Section 3

ASPHALT PAVEMENT DESIGN

3.1 DESIGNING AN ASPHALT PAVEMENT STRUCTURE (THICKNESS)

Pavements constructed of hot-mix asphalt are typically designed based on traffic projections over a 20 year period. Yet despite our best efforts, it is not uncommon to see severe rutting and cracking in asphalt pavements well before then as environmental conditions and heavy traffic loading take their toll. The result: rougher rides, higher user costs, higher pavement maintenance and rehabilitation costs, and more work zones for motorists to negotiate. In order to provide a pavement which will serve its intended purpose for a reasonable time at a reasonable costs, Engineers must utilize proper design procedures based on projected traffic over the design period and consider the environmental conditions, subgrade strength, material properties and other factors that will allow construction of a pavement that will perform satisfactorily. When designing and building a road for all-weather use by vehicles, the basic objectives are to:

(a) Have sufficient total thickness and internal strength to carry expected traffic loads.
(b) Prevent the penetration and/or internal accumulation of moisture, and
(c) Have a top surface that is smooth, skid resistant, and resistant to wear, distortion and deterioration by traffic, weather and deicing chemicals.

The subgrade ultimately carries all traffic loads; therefore, the structural function of a pavement is to support a wheel load on the pavement surface and transfer and spread that load to the subgrade, without over-taxing either the strength of the subgrade or the internal strength of the pavement itself. Figure 3-1 shows the wheel load being transmitted to the pavement surface through the tire. The pavement then spreads the wheel load to the subgrade which reduces the stress applied to the subgrade. Figure 3-2 shows how a wheel load, W, slightly deflects the pavement structure, causing both tensile and compressive stresses within the pavement. By proper selection of pavement materials and with adequate pavement thickness and strength, the stress at the bottom of the pavement will be small enough to be easily supported by the subgrade and the pavement will be able to resist the internal stresses caused by the loading.

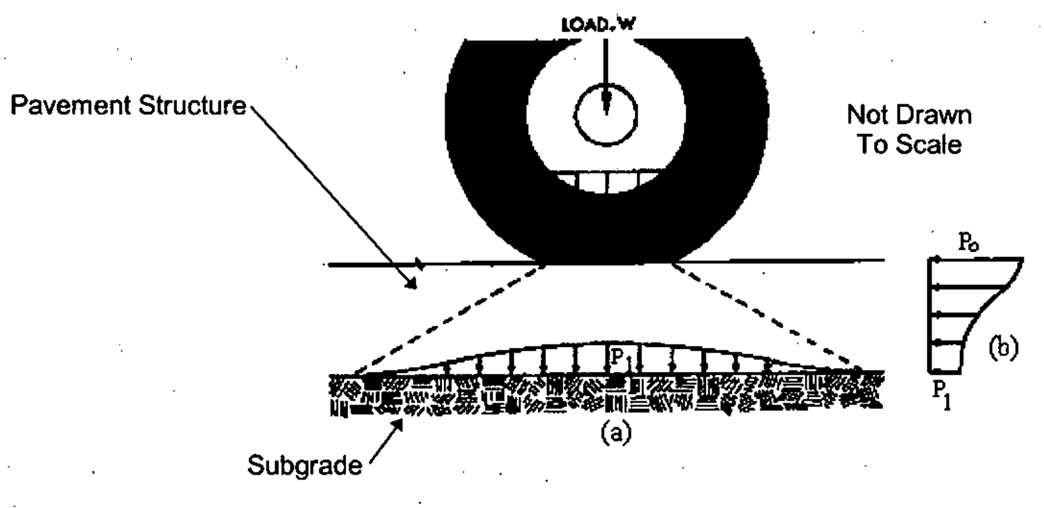


Fig. 3-1: Spread of wheel-load through pavement structure

In determining pavement thickness, the following factors are considered:

(a) Traffic - The amount of traffic predicted to use the facility. The number of trucks predicted to use the highway is particularly important, as one pass of a tractor-trailer truck equals approximately 4,000 passenger vehicles,

(b) Soil Support Value - The soil subgrade strength, i.e., the type of soil of which the subgrade is composed - sand, clay, silt, etc,

(c) Regional Factor - Accounts for the effect of various climatic conditions. For instance, the effect and number of freeze-thaw cycles in the mountain region will require a thicker pavement structure than the milder climate in the eastern part of the state, and

(d) Strength and other influencing characteristics of the materials available or chosen or the layers or courses in the total asphalt pavement structure.

