

GUIDELINE FOR ASPHALT PAVEMENT DESIGN IN COLORADO

Preliminary Document

A. Commentary

B. Subgrade Investigation

1. Time of Investigation

Time of investigation is normally performed at the completion of site grading. Subgrade should be near final elevation. For CIP projects, this may not be feasible. It is important to evaluate subgrade characteristics at final elevation in cut areas.

2. Spacing of Borings

Streets; 250 feet to 500 feet with a minimum of one per street
Parking lots; Judgment of the geotechnical engineer

3. Depth of Exploration

Five to 10 feet with a minimum five to 10 feet below final subgrade elevation in cut area. Minimum of 20% to 25% is suggested to be 10 feet.

4. Sampling Procedures

Generally by auger procedures but excavation of test pits appropriate under various circumstances. Split spoon sampling generally recommended for granular soils and California sampler for cohesive soils. Large disturbed samples for subgrade support and Proctor testing. Drive samples in the upper 1 to 2 feet below final grade and as necessary to determine the underlying subsurface profile.

5. Subgrade Conditions

Considerations should be given to evaluate existing ground water levels and underlying bedrock.

C. Laboratory Testing

1. Natural Moisture Content and Dry Density

2. Classification

3. Swell-Consolidation

4. Subgrade Support; R-value, CBR, Remolded Unconfined Compressive Strength. Commentary on appropriateness of using soil classification.

5. Water Soluble Sulfates

6. Proctors

7. Remolded Swell

D. Determination of Subgrade Design Strength

1. Correlation of R-value, CBR, Unconfined Compressive Strength to Resilient Modulus

CDOT has a correlation for R-value, AASHTO has several for CBR and MGPEC has equations for unconfined compressive strength. Designer should closely consider the results when selecting final design resilient modulus

E. Subgrade Preparation

1. Compacted Subgrade - Moisture-Density Treatment of upper 8 to 12 inches

Pavement performance is dependent upon uniform subgrade support. AASHTO T-180 and T-99 are appropriate based on soil classification

2. Swelling Subgrade

If clay subgrade soils exhibit an average swell potential greater than 2% under a surcharge pressure of 150 psf to 200 psf, swell mitigation should be addressed. Localized areas of higher swell potential should be addressed individually. CDOT Pavement Design Manual and MGPEC provides additional reference material. Care should be given to site specific situations and local geologic conditions. The following are generally accepted mitigation techniques.

a. Overexcavation and moisture-density treatment.

Typical depths of overexcavation generally range from 2 to 5 feet. Addition of moisture to a value over optimum is normally required.

b. Removal and Replacement

Depth of removal is generally on the order of 1 to 3 feet. The use of an edge drain should be considered.

c. Chemical Treatment

Generally performed in the upper 8 to 12 inches in conjunction with moisture-density treatment alternative. A laboratory mix design should be performed to determine the optimum concentration of chemical stabilization agent to be used. Typical concentrations include 4% to 6% lime, 3% to 5% cement, and 8% to 12% fly ash.

3. Soft and Saturated Subgrade

Soft and saturated subgrade conditions may exist in the presence of shallow groundwater, beneath existing pavements, areas where collapsible soils are present, and areas influenced by surface water. The conditions need to be mitigated in order to provide for a stable paving platform. Care should be given to site specific situations and local geologic conditions. The following alternatives are generally accepted mitigation techniques.

a. Chemical Treatment

Generally performed in the upper 8 to 12 inches. Typical drying agents include lime, fly ash and cement. Concentrations are based on field performance associated with providing a stable paving platform.

b. Mechanical Treatment

Subgrade can be stabilized using non-reinforced and reinforced techniques. Non-reinforced techniques generally consist of placing large diameter aggregates or recycled materials to depths required to provide a non-yielding platform. Typical depths range from 2 to 4 feet. The reinforced techniques generally include a system of a geosynthetic and an aggregate layer. A typical thickness for the layer system is 1 to 2 feet.

4. Other, fill containing debris, organics, etc.

Unusual areas should be evaluated on a site specific basis.

F. Design Traffic

The design traffic for pavement thickness determination is based on the total number of equivalent 18,000 pound (18-kip) single axle loading (ESAL) application that will occur in the design lane over the life of the pavement section. Generally, flexible pavements are design for a 20-year life.

1. Site Specific Traffic Study

Site specific traffic studies generally provide the most reliable data in determining the design ESAL. In addition to average daily traffic volumes, the traffic studies should provide an estimation of the type and percentage of trucks that will use the pavement system.

2. Ranges in ESALs, based on Street Classification

If site specific traffic studies are not available, the following table should be considered based on street classification.

STREET CLASSIFICATION	RANGE 18-KIP ESAL
Arterial	1,460,000 to 1,825,000
Major Collector	730,000 to 1,095,000
Minor Collector	219,000 to 365,000
Local	58,400 to 73,000
Cul-de-sac	36,500 to 58,400

Street classifications at and above major commercial collector status, the traffic impact study should be reviewed and traffic levels considered in design.

