3.   Design Standards

3.3   Pavement Design

3.3.1   General Provisions

The sections below provide requirements for the subgrade materials evaluation, traffic analysis, and design of flexible pavements, rigid pavements, and alternative pavements. Either the methods below or the design procedure from the New Mexico Department of Transportation (NMDOT) are acceptable for design of pavements in the City of Albuquerque.

The design method contained herein was developed by the review of various methods which are now, or have been in use by different state transportation departments and/or municipalities within the southwestern United States. These methods were all based on adoption and enhancement of the 1993 Guide for Design of Pavement Structures which was published by the American Association of State Highway and Transportation Officials (AASHTO). These methods were selected due to history of performance and due to the City of Albuquerque being in a specific geographic location where experience can be called upon and certain factors will not change.

Three major overall assumptions which have been made in the development of these design procedures are:

(a)   That the adequacy of the design will be established by soils and material surveys and laboratory studies.

(b)   That the design strengths assumed for the subgrade and pavement structure will be achieved through proper construction methods.

(c)   That an adequate present and projected traffic loading for the analysis period be derived from accurate present and historical data in order to achieve the intended serviceability of the roadway.

3.3.2   Subgrade Materials Evaluation

   3.3.2.1   Sampling Methods

      1. The City of Albuquerque has chosen the R-Value test as its means of obtaining a resilient modulus for use in the 1993 AASHTO design equation for flexible pavements.

      2. The correlation between R-Value and resilient modulus is presented in Table 3.3-1.

      3. All soil tests shall be conducted under the supervision of a New Mexico Registered Professional Engineer familiar with soil sampling and testing procedures.

4. The design subgrade soil shall be defined as the upper two feet of the soil under the proposed pavement.

3.3.2.2 Frequency of Testing and Required Elements

Sampling frequency and techniques for subgrade materials (native and borrowed) shall be as follows:

1. One sample for each type of soil

2. A minimum of one sample every 300 feet for collector and arterial streets.

3. Two samples per project minimum.

4. One "R" value and proctor sample per each soil condition or three per mile of the poorest soil.

5. At least one and preferably two soil borings should go down to a depth comparable to any potential sewer or water line depth. A moisture determination should be made for each sample.

6. Sampling is to be random and shall not be restricted along any given line, but shall be spread irregularly over the proposed roadway.

7. The depth of sampling shall extend to a minimum depth of 3 feet below proposed subgrade elevation unless rock is encountered

3.3.2.3 Required Soil Tests

The following tests shall be performed on soil samples:

1. Sieve Analysis

2. Plastic Index

3. Soil correlation/analysis to determine representative soils, on which "R" value tests are to be performed.

4. With approval from the City Engineer, the designer can use NMDOT "Estimated R-value chart" based on soil type to supplement actual R-value test results on the subgrade soils encountered. Both the tested and estimated "R" values can be used to determine the design "R" value.

5. "R" value and Proctor density-moisture tests

6. Stabilization testing if subgrade stabilization is to be considered.

7. Determination of in-situ moisture content

3.3.2.4 Geotechnical Design Report

1. Pavement designs for local streets serving residential areas have been standardized and are presented in the Standard Details, Section 2400. These

standards are based on an R Value of 50 or greater. Soils investigation as outlined in the Subgrade Materials Evaluation section will be required to determine the nature of subgrade treatment needed to achieve the minimum R Value.

2. A design report shall be submitted for the construction of arterial, collector, or streets located in industrial areas. This report documents the existing pavement section material, thickness, and width and considers the design information regarding the proposed improvements. Any unusual circumstances which could affect design and/or construction should be noted. A site plan showing boring locations, soil boring logs and soil test results shall be provided.

3. The design "R" value is correlated to the Resilient Modulus (MR) for use in the flexible pavement design nomograph using Table 3.3-1.