(e) Economics

From these factors, a structural number is calculated. The structural number is an index number derived from an analysis of traffic, soil conditions, and regional factors. This number is used to determine the thickness of the total pavement and the thickness of the various layers. The following is a relative comparison of strength of various asphalt mix layers to each other and to other base types:

- 1 inch (25 mm) asphalt surface or intermediate layer ≅ 1½ inches (37.5 mm) asphalt base
- 1 inch (25 mm) asphalt surface or intermediate layer ≅ 3 inches (75 mm) aggregate base course
- 1 inch (25 mm) asphalt surface or intermediate layer ≅ 2 inches (50 mm) cement treated ABC

Obtaining the specified thickness of each pavement layer during construction is critical in order for the pavement to perform for the design life. As pavement thickness increases, small increases greatly extend the pavement life. For instance, one half inch (12.5 mm) less surface course potentially can reduce the pavement life from 20 years to 15 years. Therefore, the roadway technicians should be aware of the thickness required of each layer as specified by the plans and typical sections and the importance of obtaining that thickness in the completed pavement structure.

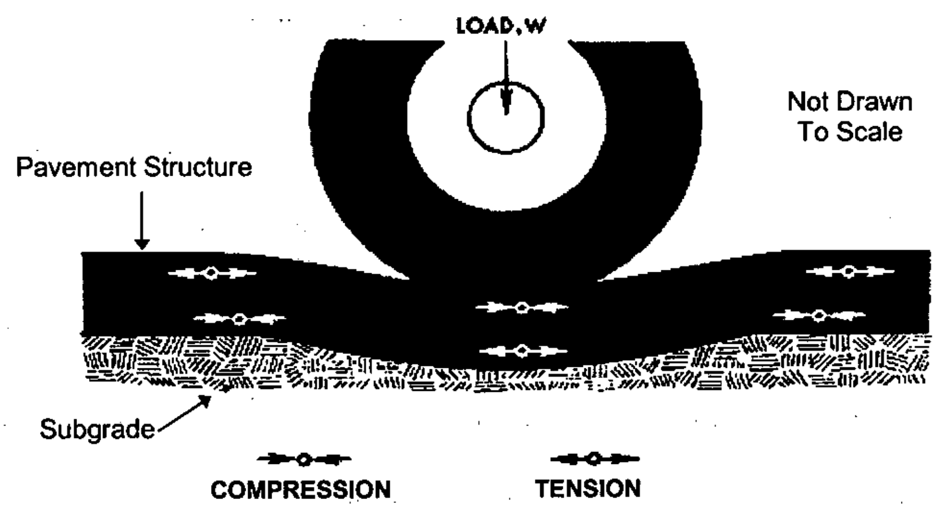


Figure 3-2: Pavement deflection results in tensile and compressive stresses in pavement structure