3. Parking Lots

The following table provides 18-kip ESALs that should be considered in design of parking lots based usage:

STREET CLASSIFICATION	RANGE 18-KIP ESAL
Automobile Parking Stalls	21,900 to 36,500
Secondary Drives	36,500 to 58,400
Primary Drives	58,400 to 73,000
Loading Docks	73,000 to 182,500

DESIGN TRAFFIC

Traffic loads are the basis for determining the structural requirements of the pavement section. They are also the most variable design criteria. Historically, the pavement design methodologies developed by AASHTO related pavement damage to the passage of an axle of any mass or load. Axle loads were normalized to the damage caused by an 18-kip single axle load. AASHTO developed a procedure whereby mixed traffic volumes of different axle loads and configurations were equated to an equivalent number of 18-kip single axle loads (ESAL).

There are three main variables in determining the design traffic loads.

1. Roadway Design Life: Most new roadways are designed for a minimum design life of 20 years, although, 30-year design life pavements have become more common. The design life for pavement rehabilitation projects is typically much shorter, from 5 to 10 years. In the absence of municipal requirements, the judgment of the geotechnical engineering should determine the roadway design life.
2. Traffic Volume: When possible, the traffic volume used in the determination of the roadway design ESAL should be based on current or recent traffic counts or transportation plan with average daily traffic (ADT) data. Population growth projections should be factored into the estimate of the traffic volume over the design life of the pavement. For many municipalities, minimum design ESALS or 18-kip Equivalent Daily Load Applications are provided based on the roadway classifications.
3. Traffic Type: The type of vehicular traffic will play a significant role in the estimation of the design ESALS for the pavement design. Heavily loaded trucks typically impart the majority of loads and subsequent damage during the design life of a pavement and should therefore be carefully estimated. These include trash trucks, school buses, delivery trucks, and construction traffic. The estimated design traffic volume is converted to 18-kip ESALS through the use of Load Equivalency Factors developed by AASHTO. Load Equivalency Factors can be found in both the CDOT and MGPEC Pavement Design Manuals.

G. Pavement Design Equation

1. 1993 AASHTO Pavement Design Procedures

The AASHTO pavement design equation should be solved through the use of DARWin™, Nomograph, other Industry Programs/Resources

Input Parameters; the following pavement design input parameters are recommended for use in solving the AASHTO pavement design equation.

- a. Initial and Terminal Serviceability
- b. Reliability
- c. Standard Deviation

H. Design Thickness

1. Layer Coefficients
2. Drainage Coefficients
3. Pavement Section Alternatives
 - a. Full Depth
 - b. Flexible Composite
 - c. HMA/Chemically Treated
 - d. HMA/Mechanically Treated

I. Asphalt Mix Selection

1. Superpave Mix Design & Mix Selection

Superpave mix designs have generally replaced Marshall and Hveem mix designs for nearly all applications in Colorado. The Superpave mix design methodology consists of three primary components. These components are:

- PG Asphalt Binder Selection
- Gyratory Compaction Level
- Aggregate Gradation and Physical Properties

A Superpave mix design can be established for all paving applications (highways to driveways). A Superpave mix design may or may not include a modified asphalt binder.

2. PG Asphalt Binder Selection:

There are generally six different grades of Performance Graded (PG) asphalt binders used in Colorado. PG 58-28, PG 64-22, PG 58-34, PG 64-28, PG 70-28 and PG 76-28. PG 64-28, PG 58-34, PG 70-28, and PG 76-28 are modified asphalt binders and are restricted to top mat of paving and where warranted based on traffic and climate conditions. PG 76-28 is generally restricted in use to very high traffic, heavy truck volume arterials or highways. PG 58-34 is generally restricted in use to very low temperature conditions to address the potential of low temperature transverse thermal cracking. Pavement distress associated with surface oxidation is mitigated primarily through mix design (gradation, asphalt binder content) and not through

asphalt binder selection. Smaller sized mixes (Sx) generally have higher asphalt binder content mixes and are used to mitigate surface oxidation, raveling, and weathering related distress.

PG ASPHALT BINDER	SUGGESTED USE
PG 58-34*	Modified asphalt Very low temp. climates, low volume roadways
PG 58-28	Unmodified, low volume roadways
PG 64-22	Unmodified, most commonly used PG grade, for low, moderate and high volume roadways
PG 64-28*	Modified asphalt Moderate to high volume roadways, colder climates
PG 70-28*, PG 76-28*	Modified asphalts very high volume roadway

* - asterisk denotes modified asphalt binder, generally restricted to top mat paving

3. Gyration Compaction Level

Superpave mixes are designed in the laboratory using a Gyration compactor. The gyration levels are 50, 75, and 100. 100 gyration mixes are generally restricted to high volume interstates or heavy truck arterial intersections. The predominate gyration level for most mixes is 75 gyration.

