Asphalt Paving Design Guide

prepared for the

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PREFACE

APAO Design Guide

This guide is published by the Asphalt Pavement Association of Oregon (APAO) for the use and benefit of designers. It covers a number of applications, including streets and driveways, commercial and industrial facilities and specialty applications such as bikeways, cart paths, tennis courts and tracks. Recent additions include chapters on Life Cycle Cost, Intersection Design, and Porous Pavements for Commercial Facilities.

The manual contains the necessary information to allow the user to do the following:

1) Select and specify the correct asphalt concrete mix for a given application.
2) Select and specify the most appropriate asphalt binder for the application and climate.
3) Select and specify the most appropriate mix design method and criteria for the application.
4) Select the appropriate structural design inputs and perform a structural design.
5) Select the appropriate construction specification for the application.
6) Understand the importance of planning for pavement maintenance, the various maintenance techniques available, and the optimum timing for the maintenance treatments.

The procedures and guidelines provided in this manual are consistent wherever possible with those provided in the Oregon Standard Specifications for Construction. The Oregon Standard Specifications for Construction is the result of a joint effort by the American Public Works Association (APWA), the Oregon Department of Transportation (ODOT) and the construction industry. Its purpose is to provide more uniform and consistent specifications and standards for all public works projects in Oregon. This design guide is consistent with the standard specification and covers the applications not included in the Oregon Standard Specifications for Construction.

Use of this manual will result in improved asphalt pavement quality and performance throughout the state of Oregon.

The Asphalt Pavement Association of Oregon (APAO)

The Asphalt Pavement Association of Oregon is a non-profit trade association representing contractors and associated firms. APAO was formed in 1969 by a small group of asphalt paving contractors to develop improved specifications and products. The Association and its members are dedicated to promoting asphalt pavements by developing programs to enhance quality and excellence in all aspects of asphalt technology.

The Association is actively involved in providing state of the practice training and education for members and customers and to develop manuals such as this one to improve the quality of asphalt pavements throughout the state.

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CHAPTER 1

Introduction

1.0 INTRODUCTION

1.1 DESIRABLE CHARACTERISTICS OF PAVEMENTS

Owners of pavements are interested in having pavements that possess the following char-acter-istics:

Smoothness. The public demands smooth pavements with a quiet ride. A recent Federal Highway Administration (FHWA) survey (1996) indicated ride to be the most important feature to users of pavements.

Durability. Agencies and private owners of pavements want them to withstand the detri-mental effects of traffic and environment for their expected service lives.

Safety. Users expect the pavements they operate on to be safe. They should offer good skid resistance, be free of surface defects, provide contrast for lane markings, minimize splash and spray and pavement glare, etc.

Aesthetics. Users of pavements are also concerned with the appearance of the pavement surface. Patches and other irregu-larities in the surface indicate the pavement is not durable and often results in roughness/ safety problems.

Pavements are generally asphalt or portland cement concrete surfaced (Fig. 1.1). This manual is a design guide for asphalt surfaced roads, but also briefly covers maintenance and rehabilitation of both asphalt and portland cement concrete surface roads.