3.2 SUPERPAVE ASPHALT MIX TYPES

An asphalt pavement structure consists of all courses or layers above the prepared subgrade or foundation. The upper or top layer(s) is the asphalt surface course. The surface course(s) may range from less than an inch (25mm) to several inches (mm) in thickness. The surface course is a high density layer designed to prevent penetration or internal accumulation of moisture. It is also designed to be skid resistant, resistant to wear, distortion, and deterioration by traffic, weather and deicing chemicals and is made using a relatively small maximum size aggregate. The layer placed immediately below the surface course is the intermediate course. The intermediate course is a high density material and is made using a slightly larger maximum size aggregate. When the expected traffic is very high or other conditions dictate, an asphalt base course may be utilized. The base is also a high density material and is made using an even larger maximum size aggregate. The base is an important structural strength element of a pavement. Its main purpose is to distribute traffic wheel loads over the subgrade and, therefore, is almost entirely designed for that purpose. Base course mixes can be constructed in relatively thick layers at a reasonable cost due to the large aggregate size and therefore, require a lower asphalt binder content. The thickness of the base course is usually dependent upon the overall strength requirements for a particular pavement based upon the anticipated traffic loading.

Listed in the following table are the Superpave mix types. The first letter of the mix type designation indicates the type of mix (Surface, Intermediate and Base), the number indicates the nominal aggregate size in millimeters, and the letter at the end indicates the level of traffic loading which the mix is designed to carry with satisfactory performance. Traffic loading is expressed in Equivalent Single Axle Loads (ESALs). As an example, an S 12.5 C mix is a surface mix with a nominal maximum aggregate size of 12.5 mm and a design loading of 3 to 30 million ESALs and will be produced using a PG 70-22 asphalt binder.

TABLE 3-1
SUPERPAVE MIX TYPES

Mix Type	General Use	ESAL Range (Million)	Binder PG Grade
S 4.75A	Surface Course	Less than 0.3	64-22
SF 9.5A	Surface Course	Less than 0.3	64-22
S 9.5B	Surface Course	0.3 to 3	64-22
S 9.5C	Surface Course	3 to 30	70-22
S 9.5D	Surface Course	More than 30	76-22
S 12.5C	Surface Course	3 to 30	70-22
S 12.5D	Surface Course	More than 30	76-22
I 19.0B	Intermediate Course	Less than 3	64-22
I 19.0C	Intermediate Course	3 to 30	64-22
I 19.0D	Intermediate Course	More than 30	70-22
B 25.0B	Base Course	Less than 3	64-22
B 25.0C	Base Course	More than 3	64-22
B 37.5C	Base Course	More than 3	64-22

3.3 PAVEMENT LAYER DEPTH GUIDELINES (FOR PAVEMENT DESIGN PURPOSES)*

A. Single Lift Depths (Minimum – Maximum) **

- S 4.75A = 0.5 - 1.0 in (12.5 - 25 mm)
- SF 9.5A = 1.0 - 1.5 in (25 - 40 mm)
- S 9.5X = 1.5 - 2.0 in (40 - 50 mm)
- S 12.5X = 2.0 - 2.0 in (50 - 50 mm)
- I 19.0X = 2.5 - 4.0 in (65 - 110 mm)
- B 25.0X = 3.0[1] - 5.5 in (75[1] - 140 mm)
- B 37.5C = 4.5 - 6.0 in (115 - 150 mm)

[1] For B 25.0 X placed on unstabilized subgrade, minimum lift thickness is 4.0 in. (100 mm)

B. Maximum Layer Total Depths**

- S 4.75A = 2.0 in (50 mm)
- SF 9.5A = 3.0 in (80 mm)
- S 9.5X = 3.0 in (80 mm)
- S 12.5X = 4.0 in (100 mm)
- I 19.0X = 4.0 in (110 mm) except 4.5 in (120 mm) for C & G Section
- B 25.0X = No Restrictions
- B 37.5C = No Restrictions

Notes:

* From "Interim Pavement Design Procedure, Pavement Layer Depths (Superpave Mixes)", Published by NCDOT Pavement Management Unit.

** Minimum layer thickness is at least 3 times the nominal maximum aggregate size.

3.4 SUPERPAVE APPLICATION RATES OF SPREAD PER INCH (mm) DEPTH

Mix Type	Rate Lbs/SY/Inch	Rate Kg/SM/mm
S 4.75 A	100	2.15
SF 9.5 A	110	2.35
S 9.5 B, C, D	112	2.40
S 12.5 C, D	112	2.40
I 19.0 B, C, D	114	2.45
B 25.0 B, C	114	2.45
B 37.5 C	114	2.45

Note: Always refer to the contract and/or typical sections for the specified average rate and approximate depth to be placed.

