Chapter 10 - Pavement Design and Technical Criteria

10.1 General

This chapter provides the basic criteria and design procedures for roadway pavements. In the City of Castle Pines, Roadway Pavement Designs are required prior to placing pavement base course or curb and gutter. Recommended design methodologies for asphalt (referred to as Hot Bituminous Pavement, Existing Bituminous Pavement, or Asphalt Paving Material) and Portland cement concrete are addressed and follow both Metropolitan Government Pavement Engineers Council (MGPEC) and the American Association of State Highway and Transportation Officials' (AASHTO) *Guide for Design of Pavement Structures*. Some criteria modifications have been made in the following design procedures. In case of discrepancy, the most stringent criteria shall take precedence as determined by the City. Contact the City Public Works Department if questions or clarifications regarding criteria.

10.2 Pavement Design Report Submittal Options

The final pavement design shall be performed after the over-lot grading has been completed and the wet utilities have been installed, if applicable. A Right-of-Way Permit must be obtained prior to taking soil samples for a pavement design. The Applicant shall obtain Permits only after the final construction plans, which include the pavement design, are approved by the City. The submittal for pavement design approval must be in accordance with these Roadway Standards.

If a street is to be built in phases (that is, the center two lanes are built first, then at some later date, more lanes are added), a new Pavement Design investigation and report for the additional lanes may be required if it has been at least 2 years since the original design was approved. The City will decide whether a new Pavement Design will be required. All approved pavement designs shall be valid for a period of at least 2 years.

10.3 Preliminary Pavement Design Reports

For all City land development approvals that involve a subdivision improvement agreement for roadway construction, upon the request by the City Public Works Department, the Applicant must provide, at a minimum, a preliminary subgrade investigation and preliminary Pavement Design report that recommends a typical pavement structural section based on the known site soil conditions, Table 10-7, and the applicable Traffic Impact Study requirements in Chapter 6 of these Roadway Standards. The preliminary reports shall use the equivalent single-axle loads (ESALs) of Table 10-2. This preliminary Pavement Design serves as a justification of the roadway improvement costs included in the subdivision improvements agreement but not for final pavement designs submittals. The preliminary Pavement Design should address the potential need for swell mitigation as discussed in Section 10.6.

A preliminary pavement design may be submitted with final construction plans. Table 10-1 provides a checklist for subgrade investigation and pavement design.

Table 10-1. Subgrade Investigation and Pavement Design Checklist

Soil consultant	OK REJECTED REVIEWED BY:		
Subdivision			
Filing Job No.			
STREET			
DATE	Yes	No	Comment
1. Vicinity map			
2. Drawings with boring locations and logs			
3. Drawing with estimated extent of soil types and ESAL			
4. Drawing with pavement alternatives			
5. Atterberg limits, gradation, % passing no. 200 sieve			
6. Soil classifications			
7. Composite samples: grouped at 250’ maximum intervals			
8. For R-value testing – Dry density & moisture content for each sample – Expansion pressure for each sample – Exudation pressure – R-Value curve			
9. Design nomograph shown with soil support values and ESALs			
10. Strength coefficient used for asphalt, base course, etc.			
11. Design calculation shown for all phases of soil report			
12. Minimum pavement section met for proper classification			
13. Special problems (expansion, frost heave, groundwater) with design & construction problems			
14. Swell mitigation measures (if applicable)			
15. Swell mitigation map			
16. Import materials limitations			

10.4 Subgrade Investigation

10.4.1 Field Investigation

The field investigation shall consist of borings or other suitable methods of sampling subgrade soils to a depth of at least 5 feet below proposed subgrade elevation (10 feet below proposed subgrade on Arterial roadways), at a spacing of not more than 250 feet unless otherwise accepted by the City Public Works Department. Every fifth hole shall be 10 feet deep. At a minimum, every third hole should be placed in the area of the sanitary sewer or storm sewer trench backfills no closer than 2 feet from the top of pipe. Boring logs shall include the Standard Penetration Test number of blows per foot, percent moisture, and free water, and should show soil types encountered in the boring. If more than one soil type is encountered in the boring, they shall be logged and sampled separately. Samples shall be taken after over-lot grading is within a tenth of a foot of finished subgrade (based on the roadway profile); the sanitary sewer and waterline (including services) have been installed and trenches are compacted; and compaction testing is complete. All borings shall be sampled using a California-type sampler in accordance with the *AASHTO T 206: Standard Method of Test for Penetration Test and Split-Barrel Sampling of Soils*.

10.4.2 Classification Testing

Each subgrade sample shall be classified using the *AASHTO M 145 Standard Specification for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes* and the ASTM D2487 *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*. The classifications require results from the following tests:

1) *AASHTO T 11, Standard Method of Test for Materials Finer than No. 200 (75 μm) Sieve in Mineral Aggregate by Washing*
2) *AASHTO T 27, Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates*
3) *AASHTO T 89, Standard Method of Test for Determining the Liquid Limit of Soils*
4) *AASHTO T 90, Standard Method of Test for Determining the Plastic Limit and Plasticity Index of Soils*

The water-soluble sulfate ion content shall be determined at a frequency of 1 test per 1,000 feet for AASHTO Type A-6 and A-7 soils. Testing shall be performed in accordance with *AASHTO T 290, Standard Method of Test for Determining Water-Soluble Sulfate Content in Soil* or CDOT CP-L 2103, *Determining the Sulfate Ion Content in Water or Water-Soluble Ion Content in Soil*.

10.4.3 Soil Grouping

To facilitate subgrade support testing, soil samples collected during the field investigation can be combined to form soil groups. These groups shall be based on the AASHTO Classification, Group Index, and location within the area investigated. Groupings shall not consist of samples with different AASHTO Classifications (note that there may be more than one group within a given classification). Composite samples can be made by combining small, equal portions of each subgrade sample contained within the group and mixed to provide a uniform composite sample of the soil group. The maximum allowable difference in the subgrade sample group index will be 5 or less for the composite sample.

10.4.4 Subgrade Support Testing

Samples shall be tested to determine the subgrade support value using R-Value testing. The pavement shall be designed for the soil (or soil group) exhibiting the lowest subgrade support value. These values shall be used in the design of pavement sections in accordance with the procedures outlined in

Section 10.4. Tests shall be conducted in accordance with the procedure listed in Section 10.4.5, R-Value Tests.