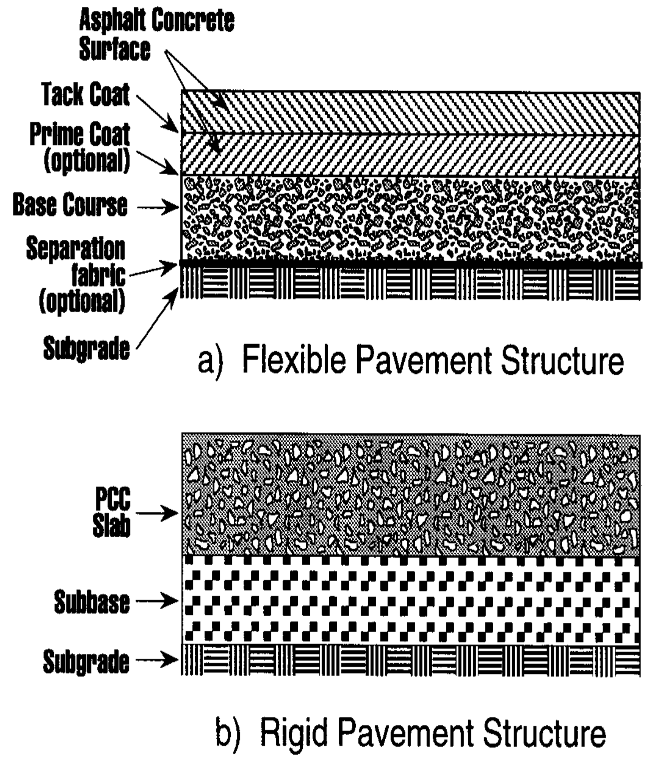

Figure 1.1 Typical Pavement Structures

1.2 ATTRIBUTES OF ASPHALT PAVEMENTS

Paving with asphalt offers several advantages including:

Stage construction. A major advantage of asphalt pavements is the potential for stage construction. The asphalt base course can be placed and used under traffic during initial construction and can then be overlaid with the final surface courses. Stage construc-tion can be used to improve on-site conditions and provide a place to store construction materials and equip-ment. It also provides an opportunity to discover and correct unanticipated problem areas such as weak subgrades, poor drainage or poorly com-pacted trenches, which can be repaired before the asphalt course is placed.

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Constructability. Asphalt pavements are machine placed and can be used by traffic almost immediately; no delay is required to allow the pavement to cure. Repair and main-tenance of asphalt surfaces is also quick and relatively easy.

Economics. Asphalt pavements are cost effective. Their construction costs, as well as long life (when properly designed and con-structed), are important attributes. In addition, the time required to maintain and rehabilitate asphalt pavements reduces the user delays when compared with other pavement materials (NAPA, 1987).

Recyclability. A major attribute of asphalt pavements is its ability to be completely recycled. Not only can the aggregates be reused, but the asphalt binder retains much of its cementing properties and can also be reused in a mix. Both hot and cold recycling tech-niques have been used successfully. Recycled pavements have been shown to perform as well as virgin mixes in the field. Most of the hot mix plants in Oregon are capable of using reclaimed asphalt pavement (RAP).

Versatility. The versatility of asphalt is evident all across the state of Oregon and throughout the United States. Factories and schools, office parks and playgrounds, and the majority of our streets and roads are surfaced with asphalt, a clear testimony to its cost effectiveness, constructability and ease of maintenance.

Safety. Asphalt pavements provide safe walking or riding surfaces with good surface friction for all users. Open-graded mixes offer additional advantages for roads such as reduced splash and spray under wet condi-tions.

1.3 ORGANIZATION OF GUIDE

This design guide is organized into the following chapters:

Chapter 2.0 presents information on considera-tions for materials, mix selection, and mix design. The guide treats hot mixes only and provides specific guidelines for selecting mix types for various applications. Desirable properties (and specifica-tions) for both the asphalt binder and the aggregates are also discussed in this chapter. Lastly, the purpose of mix design is presented along with a discussion of the mix design tech-niques currently used in Oregon. Examples of the mix design process and the resulting job mix formula are also provided.

Chapter 3.0 presents practical information for the design of facilities including con-siderations for structural design, mix design, drainage and construction considerations. The manual is applicable for various pavement types ranging from conventional to full depth asphalt pave-ments and using recycled as well as permeable materials. Finally, it discusses the relation of pavement management to the design process.

Chapter 4.0 presents information on subgrade treatment for poor soils. The manual discusses soil stabilization (lime-modified soils, cement-modified soils and emulsion-modified soils), cut and cover, moisture – density and water control and the use of geotextiles.

Chapters 5.0 and 6.0 present informa-tion on the design of various facilities including streets, driveways, com-mercial facilities, industrial facilities (Chapter 5.0) and specialty recreational and environ-mental uses (Chapter 6.0). For each type of facility, information on general design consider-ations, thickness recom-men-da--tions, drainage consider-ations and con-struc-tion practices are provided.

Chapter 7.0 provides a brief introduction to the design of porous asphalt pavements for commercial facilities. More information of the design process for porous asphalt pavement facilities is anticipated to be available shortly. Updated information will be sent automatically to registered guide holders.

Chapter 8.0 presents information on high performance intersection design. This guide introduces the four fundamental steps to intersection design: 1) insuring structural adequacy, 2) selecting and controlling materials, 3) following proper construction practices, and 4) implementing the plan.