Table 3.3-1: R-Value and Resilient Modulus (M_R) Correlation

R-Value	MR	R-Value	MR	R-Value	MR
0	2176	30	6143	60	17345
1	2252	31	6359	61	17956
2	2331	32	6583	62	18588
3	2414	33	6815	63	19242
4	2499	34	7055	64	19920
5	2586	35	7303	65	20621
6	2678	36	7560	66	21347
7	2772	37	7826	67	22098
8	2869	38	8102	68	22876
9	2970	39	8387	69	23682
10	3075	40	8682	70	24515
11	3183	41	8988	71	25379
12	3295	42	9305	72	26272
13	3411	43	9632	73	27197
14	3531	44	9971	74	28154
15	3656	45	10322	75	29146
16	3784	46	10686	76	30172
17	3918	47	11062	77	31234
18	4056	48	11451	78	32334
19	4198	49	11854	79	33472
20	4346	50	12272	80	34650
21	4499	51	12704	81	35870
22	4658	52	13151	82	37133
23	4822	53	13614	83	38440
24	4991	54	14093	84	39794
25	5167	55	14590	85	41194
26	5349	56	15103	86	42645
27	5537	57	15635	87	44146
28	5732	58	16185	88 and Higher	45700
29	5934	59	16755		

This table is based on the equation: $M_r = 2175.6e^{0.0346R}$

3.3.3 Traffic Factors in Pavement Design

3.3.3.1   Traffic Criteria for Pavement Design

1. The values of Average Daily Traffic (ADT), percent distribution of vehicle types, directional distribution and the growth factor used for the design computations shall be obtained either from the Mid-Region Council of Governments (MRCOG) or through a traffic study conducted by a New Mexico Registered Professional Engineer. The values shall be compared against those in Table 3.3-2, and unless the values are based on historical data of more than five years, the greater value shall control.

Table 3.3-2: Traffic Criteria for Pavement Design

Street Classification	ADT (both directions)	Truck Traffic Percentage				Directional Distribution	Annual Growth Rate
		SUT	STT	MTT	BUS		
Principal Arterial	12,000	3	1	1	*	50%	5%
Minor Arterial	8,500	3	1	1	*	50%	4%
Collector	6,000	3	1	1	*	50%	4%

*Contact the transit department   STT - Single Trailer Truck
SUT - Single Unit Truck   MTT - Multi-Trailer Truck

2. On smaller projects, (less than 1000 lineal feet of street construction) where traffic count data is not available and a traffic count study is not warranted, the values in Table 3.3-2 may be used, as approved by the City Engineer.

3. Pavement shall be designed for 20 years unless approval for an alternate design life is received from the City Engineer.

4. Growth Factor is determined from Table 3.3-3.

Table 3.3-3: Growth Factor

Design Period Years	Annual Growth Rate, Percent							
	No Growth	2	4	5	6	7	8	10
1	1	1	1	1	1	1	1	1
2	2	2.02	2.04	2.05	2.06	2.07	2.08	2.1
3	3	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5	5.2	5.42	5.53	5.64	5.75	5.87	6.11
10	10	10.95	12.01	12.58	13.18	13.82	14.49	15.94
15	15	17.29	20.02	21.58	23.28	25.13	27.15	31.77
20	20	24.3	29.78	33.06	36.79	41.00	45.76	57.28
25	25	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35	49.99	73.65	90.32	111.43	138.24	172.32	271.02

The table is based on the equation $Growth\ Factor = \frac{(1+r)^n - 1}{r}$

Where $r = \frac{rate}{100}$ and is not zero.

5. The ESAL Vehicle Equivalency Factor (EF) for various vehicle types are as shown in Table 3.3-4.

Table 3.3-4: ESAL Vehicle Equivalency Factor

Vehicle Type	ESAL Factor
Passenger Car	0.0008
Other 4 wheel vehicle	0.0087
Single Unit Truck	0.1890
Single Trailer Truck	2.3719
Multi-Trailer Truck	2.3187
Bus	0.6808

6. The calculation of the default ESAL (18,000-pound Equivalent Single Axle Load) is as follows:

$$ESAL = AWDT \times 365 \times Growth\ Factor(\%SUT \times EF_{SUT} + \%STT \times EF_{STT} + \%MTT \times EF_{MTT} + \%Bus \times EF_{Bus} + \%Auto \times EF_{Auto})$$

Where: The sum of the different types of vehicles equals 100% and the percentage is entered numerically. For example, 3% is entered as .03.