10.4.5 R-Value Tests

R-Values tests shall be conducted in accordance with AASHTO T 190 *Standard Method of Test for Resistance R-Value and Expansion Pressure of Compacted Soils*. The R-Value shall be determined at 300 psi exudation pressure. The reported data shall consist of the following:

5) Dry density and moisture content for each sample
6) Expansion pressure for each sample
7) Exudation Pressure – corrected R-Value curve showing the R-Value at 300 psi

10.4.6 Swell Test

All soil groups, excluding A-1 through A-4, shall be tested to determine swell or settlement potential. Tests shall be run on the "California" samples in accordance with ASTM D 4546 at a surcharge of 200 psf. The swell tests shall be plotted and the percent swell or settlement and swell pressure (psf) shall be determined and reported. All swell tests shall be run only on undisturbed samples; remolded samples shall not be used. Test results that are suspected of being too high or too low for the soil type shall not be considered in the design of the pavement but shall be reported. Any deletion of data shall be justified in the report. If the swell is 2% or greater, the pavement design report must provide mitigation measures. Refer to Section 10.4.3.

10.5 Pavement Design Criteria

10.5.1 General

This section provides the factors to be used for the design of pavements of various roadway classifications.

10.5.2 Equivalent (18-kip) Single Axle Load

The pavement design procedure in this chapter provides for a 20-year service life, given that normal maintenance is provided to keep the roadway surface in an acceptable condition. ESALs are considered equivalent units based on 20-year design criteria and an 18-kip axle loading. ESAL criteria for each City roadway classification are given in Table 10-2.

If actual traffic counts are available, they shall be used to calculate ESALs in lieu of using Table 10-2. It is recommended that a Traffic Impact Study be performed.

Table 10-2. Minimum Equivalent (18-kip) Single-Axle Load

Classification	Class Modifier	ESAL Values[a]
Local	Residential	
	Serving < 80 D.U. All Others	60,000
	Commercial/Industrial[b]	75,000
		220,000
		750,000
Entry	Residential	75,000

Table 10-2. Minimum Equivalent (18-kip) Single-Axle Load

Classification	Class Modifier	ESAL Values[a]
Collector[b]	Residential Commercial/Industrial[b]	250,000 500,000 1,500,000
Arterial[b]	All	2,000,000

[a] Alternative ESAL values may be considered with justification provided by the Traffic Impact Study proposed land uses, and traffic analysis that defines a proportion of truck vehicles.

[b] ESAL values shall be calculated based on projected traffic uses. Minimum ESAL values are as prescribed in Table 10-2.

10.5.3 Design Serviceability

Design serviceability loss (ΔPSI) is determined by subtracting the terminal serviceability index (SI) at the end of the design period from the SI at initial construction. The SI at initial construction will normally fall in the range from 4.2 to 4.6 and generally can be assumed to be 4.5. The SI at the end of the design period is the worst-case allowable condition that the pavement may reach. Table 10-3 outlines the design serviceability loss (ΔPSI) and terminal serviceability index to be used.

Table 10-3. Design Serviceability Loss and Terminal Serviceability Index

Roadway Classification	(ΔPSI)	Terminal Serviceability Index
Arterials (Minor, Principal)	2.0	2.5
Collectors	2.0	2.5
Local: Residential	2.5	2.0
Local: Commercial/Industrial	2.0	2.5

10.5.4 Functional Class and Reliability

The reliability level depends on the functional classification of the proposed roadway. The reliability factor used shall be 95% for all Arterials and shall be 90% for all Collectors and Local roads.

10.5.5 Resilient Modulus

The Resilient Modulus (M_R) can be measured directly from laboratory tests or obtained by using a correlation with R-Value. R-Value is determined by using AASHTO T 190 *Standard Method of Test for Resistance R-Value and Expansion Pressure of Compacted Soils*. The approximate value of M_R is determined by using the following equations:

$$S = [(R-5)/11.29]+3$$

$$M_R = 10[(S+18.72)/6.24]$$

Where:

M_R = resilient modulus (psi)
S = soil support value
R = R-Value obtained from AASHTO T 190 or from the Hveem Stabillometer

Designers should note that although the R-Value is used to gather input data for pavement design, the result of the R-Value test is not the M_R. It is recommended that documentation of the pavement design show that when the R-Value test is used, the M_R is an approximation from correlation formulas.

When the R-Value is reported as less than 5 or “unstable,” there is no correlation to the M_R. When the reported R-Value is 5 or less or “unstable,” the soil needs to be mitigated by an approved stabilization procedure or removal and replacement with approved materials in accordance with Section 10.4.3.

10.5.6 Flexible Pavement Design Factors

Table 10-4 outlines the design factors for flexible pavement. When subgrade stabilization is required, an R-Value of 5 shall be used to determine the Structural Number.

Table 10-4. Flexible Pavement Design Factors

Factor	Source
18-kip ESAL	Table 10-2
Reliability, R	90% Arterials and Collectors 85% Local Roads
Overall Deviation, So	0.44
Serviceability Loss, ΔPSI	Table 10-3
MR Value of the Subgrade	Soil profile report from laboratory and correlation equations
Structural Layer Coefficients (ai)	Table 10-6

10.5.7 Flexible Pavement Strength Coefficients

Table 10-6 contains the standard design strength coefficients for various pavement materials. These strength coefficients are based on materials designed in accordance with current City specifications.

10.5.8 Portland Cement Concrete Working Stress

The working stress (f_t) to be used in the design shall be 75% of the design modulus of rupture (flexural strength) of Portland cement concrete. The design modulus of rupture shall be 650 psi; therefore, the design working stress (f_t) shall be 485 psi.

10.5.9 Minimum Pavement Section

This paragraph provides the minimum acceptable pavement sections for public roadways in the City. These pavement thicknesses may be used for preliminary planning purposes or for estimating collateral requirements for subdivision improvement agreements. Final pavement designs must be based on actual subgrade support test results. Table 10-5 lists these minimum thicknesses for each roadway classification.

