CITY OF COLORADO SPRINGS
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SECTION II

Pavement Design Criteria Manual

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1.0 General

The structural design of a pavement system must be done with a clear understanding of the factors that affect the life and serviceability of the pavement. There are multiple factors in design and construction of a pavement system. This Pavement Design Criteria Manual addresses those factors having a significant effect on the pavement life and serviceability. The objective is to obtain the best quality pavement system considering factors such as: subgrade, traffic loads, pavement material, future maintenance and special considerations such as swelling or collapse prone soils, slope instabilities and frost susceptible soils. The design must be founded upon a sound theoretical and experience base since public monies are at risk and a direct fiduciary responsibility exists. This design manual assumes that all of the parts of the pavement section and subgrade, trench backfill, hot mix asphalt, aggregate base course, etc. are constructed in accordance with the City Engineering Standard Engineering Specifications and the Pikes Peak Region Asphalt Paving Specifications.

This design methodology is prescriptive in nature and represents the minimum requirements of a design. The philosophy is to provide a design system which is easy to understand and use, and allows the Design Engineer flexibility to investigate alternatives. Alternatives, when proposed, must meet minimum design requirements and have sufficient data and analyses to allow City Engineering to evaluate the alternatives. The acceptance of any design is solely up to City Engineering. In the event City Engineering rejects a design, reasons for the rejection will be provided to the Design Engineer.

Pavement design reports and recommendations for new subdivision streets are submitted to the Engineering Development Review Division of City Engineering. Pavement design reports and recommendations for City Engineering capital projects are submitted to City Engineering's project engineer.

The design basis presented in this document is based upon the 1993 American Association of State Highway and Transportation Officials (AASHTO) Design Guide. The objective is to provide design parameters for local materials and conditions, and to provide guidance on the use of AASHTO equations. The pavement designs obtained from this procedure should have equal life and serviceability provided the minimum material specifications are met, construction recommendations are followed, and proper maintenance is provided. The design methodology presented is not meant to prevent the use of alternative methods as technology changes and additional pavement systems develop. Furthermore, with City Engineering discretion and approval, the Colorado Department of Transportation 2010 Pavement Design Manual, or most current version, shall be considered for accepted design solutions for methods not contained in this Pavement Design Criteria Manual. Throughout this manual, ASTM and applicable AASHTO, or CDOT test standards apply interchangeably.

1.1 Design Report

The Design Report is to consider the conditions after design of the pavement alignment and elevation, and after the street is cut to utility grade (utility grade, or "rough" grade, is defined as within +/-0.2' of final grade). The nature of subgrade soils which expand or collapse due to wetting provide unique design problems which are best addressed during rough grading operations. A Preliminary Geotechnical Investigation of the street alignment is appropriate when expansive or collapsible soil conditions are present, and when over-excavation, moisture treatment and re-compaction of the subgrade during mass site grading is expected to be appropriate. The preliminary investigation borings must be located in both cut and fill areas, and must be properly surveyed for both horizontal and vertical location. Borings must extend below finish subgrade elevations per boring depths as discussed in Section 2.0.

2.0 Field Investigation

The field investigation should be designed to evaluate subgrade soil types, determine ground water levels that may impact pavement performance, and investigate support conditions along the alignment. As a minimum:

1. Borings shall be made at not greater than 250-foot horizontal intervals for 2-lane roadways; and not greater than 250-foot intervals in each direction for roadways with multiple lanes in each direction.
2. Additional borings shall be made to investigate conditions such as filled drainage ways, obvious deflecting subgrade, subgrade material color changes, unusual adjoining vegetation or other observable conditions which could affect pavement performance.
3. Borings are to be a minimum of 4 feet in depth below design subgrade, with every fourth (minimum of one) boring 9 feet in depth below rough roadway subgrade elevation.
4. All borings shall be sampled using "California" or thin wall Shelby tube type samplers at depths of 1 foot and 4 feet below rough cut subgrade elevation for each boring, and at a depth of 9 feet at every fourth boring. The blows per foot or Shelby pushed length and recovery, boring number, and sample description shall be documented. Bulk samples of materials found in the upper 4 feet of the subgrade shall be obtained from each boring. Should varying materials be found in the upper 4 feet, samples of each material type shall be obtained for classification.
5. Boring logs shall include a description of soil types encountered, depths at which and types of samples taken, blow counts, moisture conditions, free water and anomalous conditions.
6. If circumstances warrant, test pits are allowed provided that the engineer can provide adequate analysis for pavement design purposes meeting City Engineering criteria.

3.0 Laboratory Testing

The purpose of the laboratory testing program is to classify subgrade material and evaluate support properties and moisture sensitivity (heave, collapse, softening) that can affect long-term pavement performance. Testing programs consist of classification testing (i.e., gradation analysis, Atterberg Limits and sulfate tests) and engineering properties testing (i.e., swell/consolidation, R-value, unconfined compressive strength, California Bearing Ratio, and Resilient Modulus Tests).

3.1 Soil Classification

All samples of the subgrade soils obtained shall be tested to evaluate classification using the AASHTO system. The minimum requirements are shown in Table 1.

Table 1 **Subgrade Classification Testing**

AASHTO Soil Classification, AASHTO M 145 Group Index Number	Each soil type encountered in each boring
Natural Moisture/Density, AASHTO T 265 & AASHTO T 204	Each drive or Shelby sample
Maximum Dry Density and Optimum Moisture Content T99 / 180	Bulk sample of material governing pavement design
Liquid Limit, AASHTO T 89	Each soil type obtained in each boring
Plastic Limit, AASHTO T 90	Each soil type obtained in each boring
Percent Passing No. 200, AASHTO T 11	Each soil type obtained in each boring
Gradation Analysis, AASHTO T 27	Each sample of A-1 to A-3 soils obtained in each boring
Sulfate Tests, CDOT, CPL 2103	1 test for each 1,000 lineal feet where A-6 or A-7-6 soils are found

Soils shall be grouped based upon the AASHTO classification system for each bulk material found in the upper 4 feet and the Group Index calculated. When a greater than 7 point disparity in Group Index is noted, the subgrade soil groups shall be subdivided into two or more groups. The content of soil groups shall be plotted on a project drawing. Soils which govern the design shall be those having the highest AASHTO soil classification (i.e., A-7-6 to A-2-4), lowest subgrade support or highest Group Index, within the design length of the roadway. Roadway design can be subdivided based upon the extent of subgrade materials found along the roadway length.

3.2 Swell/Consolidation Tests

Cohesive materials (A-4, A-5, A-6 and A-7) shall be tested to determine swell or consolidation potential. Tests shall be run on "California" or thin wall Shelby tube samples collected from 1 foot below the utility grade or subgrade in accordance with ASTM D 4546 at a vertical pressure of 200 psf. Testing frequency for these materials shall be in accordance with Table 2.

Table 2 **Swell Testing Frequency**

Number of Borings	Testing Frequency
Less than 5	Each boring
5 - 25	Minimum 5 samples
Greater than 25	Minimum 7 samples or 1 per 5 borings

The test results shall be plotted and the percent swell/consolidation and swell pressure (psf) shall be determined and reported. Test results which are suspected of being not representative of "typical" conditions shall not be considered in the design of the pavement but shall be reported. Any deletion of data shall be justified in the written report. The swell/consolidation potential for a given soil group shall be the calculated average of the group.

3.3 Subgrade Support Evaluation

For the material groups which govern the design (as determined in Section 3.1) of the pavement system, compaction and strength testing shall be performed on composite samples constructed using equal amounts of bulk sampled materials with the same classification and Group Index range specification in accordance with Table 3.

Table 3 **Subgrade Strength Evaluation**

Subgrade Compaction and Strength Testing	
Unconfined Compressive Strength Test on remolded sample, compacted at 2% above Proctor optimum moisture content in accordance with AASHTO T 99, or California Bearing Ratio on remolded sample (AASHTO T 193) compacted at 2% above Proctor optimum moisture content. or Hveem Stabilometer (R-value), AASHTO T 190	For all groups Classified as A-2-6, A-6, and A-7 For all groups
Standard Proctor Compaction, ASTM D 698 Modified Proctor Compaction, AASHTO T 180	For groups classified as A-2-6, A-6, and A-7. For groups classified as A-1, A-2, A-3, A-4, and A-5.

The design soil support value shall be determined to be the lowest value obtained from the testing. In the event the Design Engineer elects to remove and replace the lowest support value to a minimum depth of 2 feet below finish subgrade, the support value of the replacement fill can be used. Technical justification (calculations) for the removal and replacement shall be provided in the report.

4.0 Pavement Design

The design methodology is based upon the 1993 AASHTO Design Guide equations and considers Traffic and Subgrade Resilient Modulus as the primary variables. Traffic loading requirements are presented in Section 4.1. The Subgrade Resilient Modulus and swell/consolidation analysis shall be determined in accordance with Section 4.2 The design equations for flexible and rigid pavements are presented in Section 4.3 and 4.4. Alternatives will be considered with advances in pavement design methods and paving material changes. Any deviation from guidelines presented in this document must be technically justified and approved by City Engineering.

4.1 Equivalent Single Axle Load (ESAL)

One of the factors used in pavement design is the loading of traffic on the roadway. This is a combination of the volume of traffic and the weight of the vehicles on the street. This factor is described in terms of 18,000-pound Equivalent Single Axle Loads or ESAL's. The calculation of ESAL's is based on the following information:

- ADT
- Lane distribution
- Truck volumes
- Truck weights and axle configurations

Since this information is not readily available for all streets, this manual provides default ESAL values for City street classifications and City-wide truck volume estimates. The ESAL values to be used for street classifications are shown in Table 4.

Pavement design can be completed using a roadway specific ESAL value. ESAL can be calculated using the technique described in the Colorado Department of Transportation (CDOT) most recent Pavement Design manual. The calculations, input data, and any assumptions must be reviewed and accepted by City Engineering.

Table 4 **City Street ESAL Default Values**

20-year ESAL	Flexible Pavement	Rigid Pavement
Freeway/ Expressway	8,000,000	11,000,000
Major Arterial	4,500,000	6,250,000
Minor Arterial	2,500,000	3,250,000
Industrial Street/Commercial Frontage	1,250,000	1,750,000
Major/Minor Collector	200,000	200,000
Local	50,000	50,000

These are one-directional and per-lane ESAL values which may not be reduced for directional travel or lane distribution.

4.2 Subgrade Support Characterization

Subgrade characterization consists of evaluating subgrade and long-term support values. The degree of moisture sensitivity and deflection sensitivity is used to evaluate the depth of moisture treatment appropriate to reduce the deflection at the surface of the completed pavement system. The support value is expressed in the form of a Resilient Modulus as determined from unconfined compressive strength, R-value, or CBR testing.

1. **Expansive Subgrade** - Tests performed to determine swell (expansion) potential in accordance with Section 3.2 shall be averaged for each soil group. For the highest average swell, the depth of moisture treatment shall be determined in accordance with Table 5. Using engineering judgment, locally differing values shall be addressed in the text of the report under the appropriate subgrade discussion section.

Table 5 **Depth Of Moisture Treatment For Expansive Soils**

Swell % at 200 psf Subgrade Soil Liner Samples	Depth of Moisture Treatment (feet)	
	Non-Arterials	Arterials
< 2	--	--
2 to 3	--	2
3 to 4	--	4
4 to 5	2	5
5 to 6	3	6
6 to 8	4	6
8 to 10	5	6
Greater than 10	6	6

Moisture treatment is the process of removing the soil, adding moisture until the soil moisture content is between 1 and 3 percent above optimum as determined by AASHTO T 99 (ASTM D 698), and compacted to at least 95 percent of maximum Standard Proctor density. Soils requiring moisture treatment per Table 5 will require a stabilized subgrade per Section 4.2.2. Moisture treatment shall extend to the back of curb as a minimum.