3.3.3.2   Analysis Period

1. The analysis period for design shall be 20 years.

2. The classification of streets is obtained from the most current Long Range Roadway System Plan.

3.3.3.3   Design Lane Traffic Computation

The following equation will determine the ESAL in the design lane:

$$ESAL_L = D_d \times D_l \times ESAL$$

Where: D_d = A directional distribution factor, expressed as a percentage, that accounts for the distribution of ESAL units by direction but not less than as shown in Table 3.3-2.

D_L = A lane distribution factor, expressed as a percentage, that accounts for distribution of traffic when two or more lanes are available in one direction (See Table 3.3-5).

Table 3.3-5: Lane Distribution Factor, DL

No. of Lanes in Each Direction	Percent ESAL in Design Lane
1	100
2	90
3	70
4	65

3.3.3.4   Example ESAL Calculation

Example for a 4-lane, minor arterial:

$$ESAL = 8,500 \times 365 \times 29.78[(0.03 \times 0.1890) + (0.01 \times 2.3719) + (0.01 \times 2.3187) + (0.95 \times 0.0008)] = 4,927,844$$

$$ESAL_L = 0.5 \times 0.9 \times 4,927,844 = 2,217,530$$

3.3.4 Structural Design of Pavement

3.3.4.1   Minimum Pavement Component Thickness

The following criteria governing minimum pavement component thickness shall apply to all major (arterial and collector) roadways. These criteria, as listed in Table 3.3-6 are derived based on engineering judgment and past experience in construction quality control.

Table 3.3-6 Minimum Pavement Component Thickness

Pavement Component	Minimum Thickness
Asphaltic Concrete (AC)	4 inches
Cement-Treated Base Course (CTB)	4 inches
Bituminous Treated Base Course (BTB)	4 inches
Aggregate Base Course (ABC)	4 inches
Subbase Material	4 inches
Soil Cement	6 inches
Asphalt Emulsion Treated Soil	6 inches

3.3.4.2   Structural Coefficients of Pavement Components

The following coefficients, listed in Table 3.3-7, shall be used for the computation of design structural number for each type of component selected:

Table 3.3-7 Structural Coefficients of Pavement Components

Component	Layer Coefficient Modification Factor (m_i)	Coefficient/Inch (a_i)
Plant Mix Seal Coat (PMSC)	N/A	0.25
Asphaltic Concrete (AC)	N/A	0.42
Bituminous Treated Base Course (BTB)	N/A	0.25
Cement Treated Base Course (CTB)	N/A	0.20
Aggregate Base Course (ABC)	1.15	0.10
Sub-base Material	1.00	0.06
Asphalt Emulsion Treated Soil	N/A	Tentative
Soil Cement	N/A	Tentative
Lime Stabilization	N/A	Tentative

1. The layer modification factor is applied to the base course layer coefficient to reflect the drainage or permeability characteristics of the selected base course.

2. Drainage coefficients are not applied to the asphaltic concrete layers, nor to the stabilized subgrade layers.

3. The modification factors may be set to other values than those recommended if the designer chooses.

4. The modification factors will range between 1.00 and 1.15 for bases approaching saturation less than 25% of the time, and base permits water removal with in one day.

5. Seek guidance from 1993 AASHTO Part 2, Section 2.4 for circumstances where the conditions stated do not apply.

The structural number is calculated using the depth in inches (d_i) for each layer as follows:

$$SN = a_1 d_1 + a_2 d_2 m_2 + \cdots + a_i d_i m_i$$

3.3.4.3   Serviceability Index

The serviceability of a pavement is defined as the ability to serve high-volume automobile and truck traffic. In the design equation, the serviceability index enters into the equation as the lowest index that will be tolerated before resurfacing or reconstruction becomes necessary.

A scale with a range of 0 through 5 was established for present serviceability rating, with a value of 5 as the highest index of serviceability and 0 as the lowest. The initial serviceability (P_o) rating and terminal serviceability (P_t) rating are recommended to be selected as shown in Table 3.3-8.