Table 10-5. Minimum Pavement Sections

Classification	ESALs	Composite Section		Treated Composite Section			Full-depth Sections	
		Asphalt (inches)	Aggregate Base Course (inches)	Asphalt (inches)	Cement-Treated Aggregate Base Course (inches)	Lime-treated Subgrade (inches)	Full-depth Asphalt (inches)	Portland Cement Concrete (inches)
Local								
Residential	(Table 10-2)	4	6	4	5	6	N/A	6
Commercial	220,000	4	6	4	5	6	N/A	7
Industrial	750,000	5	8	4	8	6	7	9
Collector								
Residential	250,000	5	6	4	6	6	N/A	7
Commercial	500,000	5	8	4	8	12	7	7
Industrial	1,500,000	6	10	5	9	12	8	9
Arterial	2,000,000	6	10	5	9	12	8	9

Notes:

Pavement Sections do not include swell mitigation.

Proposed Treated Composite Sections to increase Strength Coefficients in Table 10.6 shall require approval prior to submittal of Pavement Designs.

Lime Treated Subgrade may be used with a Composite Section or a Treated Composite Section or not at all.

10.5.10 Flexible Pavement Strength Coefficients

Table 10-6 contains the standard design coefficients for various pavement materials. Nonstandard design coefficients may be used only if approved in advance by the City Public Works Department.

Table 10.6. Strength Coefficients

Pavement Structure Component[a]	Strength Coefficients	(Limiting Test Criteria)
Conventional Materials		
Plant Mix Seal Coat	0.25	
Hot Bituminous Pavement	0.44	
Existing Bituminous Pavement	0.30 0.24	(9–15 yr.) (>15 yr.)
Aggregate Base Course	0.12	(R 78+)
Existing Aggregate Base Course	0.10	(R 69+)
Granular Subbase Course	0.07	(R 50+)
Treated Materials[b]	Verification of testing required for items listed below	
Cement-Treated Aggregate Base	0.23	(7-day, 640–1,000 psi)
Lime-Treated Subgrade	0.14	(7-day, 160 psi, PI <6)

[a] A combination of one or more of the following courses placed on a subgrade to support the traffic load and distribute it to the roadbed.

- Subbase. The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course, surface course, or both.
- Base Course. The layer or layers of specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course.
- Surface Course. One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer is sometimes called "Wearing Course."

[b] Proposed Treated Materials shall require approval prior to approval of Pavement Designs.

Note:

PI = plasticity index

10.5.11 Trench Drains

Trench drains are required along both sides of all public Collectors and Arterials with curb and gutter. All new local roads constructed on A-6 or A-7 soils that have a swell potential greater than 2% shall include trench drains if required in the pavement design. A City of Castle Pines Notice of Change will be required to add the trench drain on local roads. Trench drains shall be placed along both sides of the pavement and wherever else it is determined to be necessary. The purpose of the subsurface piping system is to provide drainage for the street subbase and to create an outlet for irrigation water. Trench drains shall discharge to the storm sewer system or to the surface drainage system upon approval from the City. No trench drains shall connect to the sanitary sewer system.

Minimum size of trench drains serving more than one lot shall be 4 inches in diameter. Typical trench drain details are provided in Appendix A.

10.5.12 Preliminary Planning Pavement Designs

Table 10-7 presents pavements designed for each functional class of road with typical worst-case subgrade conditions. These sections may be used in combination with a subgrade investigation report to begin construction with the City's approval. If swell mitigation is required, as defined in Section 10.6, or as identified during the preliminary Pavement Design investigation, it is in addition to these preliminary planning Pavement Design sections.

Table 10-7. Preliminary Planning Design Pavement Sections

Classification	ESALs	Composite Section		Treated Composite Section			Full-depth Sections	
		Asphalt (inches)	Aggregate Base Course (inches)	Treated Subgrade (inches)	Asphalt (inches)	Aggregate Base Course (inches)	Full-depth Asphalt (inches)	Portland Cement Concrete (inches)
Local								
Residential	(Table 10-2)	5	8	5	6	6	N/A	6
Commercial	220,000	5	8	5	6	6	N/A	7
Industrial	750,000	6	10	5	10	6	8	10
Collector								
Residential	250,000	6	8	5	8	6	N/A	8
Commercial	500,000	6	10	5	10	12	8	9
Industrial	1,500,000	7	12	6	12	12	9	10
Arterial	2,000,000	7	12	6	12	12	9	10

Notes:

Pavement Sections do not include swell mitigation.

Proposed Treated Composite Sections to increase Strength Coefficients in Table 10-6 shall require approval prior to submittal of Pavement Designs.

Lime-treated Subgrade may be used with a Composite Section or a Treated Composite Section or not at all.

10.6 Pavement Design Procedure

10.6.1 Flexible Pavements

The following procedure uses nomographs to determine the Structural Number (SN) and then an equation to determine the design thickness of the pavement structure. The use of this procedure to determine the pavement structure is required. Additionally, various software programs are available that are based on the AASHTO design procedure and may be used. The use of these programs is encouraged in conjunction with the use of the nomographs. The software programs should be based on the AASHTO Design Procedure. The nomographs are to be used to verify the design produced by any software programs.

The following procedure should be used in determining the SN of the pavement being designed:

1) Select the level of Reliability required in Table 10-4. Enter the nomograph, Figure 10.1, at the left scale using the Reliability level value. Connect the Reliability component with a Standard Deviation value (0.44). Extend this line to the first turning line (TL).
2) From the TL intercept, draw a line through the appropriate value for estimated traffic, the 18-kip ESAL. Extend the line to the second TL.
3) From this TL intercept, draw a line through the appropriate soil support value (roadbed soil M_R) and extend it to left edge of the Design Serviceability Loss portion of the nomograph.
4) Plot the horizontal line intercepting the selected psi value from Table 10-3. From this turning point, plot a vertical line down to the resultant Design SN.
5) Once the SN has been determined, the design thicknesses of the pavement structure can be determined by the general equation:

   $SN = a_1D_1 + a_2D_2 + a_3D_3 + \ldots$

   where

   a_1 = Asphalt strength coefficient a_2, a_3, a_n. = strength coefficients of additional pavement components
   D_1 = thickness of asphalt (inches) D_2, D_3, D_n = thickness of additional pavement component sections
6) The strength coefficients for various components of the pavement structure are given in Table 10-6.
7) The component thickness selected must meet two conditions:
   a) Total hot bituminous pavement thickness selected cannot be less than the minimum specified in Table 10-5 for the roadway classification.
   b) The base course thickness selected cannot exceed 2.5 times the hot bituminous pavement thickness selected.
8) The design must reference any mitigation measures required when the subgrade contains swelling soils as defined in Section 10.4.3.

