway, in both directions, during the first year.

G.17 INITIAL TRAFFIC NUMBER (ITN)—The average daily number of equivalent 18,000-pound single-axle load applications expected on the design lane during the first year.

G.18 LOAD EQUIVALENCY FACTOR—A multiplying factor used to determine the number of equivalent 18,000-pound single-axle loads from a given number of applications of a specific axle load.

G.19 LOADOMETER STUDY—A study in which are determined the weight carried on each axle, the number of axles, and the type of truck.

G.20 MATERIALS EVALUATION TEST METHODS—Mechanical strength tests used to evaluate materials for pavement thickness design.

1. *Bearing Value (Plate Bearing Test).* A test used to determine the strength or bearing value at the surface of the subgrade, top of subbase, top of the base course, or surface of the finished pavement. See *Soils Manual for Design of Asphalt Pavement Structures,* (MS-10), The Asphalt Institute.
2. *California Bearing Ratio (CBR).* A test used for evaluating bases, subbases, and subgrades for pavement thickness design. See *Soils Manual for Design of Asphalt Pavement Structures,* Manual Series No. 10 (MS-10), The Asphalt Institute.
3. *Resistance Value (R-Value).* A test used for evaluating bases, subbases, and subgrades for pavement thickness design developed. See *Soils Manual for Design of Asphalt Pavement Structures,* Manual Series No. 10 (MS-10), The Asphalt Institute.

G.21 PLANNED STAGE CONSTRUCTION—The construction of roads and streets by applying successive layers of asphalt concrete according to design and a predetermined time schedule.

G.22 SUBGRADE—The uppermost material placed in embankments or unmoved from cuts in the normal grading of the roadbed. It is the foundation for the asphalt pavement structure. The subgrade soil sometimes is called "basement soil" or "foundation soil."

G.23 TRAFFIC CLASSIFICATION—

Light*	Traffic conditions resulting in a Design Traffic Number (DTN) less than ten (10).
Medium*	Traffic conditions resulting in a Design Traffic Number (DTN) between ten (10) and one hundred (100).
Heavy*	Traffic conditions resulting in a Design Traffic Number (DTN) above one hundred (100).

G.24 TRAFFIC COUNT—A traffic count, often referred to as traffic volume, is a determination of the average number of all types of vehicles using a facility within a given period of time. Traffic count data are usually expressed in terms of Average Daily Traffic (ADT), in units of vehicles per day, but are not distinguished as to direction or number of lanes.

G.25 TRUCK FACTOR—The average number of Equivalent 18,000-Pound Single-Axle Loads per truck when all types of trucks are considered. It is used in determining the Initial Traffic Number.

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*Mix design criteria and other requirements vary for these three traffic classifications. Refer to *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types*, Specification Series No. 1 (SS-1), The Asphalt Institute.

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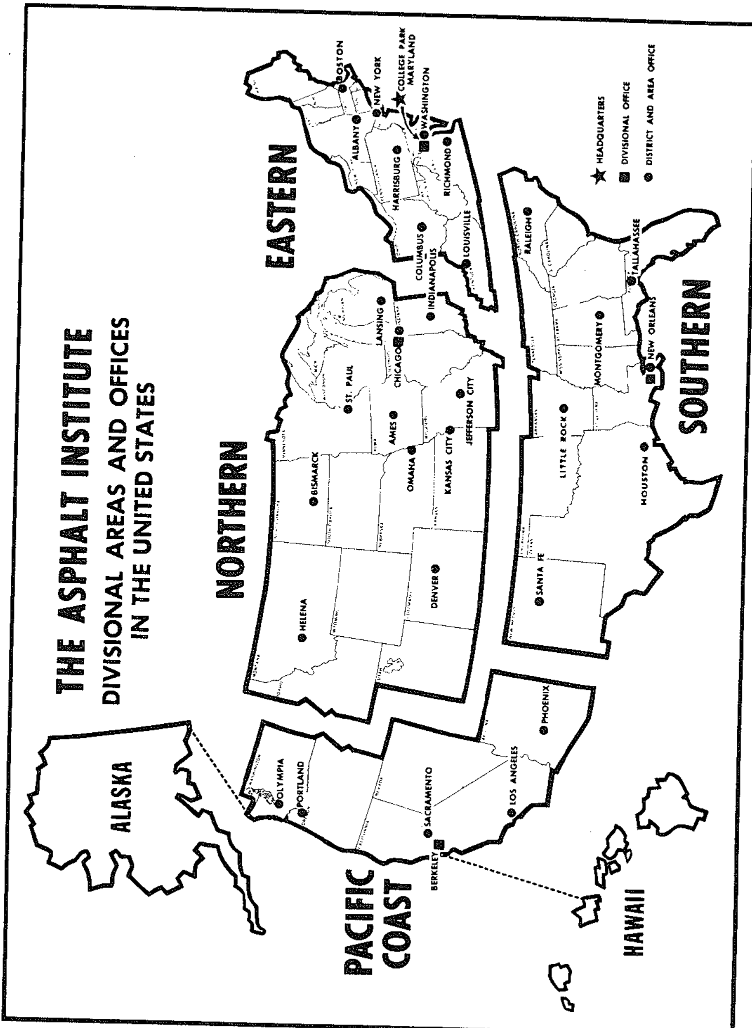
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