3.5 TYPICAL SUPERPAVE SINGLE LAYER DEPTHS / RATES

Layer Type	*Thickness/Rate (English)	*Thickness/Rate (Metric)
S 4.75A	0.5 in @ 50 lbs/sy	12.5 mm @ 27 kg/sm
SF 9.5A	1.00 in @ 110 lbs/sy	25 mm @ 59 kg/sm
S 9.5 X	1.50 in @ 168 lbs/sy	40 mm @ 96 kg/sm
S 12.5 X	2.00 in @ 224 lbs/sy	50 mm @ 120 kg/sm
I 19.0 X	2.50 in @ 285 lbs/sy	65 mm @ 160 kg/sm
B 25.0 X	3.00 in @ 342 lbs/sy	75 mm @ 184 kg/sm
B 37.5	4.50 in @ 513 lbs/sy	115 mm @ 282 kg/sm

*Approximate Minimum Thickness

3.6 TYPICAL ASPHALT BINDER CONTENTS*

PG 64-22		PG 70-22		PG 76-22	
S 4.75 A	6.7%	S 9.5 C	5.7%	S 9.5 D S 12.5 D	5.5% 5.0%
SF 9.5 A	6.6%	S 12.5 C	5.3%	OGAFC, Type FC-1 Modified	5.8%
S 9.5 B	5.9%	I 19.0 D	4.5%		
I 19.0 B & C	4.7%				
B 25.0 B & C	4.3%			OGAFC, Type FC-2 Modified	6.2%
B 37.5 C	4.3%				
OGAFC, Type FC-1	5.8%				
PADC, Type P-57	3.0%				
PADC, Type P-78M	2.5%				