NOMOGRAPH SOLVES:

$$\log_{10}W_{18} = Z_R*S_o + 9.36*\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32*\log_{10}M_R - 8.07$$

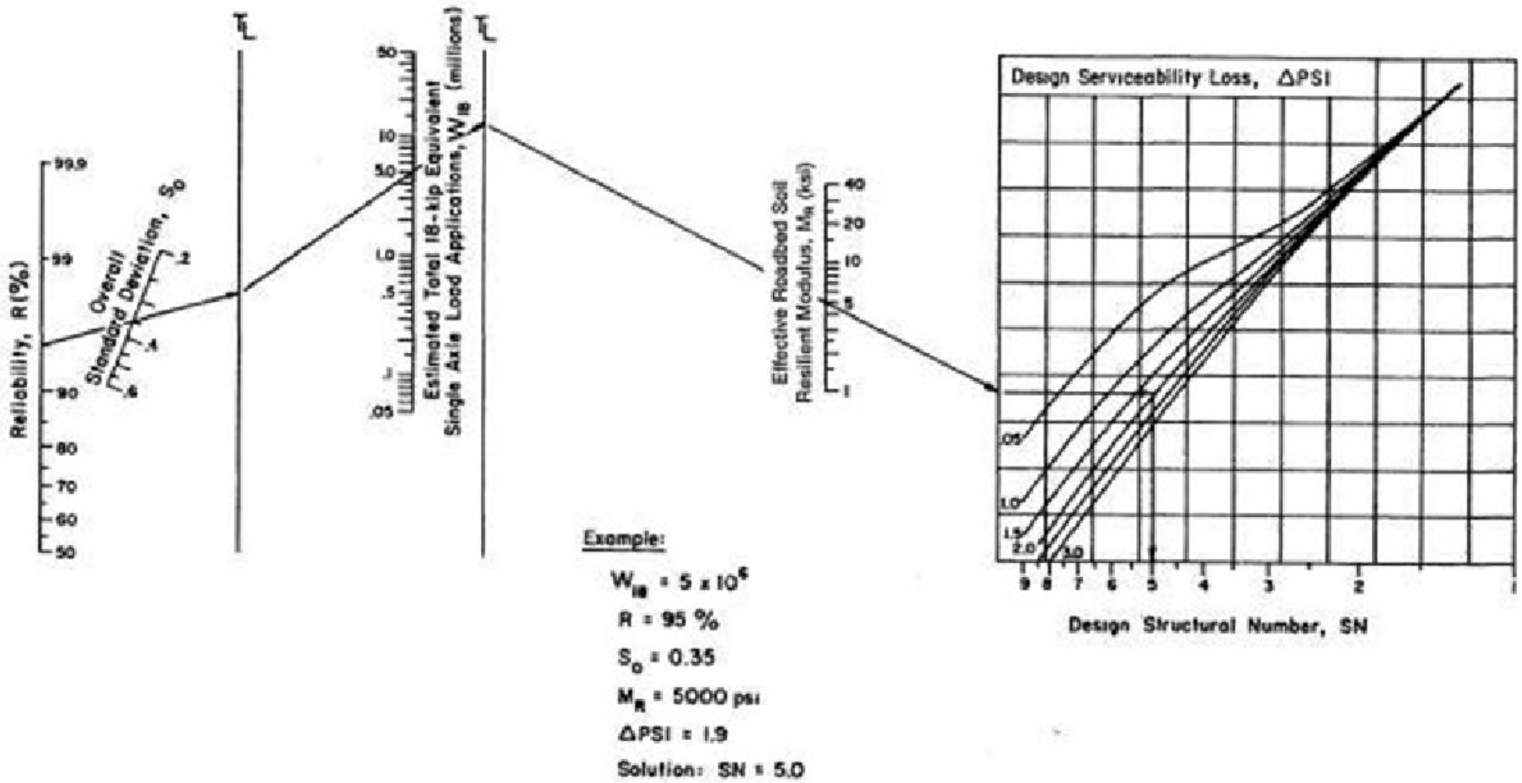

Figure 10-1. Nomograph for Asphalt Pavement

10.6.2 Rigid Pavement

The following procedure uses nomographs to determine the SN and then an equation to determine the design thickness of the pavement structure. The use of this procedure to determine the pavement structure is required. Additionally, various software programs are available that are based on the AASHTO design procedure and may be used. The use of these programs is encouraged in conjunction with the use of the nomographs. The software should be based on the AASHTO Design Procedure. The nomographs are to be used to verify the design produced by any software programs.

Use the following procedure to obtain required thickness:

1) Determine the Effective Modulus of Subgrade Reaction, K(pci) from Table 10-9 and Figure 10-4. Enter the nomograph, Figure 10-2 (segment 1), at the bottom of the Effective Modulus of Subgrade Reaction, K(pci) graph. Connect the K(pci) value with the Concrete Elastic Modulus (E_C) referenced in Table 10-8. Extend the line to the right edge of the graph.
2) Extend the line through the Mean Concrete Modulus of Rupture, S'c (pci) referenced in Table 10-8 to the first TL. Determine the Terminal Serviceability Index of the roadway (Table 10-3).
3) From the TL intercept, draw a line through the Load Transfer Coefficient, (J) referenced in Table 10-8 to the second TL.
4) From the TL intercept, draw a line through the Drainage Coefficient (Cd) referenced in Table 10-8 to the Match Line.
5) Extend the line from the Match Line (segment 2) through the Design Serviceability Loss, referenced in Table 10-3 to the left edge of the Design Slab Thickness Nomograph.
6) Select the Level of Reliability from Table 10-8. Enter the nomograph Figure 10-3 (segment 2) at the bottom of the Reliability line. Connect the Reliability component with the Overall Standard Deviation (So) from Table 10-8. Extend this line to the TL.
7) From the TL intercept, draw a line through the appropriate ESAL applications to the bottom edge of the Design Slab Thickness nomograph. Extend lines from the left and bottom of the Design Slab Thickness nomograph to intercept at the appropriate Design Slab Thickness, D (inches).
8) The design must reference any mitigation measures required when the subgrade contains swelling soils as defined in Section 10.4.3.