2. **Subgrade Stabilization** - Subgrade soils treated to have high moisture contents typically have low support values and will be soft and yielding during paving. Stabilization of at least the upper 12 inches by chemical or mechanical methods will be necessary. This depth includes any approved Chemically Treated Subgrade section (CTS). The depth of treatment has to be determined by the design engineer in the design report, or as an addendum to the report, based upon the actual field conditions. Subgrade stabilization shall extend to the back of curb as a minimum.

a. Chemical Stabilization - Chemical stabilizing agents include lime, fly ash, combinations of lime/fly ash, and lime/Portland cement. Other agents or combinations can be used with approval by City Engineering and provided the mix design requirements are satisfied. Laboratory mix designs shall meet the following criteria:

1. For Lime treatment the pH shall be equal to or higher than 12.3 before compaction (not required where swell is less than 4 percent)

2. Unconfined Compressive Strength between 160 psi and 700 psi (ASTM 2166)

3. Swell less than one percent at 200 psf (ASTM D 4546)

When lime is used, Plasticity Index is to be reported from initial to final construction to all interested parties (e.g., Stabilization Contractor, Geotechnical Engineer and City Inspector) and shall not be used for acceptance purposes. The design stabilizing agent percentage as determined by the designer shall be increased by 1.0 percent in the field to account for waste, inert materials, and construction variability.

If water soluble sulfate contents exceed 0.2 percent, the treatment shall be accomplished using a double application method. A double application method consists of an initial treatment of Lime and allowing it to mellow for a minimum period of 7 days (with constant wetting). After the mellow period, the subgrade should be mechanically mixed prior to applying the remaining percentage of chemical stabilizer (Lime, Fly Ash or Cement). This shall be presented and discussed in the design report. All chemical stabilization shall be performed in accordance with Section 6.5.

b. Mechanical Stabilization **-** Soft, yielding soils may be stabilized mechanically using geogrids in conjunction with aggregate base course or recycled concrete to provide a stable construction platform. All mechanical stabilization shall be performed in accordance with Section 6.6.

3. **Resilient Modulus** - Subgrade support characteristics using the 1993 AASHTO design methodology consider the Resilient Modulus (Mr). Equipment to directly determine the Resilient Modulus may not be available to some local firms. A series of correlations and alternative equations are provided to aid firms that do not have the appropriate equipment to estimate the design Mr. equations to estimate values using R-value for non-cohesive subgrade materials, a modified unconfined compressive strength procedure or CBR for cohesive subgrade materials are included with this document. The subgrade strength characteristics shall be evaluated in accordance with the requirements of Section 3.0 Laboratory Testing. These values can be converted into Resilient Modulus using the following equations:

Unconfined Compressive Strength

(A-2-6 soils) **M_r = 2.23 (qu) (.75)**

(A-6 soils) **M_r = 2.15 (qu) (.75)**

(A-7-6 soils) **M_r = 3.13 (qu) (.75)**

(Claystone) **M_r = 1.68 (qu) (.75)**

Where qu = unconfined compressive strength in psf

California Bearing Ratio

M_r = (CBR) x 1500

Hveem Stabilometer (R Value)

$$M_r = 10^{\frac{S+18.72}{6.24}}$$

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

4.3 Flexible Pavement Structural Section

The thickness of the pavement section shall be determined using the design traffic 20-year, 18-kip ESAL's obtained from Section 4.1, the Resilient Modulus obtained from Section 4.2.3 and the depth of moisture treatment and stabilization obtained from Section 4.2.1 and 4.2.2.

The Structural Number (SN) shall be determined using the AASHTO 1993 design methodology or using the design nomographs provided in Figure 1 with the input parameters presented in Table 6. Using strength coefficients provided in Table 7, calculate the thickness of the various pavement layers by the following formula:

SN = a1(D1) + a2(D2) + . . . + an(D_n)

Where:

a1 = Strength coefficient for HMA

a2, a3, a4…an = Strength coefficient for lower layers

D1 = Thickness of HMA

D2, D3, D4…Dn = Thickness of additional layers

Table 6

Material Strength Coefficients

Material	Coefficient (a)
Hot Mix Asphalt (HMA)	0.44
Existing Hot Mix Asphalt	0.24 [1]
Aggregate Base Course/Recycled Concrete Base	0.12
Existing Aggregate Base Course/Recycled Concrete Base	0.10
Granular Sub-base (R = 50+, CBR = 15+)	0.07
Chemically Treated Subgrade (Constructed in accordance with Section 6.5)	0.14

Note 1: Maximum value unless supported by testing

Table 7

Flexible Pavement Design Parameters

Input	Value
Reliability (R)	95% for arterials and all commercial frontage and industrial roadways 90% for collectors 85% for local roadways 80% for cul-de-sacs
Standard Deviation (So)	0.44 for flexible pavements
Initial Serviceability =4.5 Serviceability Loss (ΔPSI)	2.5 Locals, collectors, private drives, parking lots and public alleys 2.0 Arterials and all commercial frontage and industrial roadways

4.4 Rigid Pavement Structural Section

The thickness of the pavement section shall be determined using the traffic ESAL's obtained from Section 4.1, a k-value, the depth of moisture treatment, and stabilization obtained from Section 4.2.1 and 4.2.2. For rigid pavement design, the Resilient Modulus (Mr in psi) must be converted to a Modulus of Subgrade Reaction (k-Value in pci) using the following formula.

k-value (pci) = Resilient Modulus (psi) / 19.4

The effective k-value can be determined by correcting for Loss of Support (LS) (Figure 1) with the following assumptions:

LS = 0 for concrete over an existing pavement

LS = 1.0 for Chemically Treated Subgrades

LS = 2.0 – 2.5 for Natural Subgrade Materials

The design thickness shall be determined using the AASHTO 1993 design methodology or using the design nomographs provided in Figure 3 and 4 with the input parameters presented in Table 8.

Table 8 **Rigid Pavement Design Parameters**

Input	Value
Reliability (R)	95% for arterials and all commercial frontage and industrial roadways 90% for collectors 85% for local roadways 80% for cul-de-sacs
Standard Deviation (So)	0.34 for rigid pavements
Concrete Elastic Modulus (Ec)	3,500,000 psi
Concrete Modulus of Rupture (S'c)	650 psi
Load Transfer Coefficient (J)	2.8 full reinforcement 3.6 if tied into curb & gutter 4.2 no reinforcement
Initial Serviceability =4.5 Serviceability Loss (ΔPSI)	2.5 Local, collectors, private drives, parking lots and public alleys 2.0 Arterials and all commercial frontage and industrial roadways

Joint spacing, doweling and tie bars shall be in accordance with American Concrete Pavement Association recommendations contained in Design and Construction of Joints for Concrete Streets. Dowels are required for industrial and arterial streets for longitudinal and expansion joints.

4.5 Minimum Pavement Sections

If the calculated pavement sections indicate sections thinner than the Minimum Pavement Sections shown below in Table 4.5.1, the Minimum Pavement Sections shall govern. The City Engineer prefers the use of flexible pavement designed as a composite section of hot mix asphalt over aggregate base course. Full depth pavement sections (flexible or rigid) are allowed subject to sufficient justification over chemically treated subgrade, or suitable subgrade as defined herein. Full depth pavement is not allowed over mechanically stabilized subgrade. Certain very sandy subgrade conditions may require applying a non-structural covering of aggregate base course for constructability to support the paving equipment. The City Engineer may increase the minimum pavement section at any location if conditions warrant. Following in Table 9 are the minimum pavement thicknesses required by City Engineering:

Table 9 **Minimum Pavement Thicknesses (inches)**

	Flexible Pavement			Rigid Pavement
Classification	**HMA + ABC[3]**	**HMA + CTS[2]**	**HMA[1]**	**PCCP[1]**
Major Arterial	5″ + 12″	5″ + 12″	9″	8″
Minor Arterial	4 + 12″	4″ + 12″	8″	8″
Major Residential Collector (4 lane)	4″ + 8″	4″ + 8″	5″	6″
Major Residential Collector (2 lane)	4″ + 8″	4″ + 8″	6″	6″
Minor Residential Collector	4″ + 6″	4″ + 6″	5″	6″
Residential	4″ + 6″	4″ + 6″	5″	6″
Minor Residential	4″ + 6″	4″ + 6″	5″	6″
Hillside Minor Residential	4″ + 6″	4″ + 6″	5″	6″
Industrial/Commercial (4 lane)	4″ + 12″	4″ + 12″	8″	6″
Industrial/Commercial (2 lane)	4″ + 12″	4″ + 12″	8″	6″
Frontage Road	4″ + 6″	4″ + 6″	5″	6″

NOTES: 1. Full depth pavement (asphaltic concrete) is only allowed over chemically treated or suitable subgrade. Full depth pavement is not allowed over mechanically stabilized expansive subgrade. See section 4.5.
2. CTS section as approved by the City
3. The minimum thickness of ABC shall be six inches in any application

ABBREVIATIONS: HMA = Hot Mix Asphalt
ABC = Aggregate Base Course
CTS = Chemically Treated Subgrade
PCCP = Portland Cement Concrete Pavement

4.6 Alternate Pavement Designs

City Engineering understands the need to consider emerging technologies in pavement design. In light of this, any alternate pavement design will be reviewed and considered with respect to the following criteria:

- Initial construction cost
- Life cycle cost
- Construction delay and impact
- Facility maintenance and ease of repair
- Pavement noise, smoothness
- Industry capacity and local contractor capability
- Special design provisions such as edge drains behind the curbs[1] to intercept moisture from adjoining development and prevent it from adversely affecting the road subgrade and paving section.

City Engineering reserves the right to make the pavement type selection using these and/or other criteria on City funded projects.

[1]**Special Drainage Considerations:** The design engineer should anticipate the future developed condition of the land adjacent to the roadway when making the paving design recommendations. Even when no shallow groundwater is present in the pre-developed condition it is expected that certain land uses such as single family homes and projects with irrigated landscaping present the possibility of water entering the road subgrade and adversely affecting the performance and longevity of the pavement. City forces have to install retrofit underdrain systems in many streets to mitigate these kinds of problems. Appropriate recommendations and design features to stop water from infiltrating into the pavement section will receive positive response from City Engineering.

5.0 Pavement Design Report

All pavement design reports shall be prepared by or under the supervision of, and stamped and signed by, a Professional Engineer licensed in the State of Colorado and practicing as a Geotechnical Engineer.

5.1 Report Submittal

Design reports shall be submitted to City Engineering. Pavement design reports for new subdivision streets are submitted to the Engineering Development Review Division of City Engineering. Pavement design reports for City Engineering capital projects are submitted to City Engineering's project engineer. All reports shall contain the following items:

- Description of the area of the project including the location land use, surface conditions, topography, site grading, extent of site development at the time of investigation, vegetation, and any unusual surface features.
- Listing of the sampling and testing techniques and appropriate AASHTO or ASTM designations.
- Table showing AASHTO, USCS and Group Index of the individual subgrade samples found within the drilling depths and of the groups which govern the pavement design.
- Subgrade support testing sections shall include graphs of moisture/density relation tests, R-values, CBR tests, unconfined compressive strength, swell/consolidation tests and other tests deemed to be applicable for the conditions found performed. The subgrade-support test results shall be shown along with the resulting calculated Resilient Modulus or k-Value and the equations used to determine the value.
- Where moisture sensitive subgrade soils occur, the depth of moisture treatment and subgrade stabilization other than the depth determined from Section 4.2.1 shall be discussed and the analysis shown.
- Where treatment is required due to expansive soils (Section 4.2.1), a stabilized subgrade is required (Section 4.2.2) and a report shall determine the stabilizing agent to be used. Any stabilizing agents not listed must be pre-approved by City Engineering. Special stabilization techniques required due to high water soluble sulfate contents or other conditions shall be presented. Where soils contain soluble sulfates in concentrations greater than 0.2 percent, a discussion on a double application method and sulfate resistant concrete shall be presented. Should any of these soils be stabilized, special construction precautions shall be presented (i.e., staged construction).
- The design traffic in terms of ESAL's shall be presented on a figure and discussed in the design report, including the source of traffic information.