Table 3.3-8 Serviceability Rating

Street Classification	Initial Serviceability Rating (p_o)	Standard Normal Deviation (P_t)
Principal Arterial	4.2	2.5
Minor Arterial	4.2	2.0
Collector	4.2	2.0

Using the 1993 AASHTO method of calculating ESAL's:

$$\Delta PSI = P_o - P_t$$

3.3.4.4   Reliability and Statistics

The AASHTO '93 method of calculation incorporates reliability and statistics to account for the degree of certainty how designs will perform as expected over the 20 year analysis period. For use in the 1993 AASHTO equation, recommended Reliability and Standard Deviation values are provided in Table 3.3-9 for Principal Arterial, Minor Arterial, and Collector Streets:

Table 3.3-9 Reliability and Statistical Values

Street Classification	Reliability Level	Standard Deviation (S_o)	Standard Normal Deviation (Z_R)
Principal Arterial	85%	0.45	-1.037
Minor Arterial	80%	0.40	-0.841
Collector	75%	0.40	-0.674

Alternatively, the standard normal deviation as a function of reliability level may be chosen as from Table 3.3-10. It is not recommended to use a design reliability level of greater than 90%.

Table 3.3-10 Standard Normal Deviation Values

Reliability Level	Standard Normal Deviation (Z_R)
50%	-0.000
60%	-0.253
70%	-0.524
75%	-0.674
80%	-0.841
85%	-1.037
90%	-1.282

3.3.4.5   Economic Factors

The design engineer is encouraged to investigate the use of various combinations of pavement components in order to derive the most economic design applicable to the project characteristics and structural requirements.

3.3.5 Flexible Pavements Design

3.3.5.1   Design Procedure

A nomograph from AASHTO '93 pavement design has been provided to simplify the solution to the mathematical relationship of the Resilient Modulus value, ESAL, and the structural number (Figure 3.3-1). Pavement structural designs shall be submitted in the format as shown on Table 3.3-11.

The equation for calculation of ESAL (W_{18}) using AASHTO '93 is shown below:

$$Log_{10}W_{18} = Z_R S_o + 9.36 Log_{10}(SN + 1) - 0.2 + \frac{Log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 Log_{10}M_R - 8.07$$
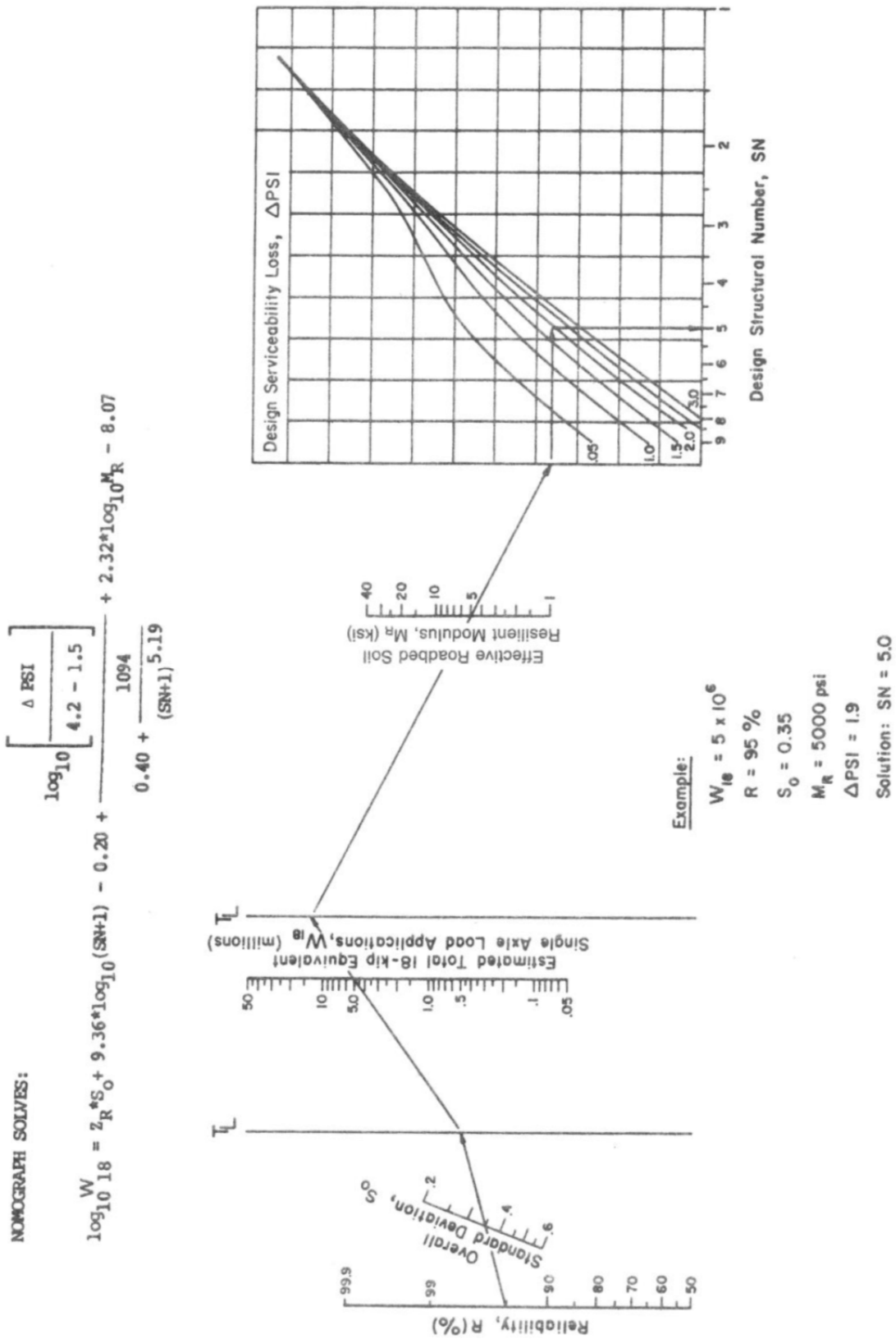
Figure 3.3-1 Design Chart Flexible Pavements