NOMOGRAPH SOLVES:

$$\log_{10}W_{18} = Z_R*S_o + 7.35*\log_{10}(D+1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1+\frac{1.624*10^7}{(D+1)^{8.46}}} + (4.22-0.32p_t)*\log_{10}\left[\frac{S_c' * C_d\left[D^{0.75}-1.132\right]}{215.63*J\left[D^{0.75}-\frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$

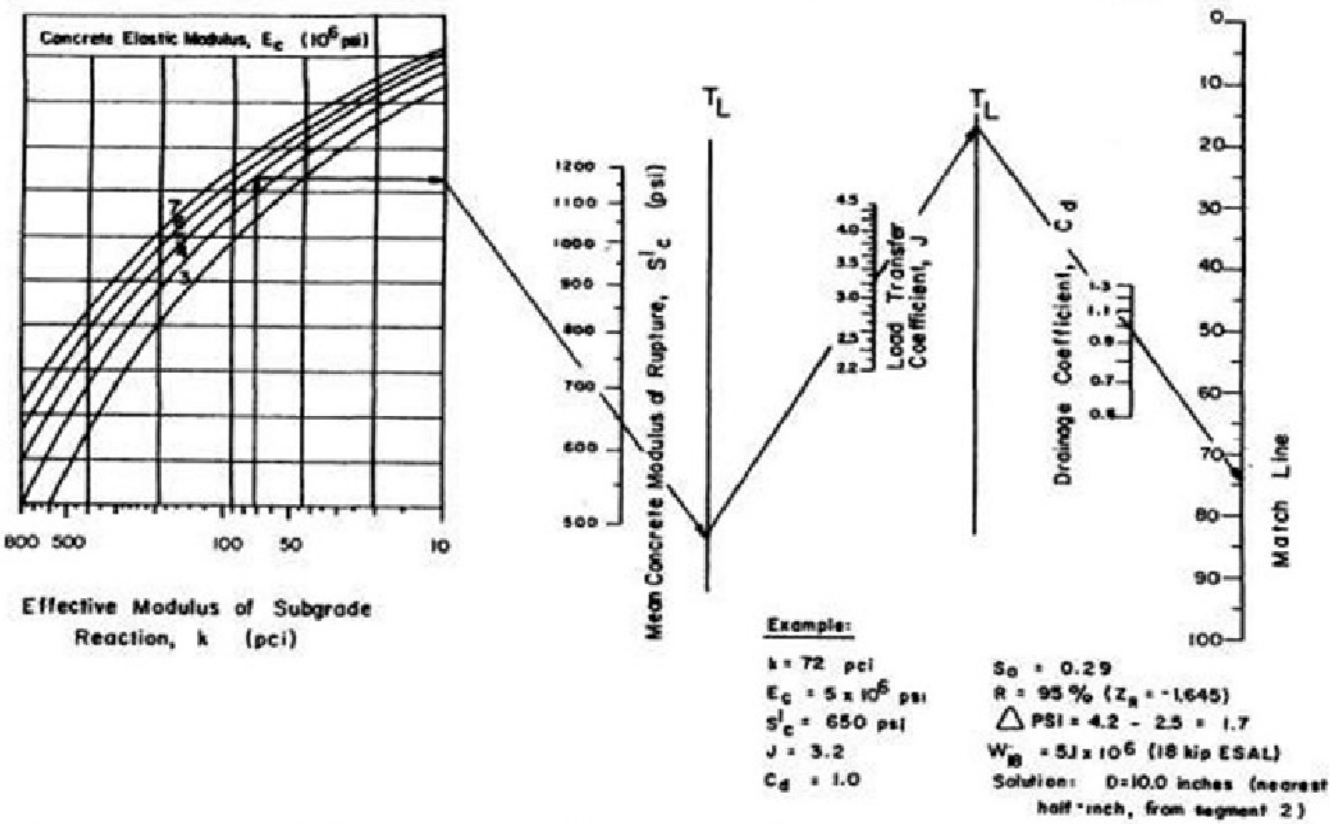

Figure 10-2. Nomograph for Rigid Pavement Design (Segment 1)