- Design pavement thicknesses including hot mix asphalt, Portland cement concrete or composite sections shall be shown on a figure for the various street sections. If computer software is used to develop solutions, the print out from the software shall be included in the report. If nomographs are used, they shall be included in the design report for each soil group and traffic loading condition.
- A discussion of design and construction concerns shall be presented, followed by specific recommendations to mitigate the concerns. Factors such as, but not limited to, swelling heave, frost heave, collapsing soils, difficult excavations, steeply dipping bedrock, organic soils, high water table, median landscaping, low density , collapse prone soils, or utility trench settlement effects must be presented, discussed, and mitigation recommendations presented.
- Where two minor arterial or higher classification streets intersect, the design should consider the combined traffic volumes. The use of Portland Cement Concrete Pavement at high traffic volume intersections may be deemed necessary by City Engineering. High volume asphaltic concrete may also be appropriate. City Engineering will determine the extent of the "high volume" intersection treatments.
- The report shall include a discussion of material requirements to meet the design assumptions. The report shall refer to appropriate City of Colorado Springs and Pikes Peak Region material and construction specifications. Hot mix asphalt design recommendations, in accordance with the City of Colorado Springs and the Pikes Peak Region Asphalt Paving Specifications, shall also be included. CDOT requirements may also apply for high traffic intersections.
- Additional concerns with respect to design, construction, maintenance, and other project aspects should be presented and discussed.
- For subdivision streets, any issues identified in the Geologic Hazard Study relating to soil stability or special design requirements must be discussed.
- Reference List

5.2 Figures

To evaluate the design, figures are necessary to present information and design data. All reports must have the following:

1. **Project location including:**
   a. A vicinity figure showing the project location using existing landmarks, roadways.
   b. Location of exploratory borings and the estimated extent of subgrade soil types by soil groups and AASHTO classifications.
2. **Graphical representation of exploratory borings:**
   a. Graphical boring logs shall be represented using AASHTO classifications for materials. Bedrock shall be represented in accordance with local practice, i.e., sandstone, claystone, interbedded bedrock, weathered claystone.
   b. The boring logs shall also provide the following:

1. Sampling depths and length, including blow count, push depth, and recovery
2. Moisture content, dry density, percent swell/consolidation – under a 200 psf pressure
3. Atterberg Limits (liquid limit, plasticity index)
4. Percent passing the No. 200 sieve

c. Figures showing swell/consolidation, moisture/density relations, unconfined compressive strength, and results of Hveem/stabilization or CBR testing.

d. Design pavement section alternatives and special alternatives

3. **Recommended Pavement System:**

a. The design alternatives, based upon engineering, shall be presented on a "Recommended Pavement Alternatives" figure, illustrating the extent of each alternative pavement section along with a legend describing each pavement alternative, the design ESAL, and the subgrade group used for the design.

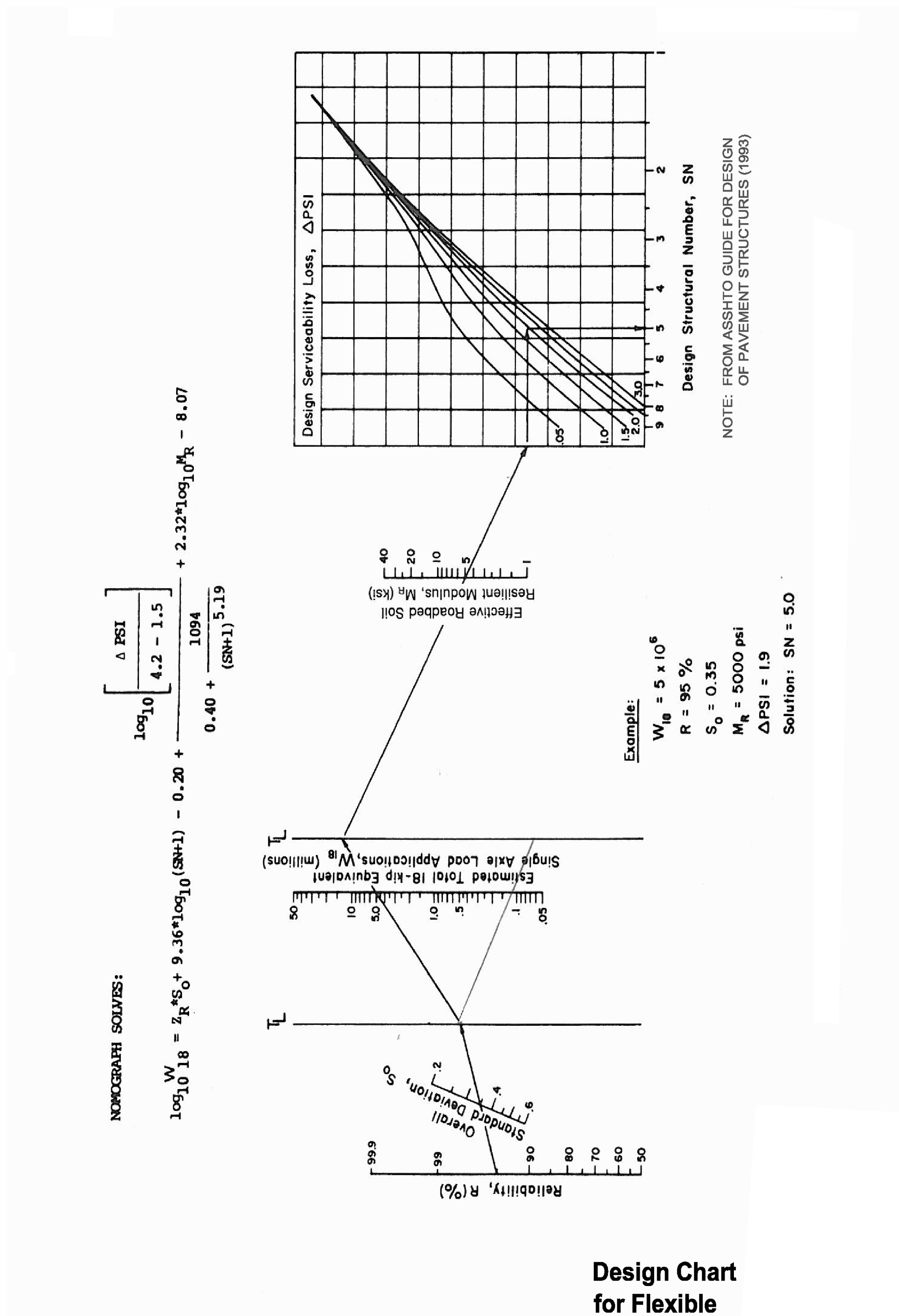
b. Special considerations such as soft soils, organic materials, treatments shall be presented on the "Recommended Pavement Alternatives" figure.

c. Structures such as bridges, box culverts, interchanges, and turn lanes shall be shown on all site figures.

d. Where lanes have different pavement sections, the variations shall be clearly shown on the "Recommended Pavement Alternatives" figure.