* By Weight of Total Mix

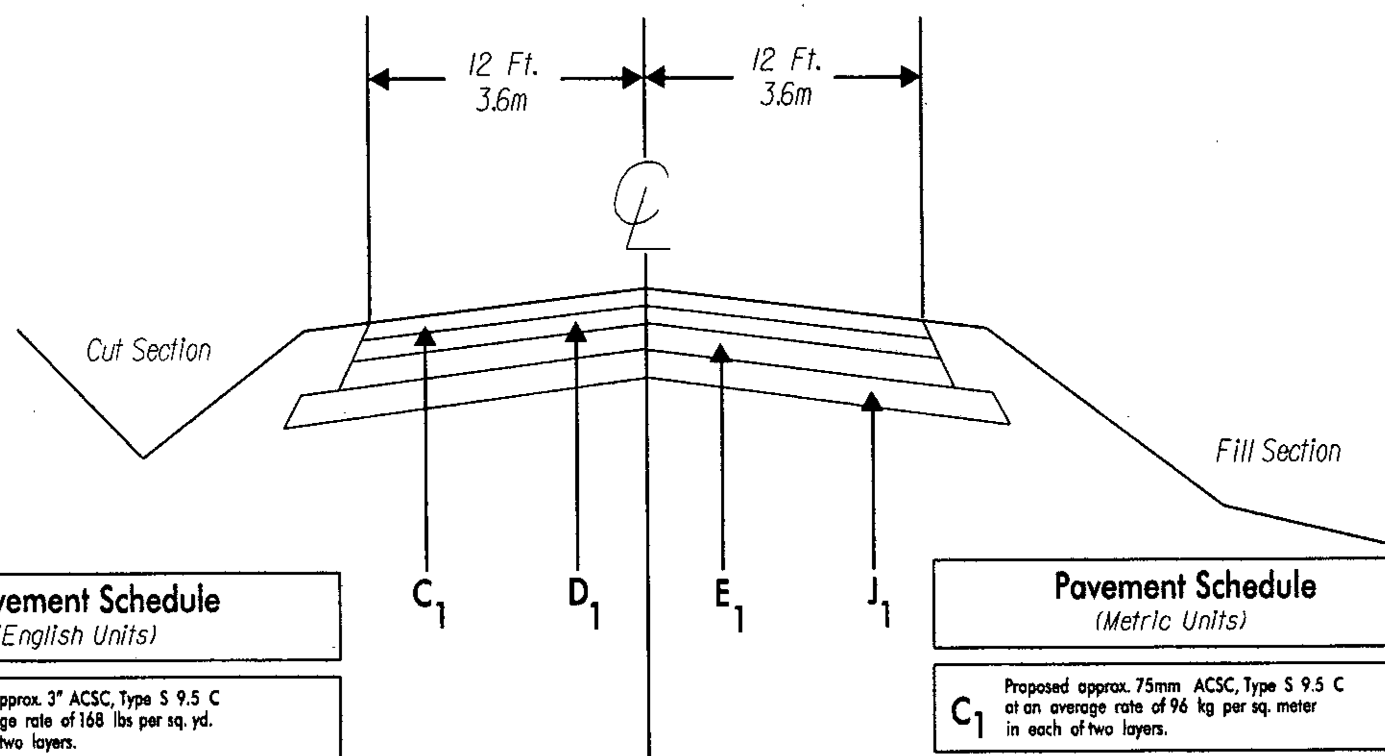
3.7 LAYER COEFFICIENTS

The following are layer coefficients used in designing and building a pavement structure to the required structural number. These coefficients are per inch (mm) depth for the appropriate type mix or base.

	(per in)	(per mm)
Asphalt Concrete Surface Course, Type S 4.75A	N/A	N/A
Asphalt Concrete Surface Course, Type SF 9.5A	0.44	0.017
Asphalt Concrete Surface Course, Type S 9.5X	0.44	0.017
Asphalt Concrete Surface Course, Type S 12.5X	0.44	0.017
Asphalt Concrete Intermediate Course, Type I 19.0X	0.44	0.017
Asphalt Concrete Base Course, Type B 25.0X	0.30	0.012
Asphalt Concrete Base Course, Type B 37.5X	0.30	0.012
Aggregate Base Course, ABC	0.14	0.0055
Cement Treated ABC, CTABC	0.23	0.009
Lime Stabilized Subgrade, Soil-Lime	0.13	0.0051
Cement Stabilized Subgrade, Soil-Cement	0.14	0.0055
Permeable Asphalt Drainage Course (PADC)	0.14	0.0055

Note: This Section covers asphalt mixes that are considered to be standard asphalt mixes. Other specialty type mixes such as Friction Courses, Drainage Courses, Ultra Thin Bonded Wearing Course, and Hot In-Place Recycled mixes are covered in the Standard Specifications and the NCDOT Construction Manual.

Example Roadway Typical Section



Pavement Schedule
(English Units)

C_1	Proposed approx. 3" ACSC, Type S 9.5 C at an average rate of 168 lbs per sq. yd. in each of two layers.
D_1	Proposed approx. 2 1/2" ACSC, Type I 19.0 C at an average rate of 285 lbs per sq. yd.
E_1	Proposed approx. 5" ACBC, Type B 25.0 C at an average rate of 570 lbs per sq. yd.
J_1	Proposed 8" Aggregate Base Course

Note: Rates and depths shown are examples only. See specific project Pavement Schedule for exact rates and depths.

Pavement Schedule
(Metric Units)

C_1	Proposed approx. 75mm ACSC, Type S 9.5 C at an average rate of 96 kg per sq. meter in each of two layers.
D_1	Proposed approx. 60mm ACBC, Type I 19.0 C at an average rate of 160 kg per sq. meter
E_1	Proposed approx. 125mm ACBC, Type B 25.0 C at an average rate of 300 kg per sq. meter
J_1	Proposed 200mm Aggregate Base Course