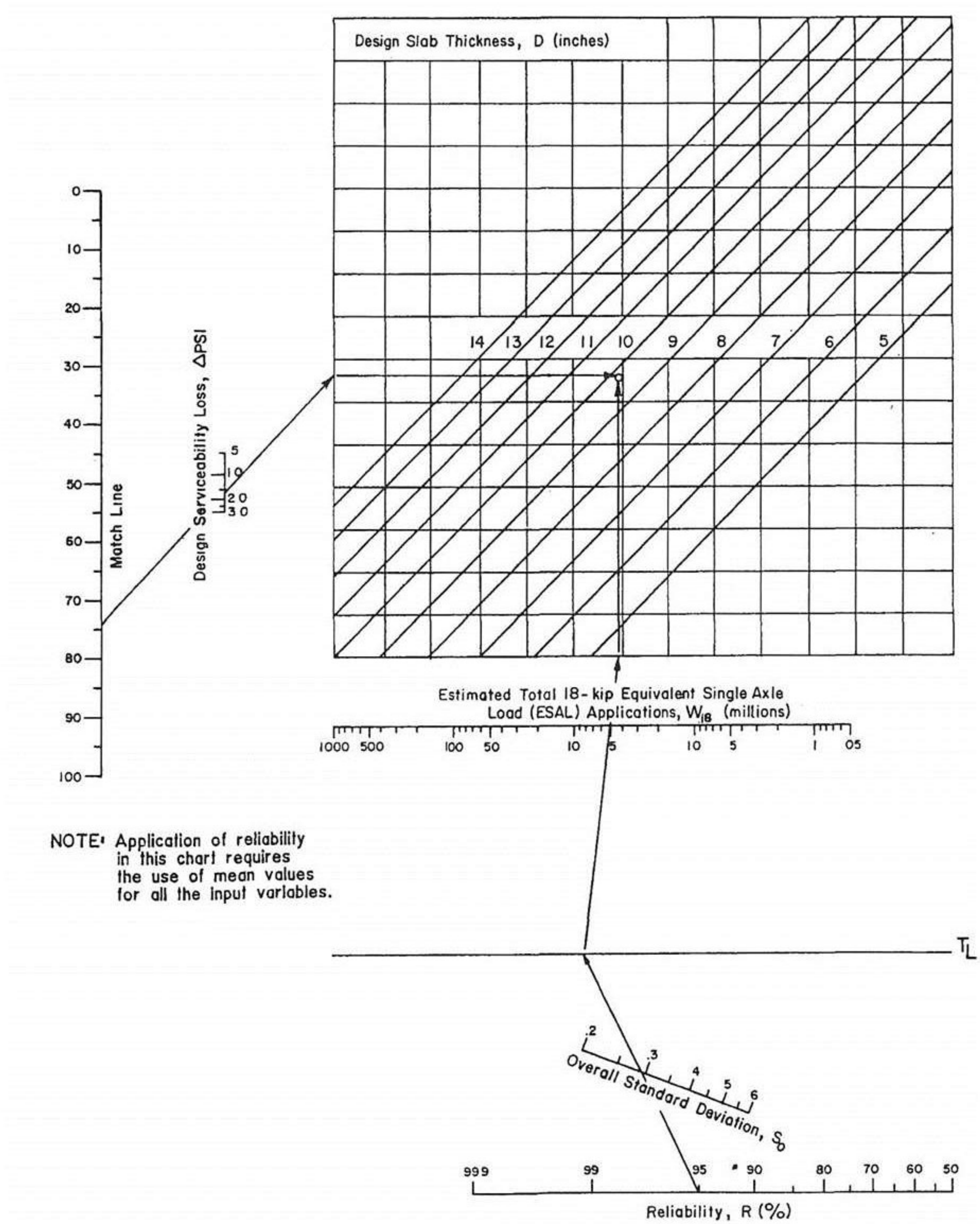

Figure 10-3. Nomograph for Rigid Pavement Design (Segment 2)

If software is used to verify the design, it will require additional input. The following table and figures are to be used to determine the additional input required by software programs. If software is used to determine the design thickness of the pavement, it is to be verified using the nomographs in this section.

Table 10-8. Rigid Pavement Design Factors

Factor	Source
18-kip ESAL	Table 10-2
Reliability, R	95% Arterials 90% Collectors and Local Roads
Overall Deviation, So	0.44
Serviceability Loss, Δ PSI	Table 10-3
Modulus of Subgrade Reaction, k	Determined in Section 10.6.2
Modulus of Rupture, S'c	650 psi
Modulus of Elasticity, Ec	3,400,000 psi
Drainage Coefficient, Cd	1.0
Load Transfer Coefficient (J)	If monolithic or tied curb and gutter are placed on both sides of the pavement, use 2.7; otherwise, use 4.2.

The Modulus of Subgrade Reaction, k, shall be determined from Table 10-9 and Figure 10-4. Table 10-9 lists k-values for soils classified as A-1 through A-7. Figure 10-4 is used with the degree of saturation to determine the k-value for soils classified as A-4 through A-7.

Table 10.9 Modulus of Subgrade Reaction, K, for A-1 to A-7 Soils

AASHTO Class	Description	Unified Class	Dry Density Natural Condition	CBR (Percent)	K-Value (psi/in)
Coarse-Grained Soils:					
A-1-a, well graded	Gravel	GW, GP	125 – 140	60 – 80	300 – 450
A-1-b, poorly graded			120 – 130	35 – 60	300 – 400
A-1-b	Coarse Sand	SW	110 – 130	20 – 40	200 – 400
A-3	Fine Sand	SP	105 – 120	15 – 25	150 – 300
A-2 Soils (Granular Materials with High Fines):					
A-2-4, gravelly	Silty Gravel	GM	130 –145	40 – 80	300 – 500
A-2-5, gravelly	Silty Sandy Gravel				
A-2-4, sandy	Silty Sand	SM	120 –135	20 – 40	300 – 400
A-2-5, sandy	Silty Gravelly Sand				
A-2-6, gravelly	Clayey Gravel	GC	120 –140	20 – 40	200 – 450
A-2-7, gravelly	Clayey Sandy Gravel				
A-2-6, sandy	Clayey Sand	SC	105 -130	10 – 20	150 – 350
A-2-7, sandy	Clayey Gravelly Sand				

Table 10.9 Modulus of Subgrade Reaction, K, for A-1 to A-7 Soils

AASHTO Class	Description	Unified Class	Dry Density Natural Condition	CBR (Percent)	K-Value (psi/in)
Fine-Grained Soils:					
A-4	Silt	ML, OL	90 – 105	4 – 8	25 – 165[a]
	Silt/Sand/Gravel Mixture		100 – 125	5 – 15	40 – 220[a]
A-5	Poorly Graded Silt	MH	80 – 100	4 – 8	25 – 190[a]
A-6	Plastic Clay	CL	100 – 125	5 – 15	25 – 255[a]
A-7-5	Moderately Plastic Elastic Clay	CL, OL	90 – 125	4 – 15	25 – 215[a]
A-7-6	Highly Plastic Elastic Clay	CH, OH	80 – 110	3 – 5	40 – 220[a]

[a] K-value of fine-grained soil depends highly on degree of saturation. Refer to Figure 10-4.