Figure 1

Design chart for flexible pavements

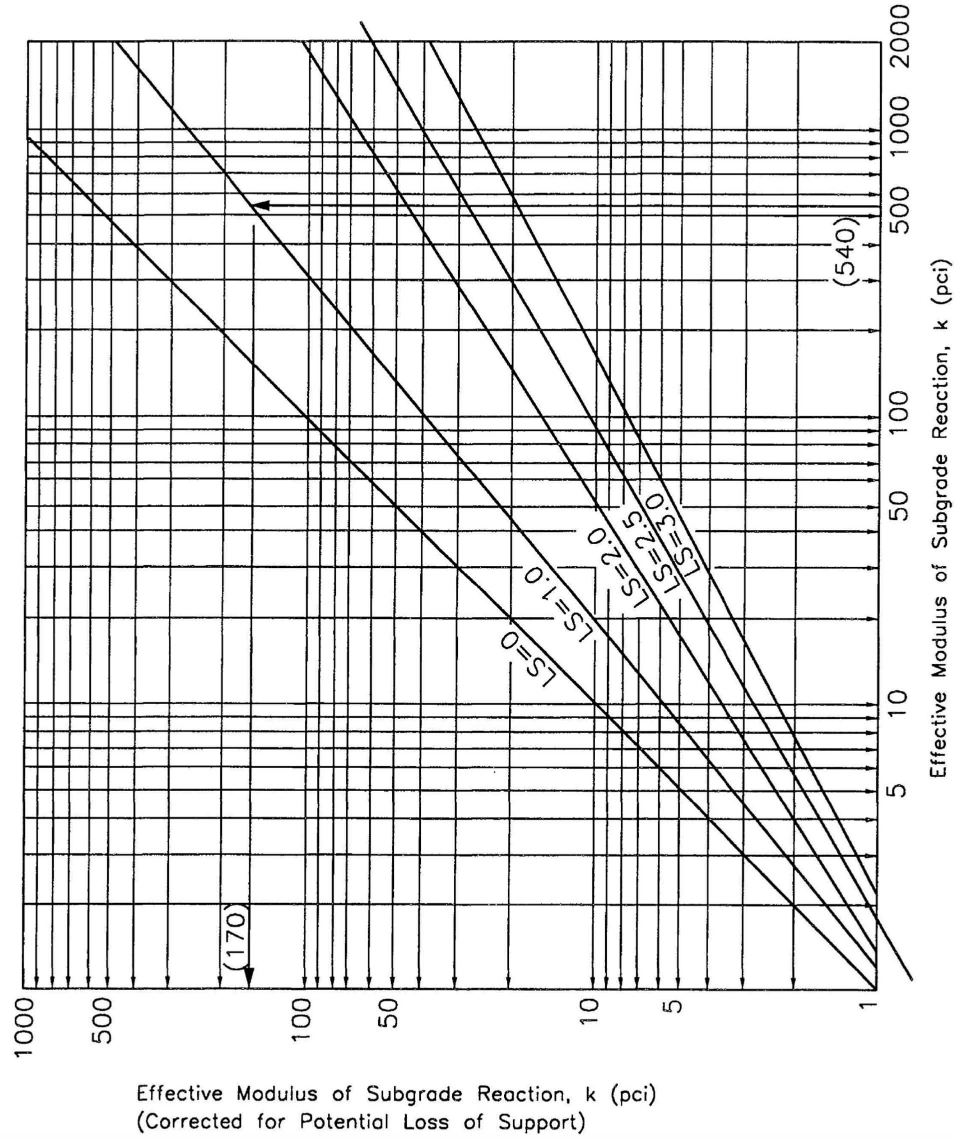


Design Chart for Flexible Pavements

FIGURE 1

Figure 2

CORRECTION OF EFFECTIVE MODULUS OF SUBGRADE REACTION FOR LOSS OF SUPPORT

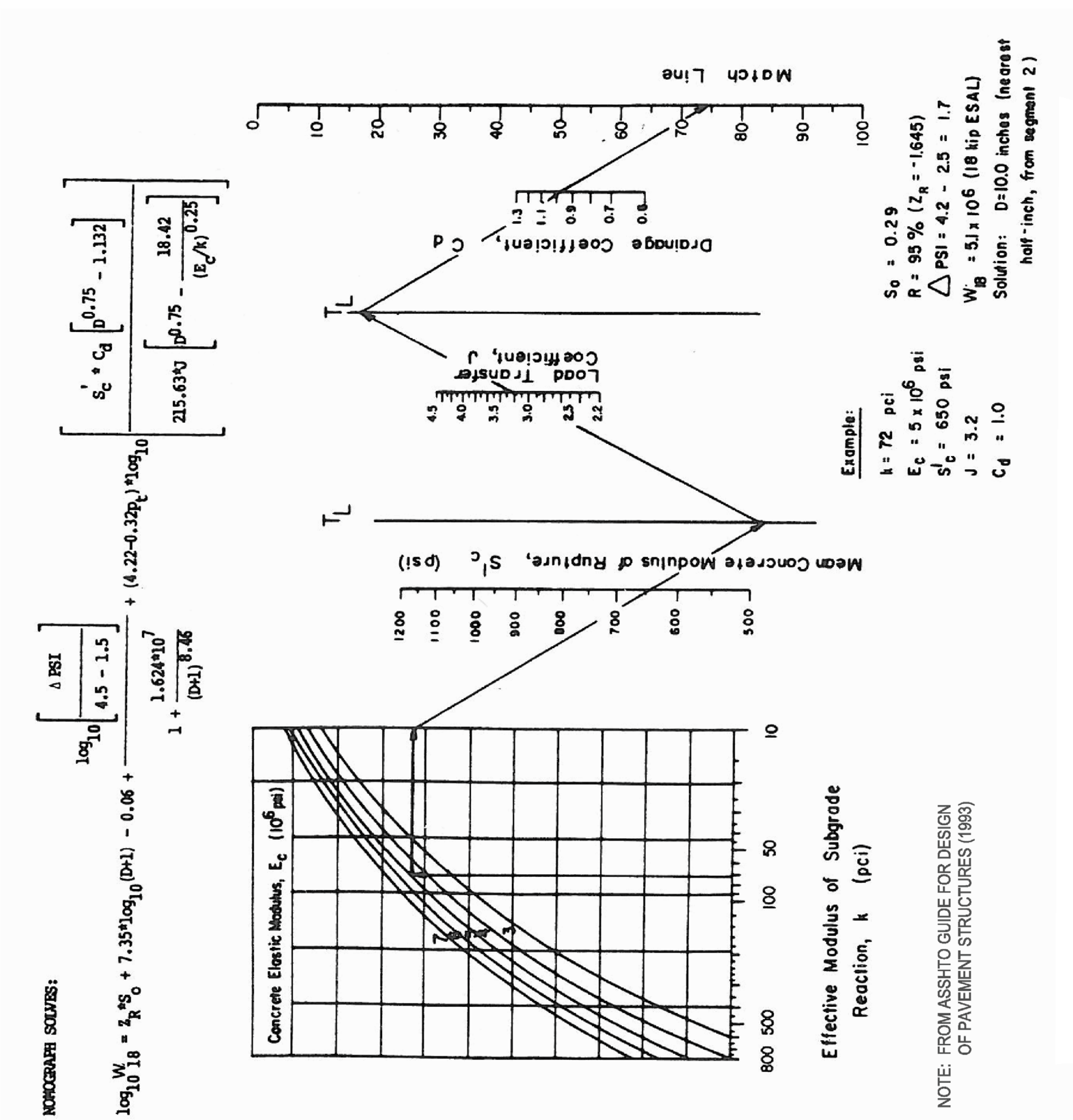


Design Chart for Rigid Pavements

FIGURE 2

Figure 3

Design chart for rigid pavements

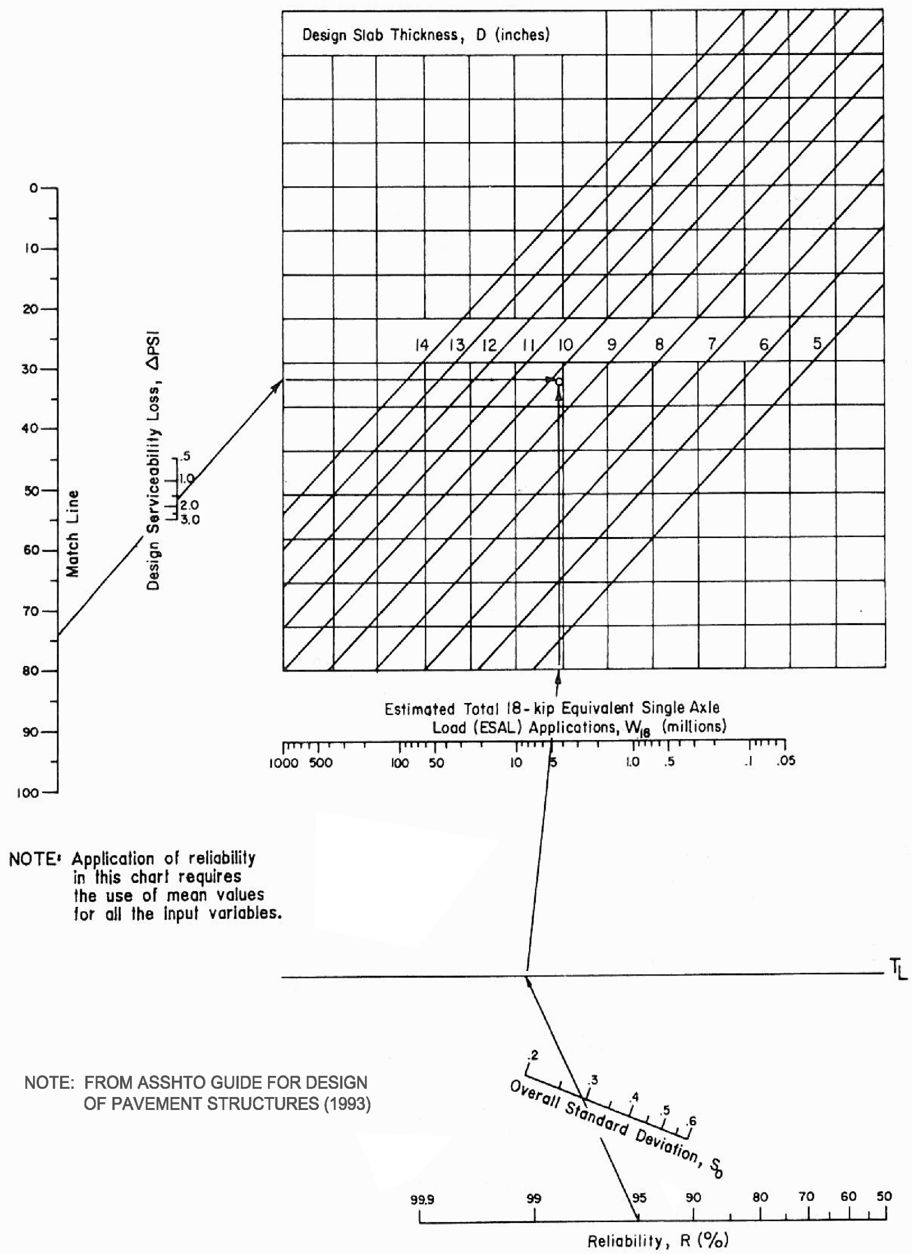


Design Chart for Rigid Pavements (Segment 1)

FIGURE 3

Figure 4

Design chart for rigid pavements



Design Chart for Rigid Pavements (Segment 2)

FIGURE 4

6.0 Construction And Material Specifications

The intent is to specify materials, equipment, methods and standards to be used for the construction of pavement systems as indicated on the plans. The design intent is to construct a pavement with adequate thickness and quality to provide a serviceable life of at least 20 years. All workmanship and materials shall be in accordance with the requirements of these specifications and special provisions, and in conformity with the lines, grades, quantities and typical cross sections shown on the plans or as directed by City Engineering.

6.1 Hot Mix Asphalt

All hot mix asphalt must meet the material specifications and construction standards presented in the current version of the Pikes Peak Region Asphalt Paving Specifications.

6.2 Portland Cement Concrete

All Portland cement concrete must meet the material specifications and construction standards presented in the current version of the City of Colorado Springs City Engineering Standard Specifications Manual.

6.3 Subgrade and Aggregate Base Course

All prepared subgrade and aggregate base course, including recycled concrete, must meet the material specifications and construction standards presented in the current version of the City of Colorado Springs City Engineering Standard Specifications Manual. Aggregate base course shall extend to the back of curb as a minimum.

6.4 Moisture Treatment for Expansive Soils

This work consists of removing, moisture conditioning, replacing, compaction, and shaping the existing expansive subgrade with moisture and density control to the extent shown on the plans. The purpose is to provide a zone of low swelling, strain absorbing material between the expansive subgrade and the pavement section. Moisture treatment shall extend to the back of curb as a minimum. The depth of removal and replacement with moisture treated subgrade shall be consistent with the plans regardless of cut, fill or backfill.

1. **Equipment -** The contractor shall provide equipment in good operating condition that is specifically designed and manufactured for the purpose of excavating, hauling, mixing, watering, leveling and compacting subgrade materials. Mixing and watering equipment shall be capable of achieving a uniform moisture content without wet or dry zones. Compaction equipment shall be adequately designed to obtain compaction requirements without adverse shoving, rutting, displacement or loosening of subgrade material. The equipment shall be available to perform the work specified within the time frames required and to be coordinated with other activities. The equipment shall be operated by skilled workman at a normal production rate for the specified type of work.

   All equipment and machinery shall be kept in good working order, free of leaks and properly muffled. All taxes, licenses and fees shall have been paid and proper licenses and permits shall be posted as required by law.

2. **Construction Methods**

   a. Compaction - The existing subgrade shall be removed, uniformly moisture treated, mixed, replaced, and compacted. Each layer shall be compacted to at least 95 percent Standard Proctor density as determined by AASHTO T 99 at 1 to 3 percent above optimum moisture content. The thickness of layers, prior to compactions, shall depend upon the type of sprinkling, mixing and compacting equipment used. Moisture/density tests should be performed every 250 linear feet, alternating lanes, to verify subgrade density meets specifications.

   After each layer of fill is complete, tests must be made to confirm moisture content and required compaction. When the material fails to meet the compaction or moisture requirements or should the material lose the required compaction or moisture or finish before the next course is placed or the project is accepted, the layer shall be processed. Reprocessing shall be done at the contractor's expense.

   The contractor may be required to excavate an area of the layer in order to facilitate the taking of density tests. Replacement and compaction of the removed material in the area shall be at the contractor's expense.

   b. Subgrade Stabilization - Moisture treatment will leave a soft yielding subgrade unsuitable for paving. Stabilization in accordance with Item 4.2.2, Subgrade Stabilization, shall be performed to the depths and limits shown on the plans.

3. **Tolerances**

   a. Grade Tolerances - Any deviation in excess of 1/2 inch in cross section and 1/2 inch in 10 feet measured longitudinally shall be corrected by loosening, adding or removing the material, reshaping and re-compacting by sprinkling and rolling. Deviations in excess of this tolerance shall be corrected by the contractor, at the contractor's expense, in a manner satisfactory to City Engineering.

   b. Compaction Tolerances - Compaction below the specified minimum shall be corrected by re-compaction. Inadequate compaction shall be corrected by the contractor, at the contractor's expense.

c. Moisture Tolerances - Any loss of moisture below the set limits shall be corrected by moisture conditioning and re-compaction. Loss of moisture shall be corrected by the contractor, at the contractor's expense.