Figure 3.1.   Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

Table 3.3-11 Structural Design Computation Form

PROJECT NAME:_____   STREET:_____

PROJECT NO:_____   FROM:_____

DESIGN ADL:_____   TO:_____

DESIGN SN:_____   COMPUTED BY:_____

Alternate	Subbase	CTB	BTB	ABC	AC	PMSC	SN
A	x(0) =	x(.2)=	x(.25)=	x(.1)=	x(.42)=	x(.25)=	
B							
C							
D							
E							
F							

Design SN_____

3.3.6 Portland Cement Concrete Streets

The current acceptable method for design of Portland cement concrete pavement is the procedure in the AASHTO Guide for Design of Pavement Structures, 1993 and the 1998 Supplement - Part II, Rigid Pavement Design and Rigid Pavement Joint Design published by the American Association of State Highway and Transportation Officials, Washington, D.C. As an alternative, PCCP design may be determined by use of accepted industry approach and software such as the American Concrete Pavement Association "Street Pave" software or NMDOT procedures.

Concrete pavement joints shall be detailed in the plans. Guidelines for joint layout can be obtained from the American Concrete Pavement Association.

Design criteria to be used in the structural design of Portland Cement Concrete Pavement (PCCP) are as follows:

1. All PCCP shall be fly-ash modified concrete as specified in the Standard Specifications or have other methods of mitigating Aggregate Silica Reaction as approved by the City Engineer.
2. Design of PCCP shall be based on flexural strength value of 600 psi at 28 days as measured by ASTM Method C 78.
3. Stabilized base course values used in conjunction with PCCP designs shall be as indicated below:

a. Portland Cement Stabilized Base – 300 psi compressive strength as measured by ASTM Method D1633.

b. Asphalt Treated Base – 1000 pound minimum Marshal stability as measured by ASTM Method D1559 (as modified in the Standard Specifications.)

4. Reliability shall be 85%.

5. Final Serviceability Index shall be 2.5.

3.3.7 Alternative Pavement

Alternative types of pavement can be used for crosswalks, parking lots, sidewalks, and trails. Alternative materials must have sufficient strength for the projected traffic and require approval of the City Engineer. Crosswalks may be a different material from the remainder of the street. Options include:

- Brick
- Pavers
- Permeable or Porous Pavement
- Stamped Concrete
- Gravel

3.3.6.1   Permeable or Porous Pavement

Requests to use permeable pavement shall include the following items:

1. Geotechnical investigation showing that the subgrade soils have sufficient percolation properties or a design that provides rainwater storage until percolation is achieved.

2. Agreement to maintain the pavement using sweeping, vacuuming or power washing.

3. Product information showing that the pavement meets American with Disabilities Act (ADA) requirements or indicate that a different material is used for ADA accessible parking spaces and accessible route.