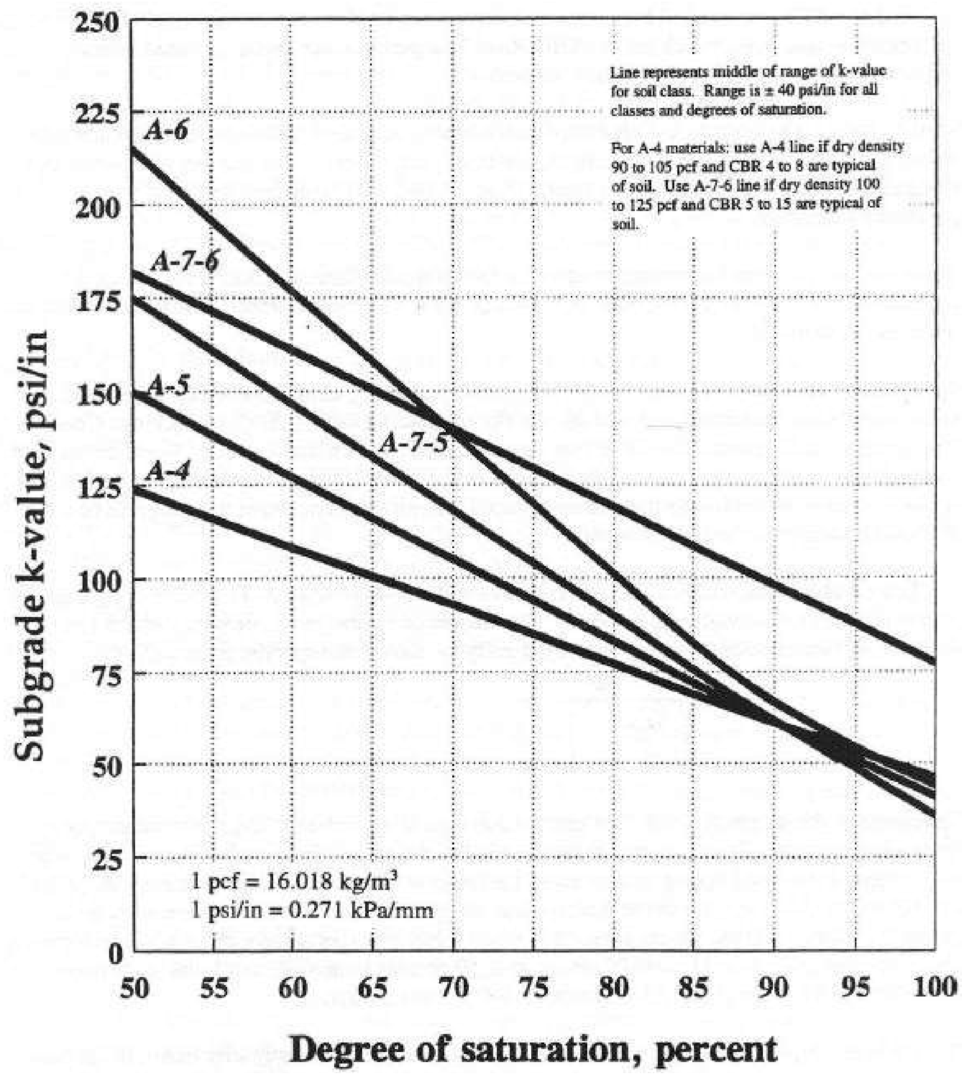

Figure 10-4. Modulus of Subgrade Reaction, K, for A-4 through A-7 Soils, Using Degree of Saturation

10.6.3 Subgrade Stabilization

The purpose of this section is to provide a zone of low-swelling, strain-absorbing material between the expansive subgrade and the pavement section. This specification shall be applied to achieve a stabilized paving platform without structural benefit to the pavement design. It is solely to address subgrade soils with an R-value of 5 or less or a subgrade material with swells of 2% or greater. The City requires that for soils with an R-value of 5 or less or a subgrade material with swell over 2%, the top 12 inches be replaced with 12 inches of Class 6 Aggregate Base Course. At a minimum, the limits of mitigation shall be from intersection to intersection on a roadway. The mitigation shall extend to 1 foot beyond the back-of-curb (if detached walk or no walk), or 1 foot beyond to the back-of-walk (if attached or monolithic walk). Alternate methods of mitigation may be proposed and will be considered on a case-by-case basis but must address the potential for soil remixing for utility installation by properly phasing construction to avoid remixing, or mitigation to a depth great enough that utilities installed after mitigation do not breach the mitigated zone.

The Design Report must reference mitigation measures when the reported R-value is 5 or less or is "unstable." These soils will need to be mitigated by an approved stabilization procedure or removed and replaced with an approved material.

1) Mitigation measures are required when the subgrade contains swelling soils (swell potential greater than or equal to 2.0% under 200 psf surcharge pressures at 95% standard compaction from a swell test run on undisturbed samples in accordance with ASTM D 4546). Moisture treatment and reconditioning is not an approved mitigation procedure. Mitigation shall include over excavation and replacement of the swelling soil with an A-2 to A-6 soil group with less than 2% swell. The over excavation shall be a minimum of 3 feet below the bottom of the approved pavement section. Upon removal of the 3 feet of material, the existing surface shall be scarified and reconditioned to a depth of 8 inches. The reconditioning shall be moisture treated and compacted according to these Specifications.
2) An option is to remove the swelling soil to a depth of 1 foot below the bottom of the pavement section, then replace the excavated materials with 1 foot of Class 6 Road Base. If the road base option is used, this may require the use of an approved geotextile fabric between the native material and the Class 6 Road Base. Upon removal of the 1 foot of material, the existing surface shall be scarified and reconditioned to a depth of 8 inches. The reconditioning shall be moisture treated and compacted according to these Specifications.
3) Other methods of swell mitigation could include the use of lime or Portland cement. Methods of mitigation to be used are subject to approval by the City Public Works Department. The submittal of an alternative for swell mitigation as described previously should include the requirements associated with the scarification and reconditioning of the subgrade below the proposed mitigation treatment.

Figure 10-5, Lime/Cement Stabilization Flow Chart, provides a good estimate of whether lime or cement is applicable for a certain soil type, depending on gradation and PI to a depth of 1 foot below the bottom of the pavement section.