4. **Testing and Inspection**

a. Testing of moisture treated soils shall be performed in accordance with Table 10.

Table 10

Schedule for Minimum Materials Sampling and Testing (Moisture Treated Soils)

Test Type	Test Standard	Minimum Frequency of Tests
In Place Soil Density And Moisture Content	AASHTO T 191 ASTM D 2167 AASHTO T 238 ASTM D 2216 AASHTO T 239	One test for each 250 lane feet (not less than one test per day).
Liquid Limit	AASHTO T 89	One test per soil type
Plastic Limit	AASHTO T 90	One test per soil type
Moisture-Density Relationships	AASHTO T 99 AASHTO T 180	One test per soil type

6.5 Chemically Stabilized Subgrade

This work consists of the contractor constructing one or more courses of a mixture of subgrade soil, approved stabilizing agent and water in substantial conformity with the design line, grades, thicknesses, and typical cross sections shown on the approved plans and the approved pavement thickness design. **Purpose -** The purpose of the work shall be to provide a structural section on which paving materials can be placed and to meet design specifications, while at the same time, protecting the underlying moisture-treated subgrade soils. Subgrade stabilization shall extend to the back of curb as a minimum. This specification can also be applied to achieve a stabilized paving platform without structural benefits.

1. **Materials**

a. Stabilizing Agents - The pre-approved stabilizing agents are listed in Table 11. Various combinations of these materials may also be used, subject to a suitable mix design. Other agents may be used with prior written approval of City Engineering.

Table 11

Approved Chemical Stabilizing Agents

Pre-Approved Stabilizing Agents		
Agents	**Must conform to requirements of**	
Lime	ASTM	C 977, C110
Fly Ash (C and F)	ASTM	C 618
Cement Kiln Dust	ASTM	D 5050
Portland Cement	ASTM	C 114

High-calcium quicklime shall conform to the requirements of ASTM C 977 and rate of slaking test shall produce a temperature rise of 20°C in 30 seconds and 35°C in 3 minutes per ASTM C110. Dolomitic quicklime, magnesia quicklime with magnesium oxide contents in excess of 4 percent or carbonated hydrated lime, shall not be used. High-calcium quicklime must be applied in slurry.

Fly ash may consist of Class C or Class F. Class F fly ash shall only be allowed in conjunction with lime or other cementitious stabilizing agents.

All stabilizing agents shall come from the same source as used in the design. If the source is changed, a new design must be submitted to City Engineering for approval. Each lot of stabilizing agent furnished shall have the supplier's certificate of compliance.

b. Water - Water used for mixing or curing should be from a potable source. In the event potable water is not used, non-potable water shall be tested in accordance with and meet the requirements of AASHTO T 26 and used in the mix design.

c. Subgrade - The subgrade material to be stabilized shall be free of roots, sod, weeds, wood, construction debris, ice, snow, or other frozen materials, deleterious matter, and stones larger than 3 inches in size. Material in the stabilized zone shall have a water soluble sulfate content of less than 0.2 percent as per CPL 2103, Method B. If the subgrade soils have a soluble sulfate content exceeding 0.2 percent, the mix design shall address the specific methodology used to prevent adverse effects of sulfate reactions (e.g. heaving subgrade, cracked pavement).

2. **Equipment -** All equipment shall be subject to approval by City Engineering. All equipment and machinery shall be kept in good working order, free of leaks and properly muffled.

a. Dry Application Equipment - Equipment for spreading dry stabilizing agent shall be of an approved screw-type spreader box, mixer, or other semi-enclosed equipment which is equipped with a metering device. Spreading of stabilizing agents by aggregate spreaders or motor-graders will not be allowed.

b. Slurry Application Equipment - A distributor or truck applicator shall be used and be capable of continuous agitation to keep the slurry mixture uniform. The applicator shall be capable of uniformly metering the stabilizing agent during application.

c. Mixing Equipment - Mixing equipment shall be of sufficient size to adequately mix the stabilizing agent into the soil and to pulverize the mixture. The size of the mixer shall be adequate to mix and pulverize the mixture to a minimum depth of 12 inches in a single pass. Blades, discs, and similar equipment are not allowed without prior written approval of City Engineering.

d. Compaction Equipment - Compaction equipment shall be in good working order and of sufficient size and effective force to achieve the required compactive effort.

3. **Construction Submittals -** At least 15 days prior to commencing stabilization work, the contractor shall furnish the following information to City Engineering:

   - The source and supplier of stabilizing agent and certifications, including purity of stabilizing agent, from the manufacturer's testing agency indicating that the stabilizing agent meets the appropriate requirements.
   - Description of the proposed construction equipment, construction methods, expected production rates and planned sequence of construction.
   - A mix design giving the Water Soluble Sulfate test results percentage of stabilizing agent, source of the agent, properties and any special considerations.

   For each day's work, the contractor shall furnish the following information to the City Engineering Inspector by the following day:

   - Certified truck weight tickets of stabilizing agent, delivered or used at the site.
   - A summary of the amount of stabilizing agent used each day, areas stabilized and first mixed, areas second mixed and compacted, and areas with curing completed.
   - Prior to paving, final in place soil properties per Table 6.5.11.

4. **Stabilized Mix Design**

   Mix designs shall be performed under the supervision of and signed by a Professional Engineer licensed to practice in the State of Colorado practicing as a geotechnical engineer. Mix design shall comply with the requirements of Table 12

Table 12

Stabilization Mix Design Requirements

Stabilization Mix Design Requirements			
Stabilization Agent	**Minimum pH (Notes 1 & 2)**	**Maximum Swell Potential (%) (Note 3)**	**Minimum Unconfined Compressive Strength (psi) (Note 4)**
Lime	12.0	1.0	160
Fly Ash	N/A	1.0	160
Cement Kiln Dust	N/A	1.0	160
Portland Cement	N/A	1.0	160
Lime-Fly Ash	12.3	1.0	160

Notes:

1. *When lime is used, the pH should be no less than 12.0 as measured after completion of initial mixing with stabilizing agent and at ambient temperature.*
2. *Testing of pH is to be done in accordance with Eades-Grim pH test method (ASTM D 6276).*
3. *Swell Potential to be less than 1.0 percent at 200 psf, ASTM D 4546.*
4. *Minimum of 160 psi (Mr > 34,800 psi, where Mr = 10,000+124qU) in five (5) days of moist curing at 100ºF (38ºC) or ambient (72°F) for seven (7) days. Testing is in accordance with ASTM D 1633 Method A for pozzolanic agents and ASTM D 5102 Procedure B for Hydrated Lime.*

When lime is used, Plasticity Index is to be reported from initial to final construction to all interested parties and shall not be used for acceptance purposes. The design stabilizing agent percentage as determined by the designer shall be increased by 1.0 percent in the field to account for waste, inert materials, and construction variability.

5. **Processing Materials -** It is the primary requirement of this specification to secure a completed subgrade structural section containing a uniform stabilized mixture. The mixture is to have a uniform density and moisture content, free from loose or segregated areas, well bound for its full depth, well cured, and with a surface suitable for placing subsequent courses. It shall be the responsibility of the contractor to regulate the sequence of their work, to use the proper amount of stabilizing agent, maintain the work, and rework the courses, as necessary, to meet the requirements.

   a. Application - The subgrade shall not be treated when the ambient air temperature falls below 40°, or when the subgrade material is frozen, or when weather predictions suggest that subgrade material temperature may fall below freezing within 24 hours, unless prior written approval of City Engineering has been issued. Prior to beginning any treatment, the subgrade shall also be constructed and finished to a smooth and uniform surface that is in conformity to the grade and typical section specified. Variation from the subgrade plan elevation specified shall not be more than ± 0.08 ft. The in-place density shall be at least 95% of maximum dry density as determined by ASTM D 698, Standard Proctor Density, and within 0 to 3% of optimum moisture content for fly ash or cement treated soils. For lime treated materials, the moisture content shall be at least 3% above optimum. Stabilizing agent shall be applied at the minimum rate specified by the mix design for the depth of stabilized subgrade shown on the plans. The rate shall be determined from a design using the on-site soils and shall meet the requirements found in Section 4.2.2. Rate of application shall be verified using area/quantity calculations or testing of stabilized subgrade. Stabilizing agent shall be spread only on that area where the first mixing operations can be completed during the same working day. Lime slurry shall not be left exposed to the air for more than four hours without initial mixing. City Engineering reserves the right to require variation of the rate of application of stabilizing agent from the mix design application rates during the progress of construction as necessary to maintain the desired characteristics of the stabilized subgrade.

   Stabilizing agent shall be applied using the following methods:

1. Slurry Placement - The distribution of stabilizing agent shall be attained by successive applications over a measured section of subgrade until the proper amount of agent has been spread. The amount spread shall be the amount required for mixing to the specified depth, which will result in the percentage determined in the design. When quicklime is used in place of hydrated lime the amount of quicklime used will be determined by the certified lime purity for each load supplied as follows:

   Quicklime delivered X % purity * 1.32 = A

   Quicklime delivered *X % inert material = B

   A + B = total hydrated lime available

   Note: When a double treatment of lime is required, the first 50 percent of the agent shall be placed, moisture treated and allowed to mellow or cure for up to three weeks, as determined by the Design Engineer. The last half of the lime shall then be applied.

2. Dry Placement (This method can only be used for Fly Ash, cement kiln dust, and Portland cement) - The amount of stabilizing agent spread shall be the amount required for mixing to the specified depth, which will result in the percentage specified by the design. The stabilizing agent shall be distributed in such a manner that scattering by wind will be minimal. Agents shall not be applied when wind conditions, in the opinion of City Engineering's inspector, are detrimental to a proper application. The blended material shall be sprinkled or watered until moisture content is as specified in subgrade stabilization design. The combination of stabilizing agent, soil and water shall be called the "mixture." After spreading of stabilizing agent and during mixing, water shall be added to hydrate the agent and for dust control.

b. High Sulfate Treatment - Where sulfates are over 0.2 percent the designer must address the method of treatment.

c. Mixing - No stabilization shall take place when precipitation may cause damage to the subgrade. Mixing shall be continuous. The full depth of the treated subgrade material shall be mixed with an approved mixing machine to the specified depth below the bottom of the pavement structure and/or curb. The mixing machine shall make a sufficient number of passes to adequately achieve 100 percent of the material passing the one-inch sieve and 60 percent passing the 1/4-inch sieve. Water shall be added to the subgrade during mixing to provide a moisture content of at least 3 percent above the optimum moisture of the mixture or as specified in subgrade stabilization design. Mixing and remixing will be performed, as necessary, to assist the stabilizing agent-soil reaction and produce a homogeneous mixture. Mixing and remixing shall continue until the combination of stabilizing agent and subgrade material is free of streaks or pockets of stabilizing agent.

d. Mellowing (Lime or Lime/Fly Ash Only) - The moisture content of the subgrade mixture shall be maintained above optimum for a minimum of 2 days and until the subgrade stabilization design criteria is met. Remixing will be done as necessary to assist the reaction, as determined by the design engineer. Application of water shall be performed as necessary during the mellowing period; the material shall maintain a moisture content of at least 3 percent above optimum. The stabilized material shall not be subjected to traffic. If during the mellowing period the material is not in a semi-loose state, the chemical reaction process may slow and, therefore, require additional time and/or mixing as determined by the design engineer.