SUPERPAVE GYRATION LEVEL	SUGGESTED USE	TRAFFIC LEVEL (DESIGN ESALS)
50	Very low volume pavements – trails, parking lots, minor residential streets	Less than 500,000
75	Predominate gyration level, minor and major residential, minor and major collectors, minor and major arterials, highways	500,000 to 3 Million
100	Very high volume, heavy truck intersections, heavy truck major arterials, high volume interstate highways	Greater than 3 Million ESALS

4. Aggregate Gradation & Lift Thickness

There are three generally accepted mix types used in Colorado – SG (1”), S (3/4”), and Sx (1/2”). SG is reserved for bottom or lower lift paving in multi lift applications. Both S and Sx mixes can be used for top mat paving and both can be used in high traffic conditions. The generally accepted standard for lift thickness is three times (3X) the nominal maximum aggregate size. Thus the minimal thickness for an SG gradation should be 3”, 2-1/4” for S, and 1-1/2” for Sx. Adjustments in mix design gradation should be considered when the lift thickness is less than the minimums shown. For thin lift overlays (less than 1-1/2”), the maximum aggregate size should be 100% passing the 3/8” sieve.

SUPERPAVE AGGREGATE GRADATION	MINIMUM LIFT THICKNESS	SUGGESTED USE
Sx (Modified)*	1”	Preventive Maintenance thin lift overlays, surface mixes
Sx (1/2”)	1½”	Surface mixes, some intermediate mixes
S (3/4”)	2¼”	Bottom, intermediate and some surface mixes
SG (1”)	3”	Bottom mats for multi lift paving

J. Recycled Asphalt Pavement (RAP)

The use of recycled asphalt pavement (RAP) in hot mix asphalt mixtures has progressed in recent years. Improved quality control and quality assurance practices, environmental benefits, and the cost and availability of asphalt binder have all been reasons for the increased use of RAP in Colorado. The generally accepted practice is to allow up to 25% RAP in lower lifts and 20% RAP in the top mat of paving. This matches what is allowed by CDOT. Higher amounts of RAP could be considered but should be subject to Engineer approval and dependent application (residential, collector, arterial).

K. Recent/New Technologies

1. Perpetual Pavements
2. AASHTO M-E Design Approach

The Mechanistic-Empirical Pavement Design Guide (MEPDG) ¹ represents a major change in the way pavement design is performed. Mechanistic refers to the application of the principles of engineering mechanics and empirical is

¹ AASHTO *Mechanistic-Empirical Pavement Design Guide, A Manual of Practice*, July 2008, Interim Edition, American Association of State Highway and Transportation Officials, 444 North Capitol St. NW, Suite 249, Washington, DC 20001

based upon experience or observation alone. The MEPDG uses a rational design approach that has three basic elements:

- a. theory used to predict a critical distress response parameter (stresses, strains, deflections, etc.) (mechanistic part),
- b. an evaluation of the materials properties applicable to the selected theory, and
- c. the determination of the relationship between the magnitude of the critical distress parameter in question to the performance level desired (empirical part).

The output from the MEPDG is a prediction of distresses and International Roughness Index (IRI) (smoothness) at each selected reliability level. Thus, it is not a direct thickness design procedure.

The MEPDG uses an iterative trial design process (combination of layer types, layer thickness, and design features) for a given set of site conditions and failure criteria at a specified level of reliability. Traffic, materials, and climatic inputs are combined with structural elements to develop a trial design. MEPDG considers the mechanistic relationship between stress and strain (linear or nonlinear), the time dependency of strain under a constant stress level (viscous or non-viscous), and the degree to which the material can rebound or recover strain after stress removal (plastic or elastic). Pavement responses to the combined effects of load and climate are computed using sophisticated finite element (rigid pavements) and elastic layer (flexible pavements) computer models. The design and analysis of a trial design is based upon the concept of total accumulated damage. An incremental damage approach is used to calculate the accumulated damage in the pavement over the design life. The design life is divided into time periods of 2 weeks for flexible pavements and 1 month for rigid pavements. In each time increment, the daily, seasonal, and long-term changes in material properties, traffic, and climate are considered. The total damage over the design life is the sum of the damage accrued in each time increment. The procedure empirically relates damage over time to pavement distresses. The distress types considered in the MEPDG are rutting, fatigue cracking, and thermal cracking in asphalt-surfaced pavements, joint faulting and transverse cracking in jointed plain concrete pavements, and punchouts in continuously reinforced concrete pavements. In addition, pavement smoothness (IRI) is analyzed for all the pavement types. The design procedure verifies whether the pavement structure will sustain the prevailing traffic loads and climatic conditions without exceeding the design limits. If the trial design meets the performance criteria, a feasible design has been reached. If not, the designer can modify the trial design as needed until the criteria are met.