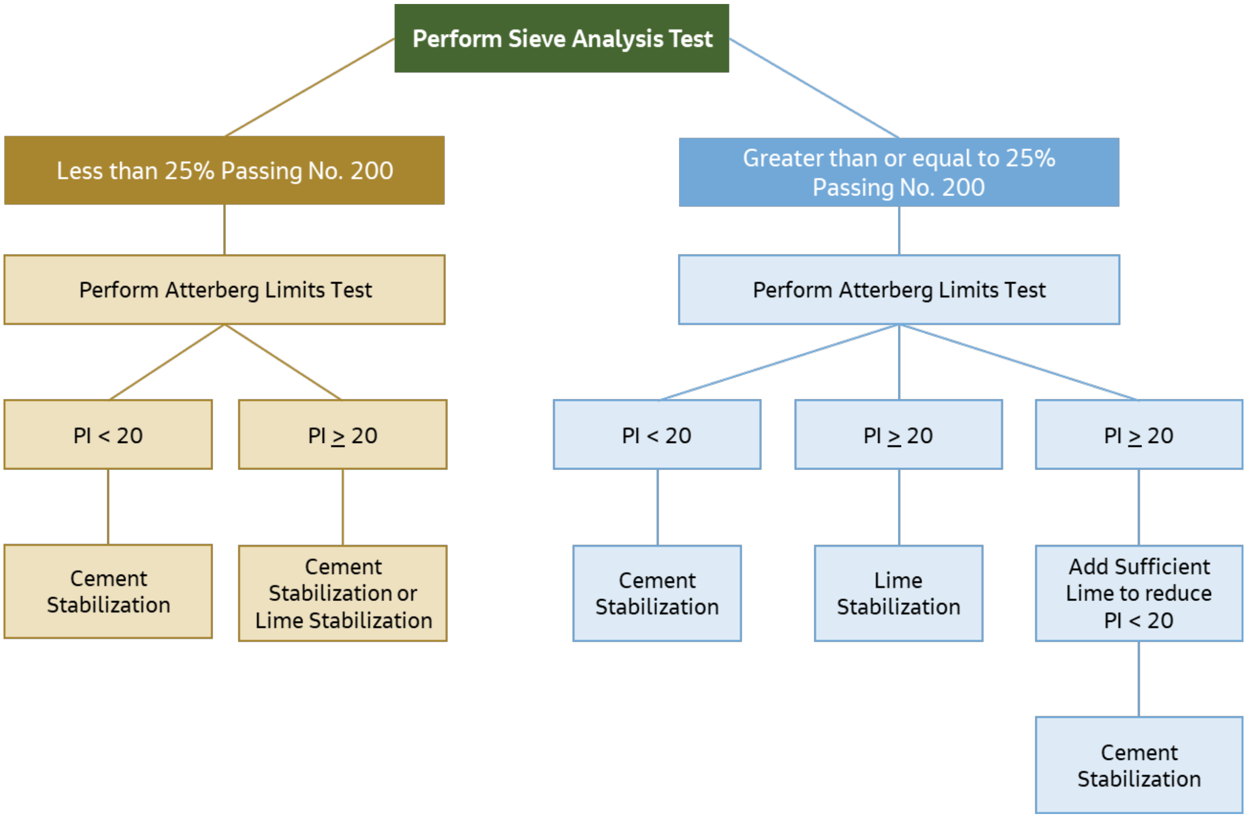

Figure 10-5. Lime/Cement Stabilization Flow Chart

Design reports recommending permeable layers, such as untreated aggregate base course in the pavement system, must present the measures to be used to create adequate drainage of such layers and to maintain segregation of the layers from the swelling soils. Trench drains are required for all pavements constructed on A-6 or A-7 soils in accordance with Section 10.3.11.

10.7 Material Specifications

10.7.1 General

The specifications presented in this section are performance oriented. The City's objective in setting forth these specifications is to achieve an acceptable quality pavement structure. Asphalt and concrete pavement laboratory mix designs must be approved every 2 years by the City Public Works Department. All sources for the mined or manufactured materials used in mix designs must also be approved every 2 years by the City Public Works Department as having met the appropriate materials performance specifications. This approval is a condition of using those material sources for public improvement construction. For the purpose of these Roadway Standards, public improvements are all roadway improvements, sidewalks, curbs and gutters, appurtenant drainage basins or structures, storm sewers and their access ways, other public works within City rights-of-way, and City-mandated stormwater detention structures built on private property and maintained by the property owner(s).

10.7.2 Procedure for Material Source Approval

Material suppliers for any City public improvements shall supply written certified documentation along with material test results. The certified documentation must be stamped and signed by a PE licensed in the State of Colorado. The material testing must be performed by an AASHTO-accredited laboratory. The documentation and material test results shall be submitted yearly by April 15th or a minimum of 14 days prior to construction and may include the following:

1) Material type, source, and location being tested to meet City specifications
2) Test procedures employed
3) Supplier's manufacturing, mining, or treating process by which the tested materials were processed
4) Material test results
5) A signed statement by the material supplier that the materials meet City specifications

10.7.3 Approval Conditions

10.7.3.1 Conformity to the Contract

Materials used in City public improvements will be sampled randomly and tested with the applicable procedures to verify compliance with material specifications. Additional samples may be selected and tested at the City's discretion. These tests are in addition to the requirements of Chapter 12.

Any and all material used to construct City public improvements that is not from a certified source, or that is from a certified source and fails one or more random material tests, may be subject to complete removal and replacement as a condition of City acceptance of that public improvement. Additional tests will be required to confirm the existence and extent of the sub-standard material prior to the initiation of remedial action. The extent of the material to be removed will be at the discretion of the City Public Works Department.

10.7.4 Use of Materials Not Listed in Section 10.5.5

Materials in this section and provided with a set of specifications are those deemed by the City to be the primary structural materials commonly or typically used in public improvements. Ancillary public improvement materials, such as manufactured paints and coatings, bonding agents, sealers, gaskets, and insulating materials, should comply with specifications for the appropriate material employed. Alternative materials for construction may be proposed for use. Decisions on acceptability of alternative materials will be made by the City's Public Works Director.

10.7.5 Material Specifications

10.7.5.1 Asphalt

Asphalt material shall conform to the MGPEC Asphalt Pavement Materials Specification. Alternate mix designs may be submitted to the City for review and approval.

10.7.5.2 Portland Concrete Pavement

Portland Cement Concrete Materials shall conform to the MGPEC Portland Cement Concrete Materials Specification. Alternate mix designs may be submitted to the City for review and approval.

10.7.5.3 Aggregate Base Course

Aggregate Base Course shall conform to the MGPEC Aggregate Base Course Materials Specification.

10.8 Subgrade Investigation and Pavement Design Report

The report shall be prepared by, or under the supervision of, and signed by a licensed PE registered in the State of Colorado and shall include the following information:

1) Vicinity map to locate the investigated area
2) Scaled drawings showing the location of borings
3) Scaled drawings showing the estimated extent of subgrade soil types and ESAL for each street
4) Pavement design alternatives for each street on a scaled drawing
5) Tabular listing of sample designation, sample depth, Group Number, Liquid Limit, Plasticity Index, percent passing the No. 200 sieve, AASHTO Classification, Group Index and soil description
6) R-value test results of each soil type used in the design
7) Pavement design nomographs properly drawn to show Soil Support – ESAL, SN
8) Design calculations
9) Software pavement design summary report
10) A discussion regarding potential subgrade soil problems, including, but not limited to, the following:
    a) Heave or settlement prone soils
    b) Frost susceptible soils
    c) Ground water
    d) Drainage considerations (surface and subsurface)
    e) Cold weather construction (if appropriate)
    f) Other factors or properties that could affect the design or performance of the pavement system