e. Final Mixing (Lime or Lime/Fly Ash Only) - Final mixing of the treated subgrade shall not occur if the temperature of the soil to be stabilized is below 40°F. The treated subgrade shall be maintained at a temperature of 40° F or above until the treated material has been compacted. The material shall be uniformly mixed by an approved method to meet the following requirements when tested dry by laboratory sieves:

Sieve Size	Minimum Percent Passing
1-inch sieve	100
No. 4 sieve	60

6. **Compaction -** Compaction of the mixture, for the full depth of the stabilized subgrade shown on the plans, shall begin as soon as practical after final mixing. Stabilized subgrade with cementitious stabilization agent shall be completed within 90 minutes of the time the cementitious stabilization agent and water are mixed. The field density of the compacted mixture shall be at least 95 percent of the maximum dry density of laboratory specimens prepared from samples taken from the treated subgrade material immediately prior to compacting. The specimens shall be compacted and tested in accordance with ASTM D 698 or ASTM D 558, as specified in the subgrade stabilization mix design. The in-place field density shall be determined in accordance with ASTM D 1556, ASTM D 2167 or ASTM D 2922. The moisture content of the mixture of shall be between 0 to 3 percent above the optimum moisture content. The optimum moisture content shall be determined in accordance with ASTM D 698 or ASTM D 558, as specified in subgrade stabilization design. Initial compaction shall be done by means of a sheepsfoot or segmented wheel roller. Final compaction shall be by means of a smooth wheel or pneumatic tired roller. Areas inaccessible to a mechanical roller shall be compacted to the required density by other means acceptable to the design engineer. All irregularities, depressions, or weak spots which develop shall be corrected immediately by scarifying the areas affected, adding or removing materials as required, and reshaping and re-compacting by moisture conditioning and rolling. Adding additional stabilized material to an initial cured section, resulting in lamination and potential slip plane, is not allowed. The surface of the course shall be maintained in a smooth condition, free from

undulations and ruts, until other work is placed thereon or the work is accepted. Should the material, due to any reason or cause, lose the required stability, density, and finish before the next course or pavement is placed, it shall be corrected and refinished at the sole expense of the contractor, as directed by City Engineering.

7. **Finishing and Curing -** After the final layer of stabilized subgrade has been compacted, the shape of the surface shall be achieved by blading. The surface shall be smooth and conform to the required lines, sections, and grades, in accordance with the plans and thoroughly cured, or to within a minimum of 0.1 foot above the finished subgrade elevation to allow for trimming to final grade prior to placement of surface coarse. The completed section shall then be finished by rolling with suitable pneumatic tired equipment with sufficiently light effort to prevent hairline cracking. Curing may be accomplished by periodic water application to maintain moisture content preventing sloughing or cracking of the surface of the stabilized subgrade to a depth no greater than 0.1 foot, or by the utilization of a bituminous seal. When bituminous seal is utilized, the minimum application will be at the rate of 0.12 gallons per square yard, as directed and approved by the design engineer. The completed section shall be cured for a minimum of 5 days before further courses are added or any traffic is permitted, unless otherwise permitted by the design engineer. The moisture cure duration may be reduced if a non-yielding surface is obtained to support construction traffic and either the next layer of stabilized soils are placed or the pavement layer is constructed, as approved by the Engineer. If the surface of the finished layer is above the approved plan elevation tolerance specified in this section, the excess material shall be trimmed, removed, and disposed of. Any low areas will be replaced with the subsequent surface courses. No loose material shall be left in place after trimming. After trimming the stabilized subgrade surface shall be rolled again with a steel wheel or pneumatic tired roller to seal the surface.

8. **Tolerances**

   a. Thickness - Stabilized zone thickness shall be verified by the use of phenolphthalein and shall be performed at intervals of approximately 500 feet in each lane. When the measurement of the thickness is deficient by more than 1 inch from the plan thickness, two additional locations shall be measured randomly within the deficient area and used in determining the average thickness. When the average thickness is deficient by more than 1 inch, the entire area shall be reprocessed to meet the design parameters or the roadway design section must be re-evaluated.

   b. Grade - Prior to placement of surface course, any deviation in excess of 1/2 inch in cross-section and 1/2 inch in 10 feet measured longitudinally shall be corrected. Variations in excess of this tolerance shall be corrected by the contractor, at the contractor's expense, in a manner satisfactory to City Engineering. Thickness requirements shall be met in areas corrected for grade.

c. Strength - The stabilized subgrade must develop a laboratory compressive strength of at least 160 psi at 5 days in accordance with Table 6.5.4. Samples shall be molded from stabilized soil within 1.5 hours of final mixing with the material compacted per ASTM D 558 or ASTM D 698, as specified in subgrade stabilization design, at the field moisture content.

9. **Conformity with Plans and Specifications -** When thickness and/or strength criteria fail to meet design parameters, even after all possible attempts have been made to correct said deviations, remediation will be required as listed in Table 13. Evaluation of the roadway pavement section will be made by the Design Engineer with written approval of City Engineering. The pavement structural section shall be adjusted to compensate for any deficiency in the stabilized subgrade thickness and strength, at the contractor's expense. Placement of subsequent surface course will not occur until the stabilized subgrade has been accepted in writing by City Engineering.

Table 13

Conformity Specifications

Deficiency	Remediation
Less than 25% of design thickness	Evaluate roadway design section
Greater than 25% of design thickness	Remove and replace
Less than 25% of required strength	Evaluate roadway design section
Greater than 25% of required strength	Remove and replace

10. **Measurement -** The area of stabilized subgrade shall be measured by the plan quantities completed, in place, and accepted. No separate measurement of depth or area, except as required for thickness testing shall be performed. The quantity of stabilizing agent accepted and used shall be measured by the ton of fly ash, Portland cement, cement kiln dust, or hydrated lime used (or the calculated dry hydrated lime content of the lime slurry).

11. **Testing and Inspection -** Testing and inspection shall be performed in accordance with Table 14.

Table 14

Schedule for Minimum Materials Sampling and Testing (Chemically Stabilized Soils)

Test Type	Test Standard	Minimum Frequency of Tests
Sampling	AASHTO T 87	One per 2,500 square yards
Sample Preparation	ASTM D 3551	
Maximum Dry Density and Optimum Moisture Content	ASTM D 698 (Lime) ASTM D558 (Cement)	Minimum of one per soil type or as directed by City Engineering
In Place Soil Density	ASTM D 1556 ASTM D 2167 ASTM D 6938	One test for each 250 lane feet (not less than one test per day)
In Place Moisture Content	ASTM D 2216 ASTM D 6938	
Ph	ASTM D 6276	One test per 2,500 square yards
Swell	ASTM D 4546 Method B	Minimum one test per 2,500 square yards or as directed by City of Colorado Springs,
Unconfined Compressive Strength (Lime)	ASTM D 5102 (Procedure B)	One set of four cylinders per 2,500 square yards.
Compressive Strength Cementitious Agents	ASTM D 1633 (Method A)	One set of four cylinders per 2,500 square yards.
Atterberg Limits	AASHTO T 89 & T 90	One test per 2,500 square yards
Stabilization Thickness	As directed by testing agency	One test every 500 feet per lane

6.6 Mechanically Stabilized Subgrade

This work includes mechanically stabilized subgrade of base/subbase course and/or subgrade improvement in the construction of paved or unpaved roadways. Design details for geogrid reinforcement, such as geogrid type, fill thickness, pavement cross-section and associated details, shall be as shown on the project drawings. Purpose - The purpose of the work shall be to provide a stabilized paving platform section on which paving materials can be placed. Subgrade stabilization shall extend to the back of curb as a minimum. This item shall not be used to retain moisture in subgrades unless retaining moisture in the section can be assured. This specification shall be used for a construction platform and not as a means of mitigating swell.

1. **Materials**
   - *a.* Definitions
     - *1.* **Mechanically Reinforced** - Placement of a geogrid immediately over a soft subgrade soil in order to improve the bearing capacity and mitigate deformation of the subgrade soil. The goal of this application may be to reduce deeper excavation requirements, improve construction efficiency, reduce the amount of aggregate subbase/base material required, provide a stiff working platform for pavement construction, or combination of these.

2. **Geogrid** - A biaxial polymeric grid formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, or earth to function primarily as reinforcement.
3. **Multi-Layer Geogrid** - A geogrid product consisting of multiple layers of grid which are not integrally connected throughout.
4. **Extruded Geogrid** – A geogrid product formed by extrusion of a polypropylene or polypropylene/polyethylene copolymer sheet followed by its perforation with a precise arrangement of holes and subsequent stretching, or drawing, into the finished product.
5. **Woven Geogrid** – A geogrid product formed by weaving discrete strips of polymer into a network. These geogrids usually require a protective coating to protect the polymer from pre-mature degradation.
6. **Minimum Average Roll Value (MARV**) - Value based on testing and determined in accordance with ASTM D4759-92.
7. **True Initial Modulus in Use** - The ratio of tensile strength to corresponding zero strain. The tensile strength is measured via ASTM D6637 at a strain rate of 10 percent per minute. Values shown are MARVs. For multi-layer geogrid products, rib tensile testing shall be performed on the multi-layer configurations, as prescribed by ASTM D6637
8. **Junction Strength** - Breaking tensile strength of junctions when tested in accordance with GRI-GG2 as modified by AASHTO Standard Specification for Highway Bridges, 1997 Interim, using a single rib having the greater of 3 junctions or a minimum 8 inch machine direction sample and tested at a strain rate of 10 percent per minute based on this gauge length, values shown are MARVs. For multi-layer geogrid products, junction strength testing shall be performed across junctions from each layer of grid individually, and results shall not be assumed as additive from single layers to multiple layers.
9. **Flexural Stiffness** (also known as Flexural Rigidity) - Resistance to bending force measured via ASTM D1388-96, Option A, using specimen dimensions of 864 millimeters in length by 1 aperture in width, values shown are MARVs. For multi-layer geogrid products, flexural stiffness testing shall be performed directly on the multi-layer configuration without using any connecting elements other than those used continuously throughout the actual product, and results shall not be assumed as additive from testing performed on a single layer of the multi-layer product.
10. **Aperture Stability Modulus** (also known as Torsional Rigidity or Torsional Stiffness) - Resistance to in-plane rotational movement measured by applying a 20 kg-cm (2.0 m-N) moment to the central junction of a 9-inch by 9-inch specimen restrained at its perimeter, values shown are MARVs. For multi-layer geogrid products, torsional stiffness testing shall be performed on each layer of grid individually, and results shall not be assumed as additive from single layers to multiple layers.

11. **Granular Fill Material –** The preferred gradation for base reinforcement application is well-graded crushed aggregate fill with a maximum particle size (100 percent passing) of 1 ½ inches, and less than 10% fines (passing the #200 sieve). Recycled concrete may be used only with polypropylene geogrids in accordance with Federal Highway Administration (FHWA) 2001.

2. **Manufacturers**
   a. All manufacturers will be considered provided they meet the submittal process as per Table 6.6.3.

3. **Geogrid Material Properties**
   a. Structural Soil Reinforcement Geogrid – The geogrid shall be integrally formed and deployed as a single layer having the following characteristics according to Table 15 (all values are minimum average roll values unless a range or characteristic is indicated.)
   b. Geotextile materials shall not be considered as an alternate to geogrid materials for subgrade improvement or base/sub-base reinforcement applications. A geotextile may be used in the cross-section to provide separation, filtration or drainage; however, no structural contribution shall be attributed to the geotextile.

Table 15

Geogrid Structural Properties

Property	Test Method	Units	Type 1	Type 2
Aperture Stability Modulus at 20 cm-kg (2.0 m-N)	Kinney (2001)	m-N/deg	0.32	0.65
Rib Shape	Observation	N/A	Rectangular or Square	Rectangular or Square
Rib Thickness	Calipered	In	0.03	0.05
Nominal Aperture Size	I.D. Calipered	In	1.0 to 1.5	1.0 to 1.5
Junction Strength	GRI-GG2-2000 1	ratio	Note [1]	Note [1]
Flexural Rigidity	ASTM D1388-96 Note [2]	Mg-cm	250,000	750,000
Minimum Tensile Strength @ 2% Strain:	ASTM D6637-01 Note [4]			
- MD[3]		Lb/ft	280	410
- CMD[3]		Lb/ft	450	620
Minimum Tensile Strength @ 5% Strain:	ASTM D6637-01 Note [4]			
- MD[3]		Lb/ft	580	810
- CMD[3]		Lb/ft	920	1,340

NOTES:

1. The ratio of Junction Strength/Ultimate Tensile Strength must meet or exceed 75%.

2. Resistance to bending force measured via ASTM D-5732-95, using specimens of width two ribs wide, with transverse ribs cut flush with exterior edges of longitudinal ribs (as a "ladder"), and of length sufficiently long to enable measurement of the overhang dimension.

3. MD = machine direction (along roll length); CMD = cross-machine direction (across roll width).

4. True resistance to elongation when initially subjected to a load determined in accordance with ASTM D6637 without deforming test materials under load before measuring such resistance or employing "secant" or "offset" tangent methods of measurement so as to overstate tensile properties.

4. **Construction Platform Design**

   Construction platform design shall be performed under supervision of and signed by a Professional Engineer registered in the State of Colorado practicing as a geotechnical engineer. The recommended procedure shall be followed as outlined in AASHTO PP 46-01. Appropriate partial safety factors shall be applied to results obtained using geogrids having properties or characteristics outside the range of rigorous model validation (Giroud and Han, 2004). This method has been endorsed by numerous Department of Transportations and Government Agencies such as the Federal Highway Administration and Army Corps of Engineers. A piping ratio analysis (D15fill/D85subgrade) shall be performed to determine the need of a separation fabric. If the piping ratio is less than 5 then no separation fabric is required. If the piping ratio is greater than 5 then a separation fabric is required below the geogrid. Final determination of construction platform shall be approved by City Engineering.

5. **Utility Cuts**

   Repair of utility cuts in geogrid material shall be accomplished per manufacturer specifications.

6.7 Proof Rolling

The Subgrade platform shall be thoroughly proof-rolled to the satisfaction of the City Inspector prior to placement of base course (or paving) and the base course shall be thoroughly proof-rolled to the satisfaction of the City inspector prior to paving. Reference Section 205 of the City's Standard Specifications.

6.8 Water Testing

As soon as practical upon final pavement construction the finished pavement surface shall be water-tested to the satisfaction of the City Engineering inspector to confirm positive surface drainage in all directions prior to acceptance of the street. Water shall be applied using a water truck spray bar or similar device at a rate adequate to demonstrate positive drainage flow across the crown and into the street gutters.

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7.0 Definitions

AASHTO: American Association of State Highway and Transportation Officials

Adhesive Failure: Loss of bond between the joint sealant and the joint, or between the aggregate and the binder.

Agency: The jurisdiction or owner of the project and its representatives.

Aggregate Base (base course): Crushed stone or gravel, immediately under the surface course.

Aggregate Interlock: Interaction of aggregate particles across cracks and joints to transfer load.

Alligator Cracks: Interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wire.

Analysis Period: The period of time for which the economic analysis is to be made; ordinarily will include at least one rehabilitation activity.

Asphalt Emulsion Slurry Seal: A mixture of emulsified asphalt, fine aggregate and mineral filler, with water added to produce slurry consistency. Seals are used as a preventative maintenance treatment to provide a new wearing surface and to fill small cracks.

Asphalt Leveling Course: A course (asphalt-aggregate mixture) of variable thickness used to eliminate irregularities in the contour of an existing surface prior to superimposed treatment or construction.

Asphalt Overlay: One or more courses of asphalt construction on an existing pavement. The overlay generally includes a leveling course, to correct the contour of the old pavement, followed by uniform course or courses to provide needed thickness.

Asphalt Tack Coat: A light application of emulsified asphalt applied to an existing asphalt or Portland cement concrete pavement surface. It is used to ensure a bond between the surface being paved and the overlying course. Typically 0.10 gals/yd2 of CSS1h.

ASTM: American Society for Testing Materials

Binder: Asphalt Cement used to hold stones together for paving.

Binder Course: The layer of asphalt cement concrete pavement underlying the surface course.

Bituminous: Like or from asphalt.

Bleeding or Flushing: The upward movement of asphalt in an asphalt pavement resulting in the formation of a film on the pavement surface. It creates a shiny, glass-like, reflective surface that may be tacky to the touch in warm weather.

Block Cracking: The occurrence of cracks that divide the asphalt surface into approximately rectangular pieces, typically one square foot or more in size.

California Bearing Ratio Test (CBR): An empirical measure of bearing capacity used for evaluating bases, subbases, and subgrades for pavement thickness design.

Centerline: The painted line separating opposing traffic lanes.

Channels: A ditch or canal adjacent the roadway.

Chipping: Breaking or cutting off small pieces from the surface.

Chip Seal: A thin layer of emulsified asphalt cement in which aggregate is embedded. The seal is placed to improve the texture of the pavement surface to increase skid resistance and decrease permeability of the surface.

City Street: A street whose traffic is predominantly local in character.

Cohesive Failure: The loss of a material's ability to bond to itself or its substrate. Results in the material splitting or tearing apart from itself or its substrate (i.e. joint sealant splitting).

Composite Pavement: A pavement structure composed of an asphalt cement concrete pavement wearing surface over aggregate base course or treated subgrade.

Contractor: The land developer or its agents involved in the construction of the project.

Corrugations (Washboarding): A form of plastic movement typified by ripples across the pavement surface. Most common in aggregate surficial pavements but occurs in asphalt cement concrete pavements as well.

Crack: Approximately vertical random cleavage of the pavement due to thermal or load action.

Crack Seal: An asphalt cement or similar material applied into a pavement crack to provide a non-permeable seal. The sealant must have adequate characteristics to provide bonding to each side of the crack.

CTS: Chemically Treated Subgrade

Deflection: The amount of downward vertical movement of a surface due to the application of a load to the surface.

- **Rebound Deflection:** The amount of vertical rebound of a surface that occurs when a load is removed from the surface.
- **Representative Rebound Deflection:** The mean value of measured rebound deflections in a test section plus two standard deviations, adjusted for temperature and most critical period of the year for pavement performance.
- **Residual Deflection:** The difference between original and final elevations of a surface resulting from the application to, and removal of one or more loads from, the surface.

Design ESAL: The total number of equivalent 80kN (18,000 lb) single-axle load applications expected during the Design Period.

Design Lane: The lane on which the greatest number of equivalent 80kN (18,000 lb) single-axle loads is expected. Normally this will be either lane of a two-lane roadway or the outside lane of a multi-lane highway.

Design Period: The number of years from initial construction or rehabilitation until terminal service life. This term should not be confused with pavement life or Analysis Period. By adding asphalt overlays as required, pavement life may be extended indefinitely, or until geometric considerations or other factors make the pavement obsolete.

Disintegration: The breaking up of a pavement into small, loose fragments due to traffic or weathering.

Distortion: Any change of a pavement surface from its original shape.

Drainage Coefficients: Factors used to modify layer coefficients in flexible pavements or stresses in rigid pavements as a function of how well the pavement structure can handle the adverse effect of water infiltration.

Edge Cracking: Fracture and materials loss in pavements without paved shoulders which occur along the pavement perimeter. Caused by soil movement beneath the pavement.

Effective Thickness: The thickness that a pavement would be if it could be converted to Full-Depth asphalt cement concrete pavement.

Embankment (Embankment Soil): The prepared or natural soil underlying the pavement structure.

Embrittlement: Premature (surficial) cracking of an asphalt concrete pavement due to oxidative aging of the asphalt cement.

End Result Specifications: Specifications that require the contractor to take the entire responsibility for supplying a product or an item of construction. The highway agency's responsibility is to either accept or reject the final product or apply a price adjustment that compensates for the degree of compliance with the specifications. (End result specifications have the advantage of affording the contractor flexibility in exercising options for using new materials, techniques, and procedures to improve the quality and/or economy of the end product.)

ESAL: Equivalent Single Axel Load

ESAL to Failure: The number of design 18 kip (18,000 pound) axle load cycles required to produce approximately 40 percent fatigue cracking as calculated using AAMAS equations based on asphalt cement concrete pavement Resilient Modulus and tensile strain at the bottom of the ACCP layer.

Equivalent 80kN (18,000 lb) Single-Axle Load (ESAL): The effect on pavement performance of any combination of axle loads of varying magnitude equated to the number of 80kN (18,000 lb) single-axle loads required to produce an equivalent effect.

Fatigue Cracking: A series of small, jagged, interconnecting cracks caused by failure of the asphalt cement concrete pavement surface under repeated traffic loading (also called alligator cracking.)

Fault: Difference in elevation between opposing sides of a joint or crack.

Flexible Pavement: Pavement structures generally consisting of asphalt cement concrete pavement surfacing that maintains intimate contact with and distributes loads to the subbase or subgrade and depends upon aggregate interlock, particle friction, and cohesion for stability.

Flowable Backfill: A backfill material composed of a low-strength, self-leveling concrete material, composed of various combinations of cement fly ash, aggregate, water and chemical admixtures used to "flow" into areas requiring backfill that will provide density and strength without compaction.

Fog Seal: A thin layer of emulsified asphalt cement applied to the pavement surface. The seal is placed as a preventive treatment to rejuvenate the asphalt concrete pavement by improving flexibility and to decrease the permeability of the surface.

Free Edge: Pavement border that is able to move freely.

Full-Depth Asphalt Pavement: The term FULL-DEPTH (registered by the Asphalt Institute with the U.S. Patent Office) certifies that the pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A Full-Depth asphalt pavement is laid directly on the prepared subgrade.

Functional Classification: A method of separating and classifying streets according to their purpose or function in the network of streets, i.e. residential collectors, commercial collectors, residential locals.

Grade Depressions: Localized low areas of limited size which may or may not be accompanied by cracking.

Hairline Crack: A fracture that is very narrow in width, less than 3mm (0.12 in.).

Heavy Trucks: Two axle, six-tire trucks or larger. Pickup, panel and light four-tire trucks are not included. Trucks with heavy-duty, wide base tires are included.

Hot Bituminous Pavement: See Hot Mix Asphalt

Hydroplaning: The dangerous action of a vehicle being driven on a pavement over which a film of rain or other water has formed; on reaching a certain speed, the vehicle's tires tend to ride upon the water surface rather than the pavement, drastically reducing the driver's control of the vehicle.

Hot Mix Asphalt: High-quality, thoroughly-controlled hot mixture of asphalt cement and well-graded, high quality aggregate, thoroughly compacted into a uniform dense mass.

Incentive/Disincentive Provision (for quality): A pay adjustment schedule which functions to motivate the contractor to provide a high level of quality. (A pay adjustment schedule, even one which provides for pay increases, is not necessarily an incentive/disincentive provision, as individual pay increases/decreases may not be of sufficient magnitude to motivate the contractor toward high quality).

Instability: The lack of resistance to forces tending to cause movement or distortion of a pavement structure.

Internal Vibration: Vibration by means of vibrating units located within the specified thickness of pavement section and a minimum distance ahead of the screed equal to the pavement thickness.

Lane Line: Boundary between travel lanes, usually a painted stripe.

Lane-to-Shoulder Drop-off: The difference in elevation between the traffic lane and shoulder.

Lane-to-Shoulder Separation: Widening of the joint between the traffic lane and the shoulder.

Layer Coefficient: The empirical relationship between structural number (SN) and layer thickness which expresses the relative ability of a material to function as a structural component of the pavement.

Lime Stabilized Subgrade: A prepared and mechanically compacted mixture or lime, water and soil below the pavement system.

Lime-Fly Ash Base: A blend of mineral aggregate, lime, fly ash and water, combined in proper proportions which, when compacted, produces a dense mass.

Lime-Fly Ash Stabilized Subgrade: A prepared and mechanically compacted mixture of lime, fly ash, water and soil below the pavement system.

Load Equivalency Factor (LF): A factor used to convert applications of axle loads of any magnitude to an equivalent number of 80kN (18,000 lb) single axle loads.

Longitudinal: Parallel to the centerline of the pavement.

Longitudinal Crack: A crack that follows a course approximately parallel to the center line.

Maintenance: The preservation of the entire roadway, including surface, shoulders, roadsides, structures, and such traffic control devices as are necessary for its safe and efficient utilization.

Materials/Methods Specifications: Specifications that direct the contractor to use specified materials in definite proportions and specific types of equipment and methods to place the material.

Method Specifications: See Materials/Methods Specifications.

Moisture Stabilized Subgrade: Swelling soils which have been stabilized to low or nil swell by addition of moisture.

Moisture Treatment: Addition of moisture at 1 to 3 percent above standard Proctor optimum moisture content and compaction to 95 percent density.

Parametric Analysis: A study of a set of physical properties whose values determine the characteristics or behavior of something; used to isolate the significance of individual variables.

Patch: An area where the existing pavement has been removed and replaced with a new material.

Patch Deterioration: Distress occurring within a previously repaired area.

Pavement Structure (Pavement): A combination of subbase, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed.

Pavement Condition Indicator (PCI): A measure of the condition of an existing pavement section at a particular point in time, such as cracking measured in feet per mile, or faulting measured in inches of wheel path faulting per mile. When considered collectively, pavement condition indicators provide an estimate of the overall adequacy of a particular roadway.

Pavement Design (Design, Structure Design): The specifications for materials and thicknesses of the pavement components.

Pavement Distress Indicator: See Pavement Condition Indicator.

Pavement, Flexible: Pavement structures generally consisting of asphalt cement concrete pavement surfacing that maintains intimate contact with and distributes loads to the subbase or subgrade and depends upon aggregate interlock, particle friction, and cohesion for stability.

Pavement Performance: The trend of serviceability with load applications.

Pavement Rehabilitation: Work undertaken to extend the service life of an existing facility. This includes placement of additional surfacing material and/or other work necessary to return an existing roadway, including shoulders, to a condition of structural or functional adequacy. This could include the complete removal and replacement of the pavement structure.

Pavement, Rigid: A pavement structure consisting of Portland cement concrete pavement surfacing, with or without subbase.

Performance Period: See Design Period.

Performance Specifications: Specifications that describe how the finished product should perform over time. For highways, performance is typically described in terms of changes in physical condition of the surface and its response to load, or in terms of the cumulative traffic required bringing the pavement to a condition defined as "failure". Specifications containing warranty/guarantee clauses are a form of performance specifications. (Other than the warranty/guarantee type, performance specifications have not been used for major highway pavement components (subgrades, bases, riding surfaces) because there have not been appropriate nondestructive tests to measure long-term performance immediately after construction. They have been used for some products (e.g., highway lighting, electrical components and joint sealant materials) for which there are test of performance that can be rapidly conducted.)

Performance-Based Specifications: Specifications that describe the desired levels of fundamental engineering properties (e.g., Resilient Modulus, creep properties, and fatigue properties) that are predictors of performance and appear in primary prediction relationships (i.e., models that can be used to predict pavement stress, distress, or performance from combinations of predictors that represent traffic, environmental roadbed, and structural conditions.) [Because most fundamental engineering properties associated with pavements are currently not amenable to timely acceptance testing, performance-based specifications have not found application in highway construction].

Performance-Related Specifications: Specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with fundamental engineering properties that predict performance. These characteristics (for example, air voids in asphaltic pavements, and strength of concrete cores) are amenable to acceptance testing at the time of construction. True performance-related specifications not only describe the desired levels of these quality characteristics, but also employ the quantified relationships containing the characteristics to predict subsequent pavement performance. They thus provide the basis for rational acceptance and/or price adjustment decisions.

Planned Stage Construction: The construction of roads and streets by applying successive layers of asphalt cement concrete pavement according to design and a predetermined time schedule.

Plant-Mix Base: A foundation course, produced in an asphalt mixing plant, which consists of a mineral aggregate uniformly coated with asphalt cement or emulsified asphalt.

Portland Cement Concrete Pavement (PCCP): High quality, thoroughly controlled mixture of Portland cement, water, and well-graded, high quality aggregate, thoroughly mixed and placed as a uniform dense mass.

Pothole: A bowl-shaped depression of varying sizes in the pavement surface, resulting from localized disintegration.

Prepared Roadbed: In-place roadbed soils compacted or stabilized according to provisions of applicable specifications.

Prescriptive Specifications: See Materials/Methods Specifications.

Present Serviceability: The ability of a specific section of pavement to serve, for the use intended, mixed traffic on the day of rating.

Present Serviceability Index (PSI): A mathematical combination of values, obtained from certain physical measurements of a large number of pavements, so formulated as to predict, within prescribed limits, the Present Serviceability Rating (PSR) for those pavements.

Present Serviceability Rating (PSR): The mean of the individual ratings made by the members of a specific panel selected for the purpose.

Proof Roll: A test method for subgrade soils in which a loaded truck (18,000 pound axle weight) is driven over the subject area to delineate soft or yielding areas.

QA/QC Specifications: See Quality Assurance Specifications.

QC/QA Specifications: See Quality Assurance Specifications.

Quality Assurance: All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. Quality assurance addresses the overall problem of obtaining the quality of service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, quality assurance involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities.

Quality Assurance Specifications: A combination of end result specifications and materials and methods specifications. The contractor is responsible for quality control (process control), and the Agency is responsible for acceptance of the product. (Quality assurance specifications typically are statistically based specifications that use methods such as random sampling and lot-by-lot testing, which let the contractor know if his operations are producing an acceptable product.)

Quality Control: Those quality assurance actions and considerations necessary to assess production and construction processes so as to control the level of quality being produced in the end product. This concept of quality control includes sampling and testing to monitor the process but usually does not include acceptance sampling and testing.

Raveling: The wearing away of the pavement surface caused by the dislodging of aggregate particles.

Recipe Specifications: See Materials/Methods Specifications.

Reflection Cracking: Cracks in asphalt overlays that reflect the crack pattern in the pavement structure underneath.

Resilient Modulus Test: A measure of the modulus of elasticity of roadbed soil or other pavement material.

Resistance Value (R-value): A test for evaluating bases, subbases, and subgrades for pavement thickness design.

Roadbed: The graded portion of a highway between top and side slopes, prepared as a foundation for the pavement structure and shoulder.

Roadbed Material: The material below the subgrade in cuts and embankments and in embankment foundations, extending to such depth as affects the support of the pavement structure.

Roadway: All facilities on which motor vehicles are intended to travel such as secondary roads, interstate highways, streets and parking lots.

Roadway Land Use: A classification based on the use of land adjacent or serviced by the street. The classification is used to separate streets for different volume assumptions.

Roughometer: A single-wheeled trailer instrumented to measure the roughness of a pavement surface in accumulated millimeters (inches) per mile.

Rubberized Asphalt Cement: Blend of asphalt cement and pre-vulcanized rubber.

Rutting: Longitudinal surface depressions in the wheel paths.

Selected Material: A suitable native material obtained from a specified source such as a particular roadway cut or borrow area, of a suitable material having specified characteristics to be used for a specific purpose.

Serviceability: The ability at time of observation of a pavement to serve traffic (autos and trucks) which use the facility.

Shoving: Permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic pushing against the pavement.

Single Axle Load: The total load transmitted by all wheels of a single axle extending the full width of the vehicle.

Skid Hazard: Any condition that might contribute to making a pavement slippery when wet.

Slippage Cracks: Cracks, sometimes crescent-shaped, that point in the direction of the thrust of wheels on the pavement surface.

SMA (Stone Matrix Asphalt, Split-Mastic Asphalt): An asphalt mix design composed of large stones creating a stone to stone matrix, often containing large percentages of asphalt cement and fillers.

Soil Cement Base: A hardened material formed by curing a mechanically compacted intimate mixture of pulverized soil, Portland cement and water, used as a layer in a pavement system to reinforce and protect the subgrade or subbase.

Stabilized Subgrade: A subgrade soil that has been altered by a chemical agent to make suitable for subgrade construction and pavement support.

Standard Deviation: The root-mean-square of the deviations about the arithmetic mean of a set of values.

Statistically Based Specifications: Specifications based on random sampling, and in which properties of the desired product or construction are described by appropriate statistical parameters.

Structural Number (SN): An index number derived from an analysis of traffic, roadbed soil conditions, and environment which may be converted to thickness of flexible pavement layers through the use of suitable layer coefficients related to the type of material being used in each layer of the pavement structure.

Subbase: The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course.

Subbase (Subbase Course): The layer of graded sand-gravel or stabilized subgrade material between the surface of the embankment soil and the base course (and surfacing course when there is no base course).

Subgrade: The soil prepared to support a structure of a pavement system. It is the foundation for the pavement structure. The subgrade soil sometimes is called “basement soil” or “foundation soil”.

Subgrade, Improved: Any course or courses of select or improved material between the subgrade soil and the pavement structure.

Subgrade Resilient Modulus: The modulus of the subgrade determined by repeated load triaxial compression tests on soil samples. It is the ratio of the amplitude of the accepted axial stress to the amplitude of the resultant recoverable axial strain.

Surface (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 of flexible pavements is sometimes called the “wearing course”.

Surface Thickness (Surfacing Thickness, Surface, Slab Thickness (Rigid)): The thickness of surfacing material, usually expressed in inches.

Swell Potential: The percent of volume changed expected for a soil sample when wetted, as measured through laboratory tests conducted using representative overburden pressures.

Tandem Axle Load: The total load transmitted to the road by two consecutive axles extending across the full width of the vehicle.

Thermal Cracking: Cracking occurring in pavement material introduced within the material resulting from a change in temperature.

Traffic Equivalence Factor: A numerical factor that expresses the relationship of a given axle load to another axle load in terms of their effect on the serviceability of a pavement structure.

Transverse Crack: A crack that follows a course approximately at right angles to the centerline.

Triple (Tridem) Axle Load: The total load transmitted to the road by three consecutive axles extending across the full width of the vehicle.

Truck Factor: The number of equivalent 80kN (18,000 lb) single-axle load applications contributed by one usage of a vehicle. Truck Factors can apply to vehicles of a single type or class or to a group of vehicles of different types.

Twenty-Year ESAL: (ESAL20) The Equivalent Single Axle Load application for a twenty-year design. The value is the product of the Load Equivalency factor for each vehicle type, the number of each particular vehicle per day, 365 days per year, and a twenty-year period.

Upheaval: The localized upward displacement of a pavement due to swelling of the subgrade or some portion of the pavement structure.

USCS: Unified Soil Classification System.

Washboarding: See Corrugations.

Water Bleeding: Seepage of water from joints or cracks.

Weathering: The wearing away of the pavement surface caused by the loss of asphalt binder.