Chapter 9.0 presents information on life-cycle cost analysis (LCCA). It discusses how LCCA works and design inputs such as design options, analysis period, user costs and the level of detail. This chapter also introduces software programs as a means of evaluating life-cycle cost, but does not give specific software programs information.

· **Chapter 10.0** presents information on maintenance and rehabilitation of pavements. It begins with a discussion on how pavements wear out, and then discusses the need for planning for maintenance and rehabilitation activities. Various maintenance and rehabil-i-tation treat-ments are introduced. However, the design of these treatments is not addressed in this manual.

· **Chapter 11.0** provides information on specifications and what they should contain. It also includes the role of quality control and quality assurance. Lastly, it includes a discussion on dispute resolution procedures.

· ***Appendices.*** A series of appendices are included with the guide. Appendix A presents a glossary of terms used in the manual. Appendix B describes typical pavement distress types and identifies causes for each. Appendix C includes the Oregon Standard Specifications for Construction Section 00745 – Hot Mixed Asphalt Concrete (HMAC), which is referred to throughout the guide. Appendix D presents sample specifi-ca-tions for typical applications, both in CSI and general engineering formats. Appendix E includes the current specifications for asphalt materials (cements and emulsions) used in Oregon.

1.4 LIMITATIONS AND USE OF MANUAL

This guide is intended to be used by local agencies, architects, engineers and consultants who design and specify asphalt pavements for streets, driveways, parking facilities and recreational facilities. The guide is designed to determine the mix type and structural requirements to provide a durable and smooth riding surface. The manual is not intended for use in designing pavements subjected to heavy or unusual loads or requiring specialty mixes. These latter applications should be designed and specified by a pavement consultant.

The approach used in the development of the thickness recommendations is consistent with the pro-cedure used by the Oregon Department of Transportation (ODOT). It was developed by the American Association of State Highway and Transportation Officials (AASHTO) in 1993. For appli-cations not addressed in the guide, users are encouraged to contact a pavement engineering con-sul-tant. The Asphalt Pavement Association of Oregon (APAO) can direct you to appropriate pavement consultants. It is expected this guide will become the standard of practice for the design of asphalt pavements used as city streets, parking facilities and for recreational uses.

1.5 REFERENCES

American Association of State Highway and Transportation Officials, *Guide for Design of Pave-ment Structures*. 1993.

Federal Highway Administration, *National Highway User Survey*. May 1996.

NAPA, *Pavement Life Cycle Costing*. National Asphalt Pavement Association Promotional Series 20, April 1987.

Chapter 2

Considerations for Materials, Mix Selection and Mix Design

2.0 CONSIDERATION FOR MIX MATERIALS, MIX SELECTION AND MIX DESIGN

This chapter presents guidelines for selecting the materials used in asphalt mixtures including: asphalts, aggregates, and recycled asphalt pavement (RAP).This chapter also covers selection of the appropriate mixture type for a given application or environment. It also provides a brief description of mix design techniques used in Oregon together with what the user should expect from a mix design.

2.1 ASPHALT BINDER

Asphalt binders have been used in road construction for centuries. Although there are natural deposits of asphalt, most asphalt used today is produced through refining crude oil.

One of the characteristics (and advantages) of asphalt, as an engineering construction and maintenance material, is its great versatility. Although a semi-solid at ordinary temperatures, for mixing or placement purposes it may be changed to a liquid state. This is accomplished most commonly by elevating the temperature, thus producing a "hot mix." Other common means of liquefying include emulsifying (mixing with water) and/or adding other petroleum based solvents. These produce "cold mix" or "cold patch" materials. Regardless of how it is brought to a liquid state, asphalt is a strong cement that is very adhesive and highly waterproof. It is also highly resistant to most acids, alkalies and salts.

Desirable Asphalt Properties. Asphalt must provide in-service performance over a range of temperatures. During the hot summer months the material must remain in a semi-solid state to resist rutting. During the winter months the material must not become so brittle that it cracks from thermal contraction of the roadway. Because high and low temperatures change with geography, different grades of asphalt binder are available to cover different climates around Oregon and around the nation.

In general, asphalt binders can be placed into two categories; unmodified (or neat) and modified binders. Most neat asphalts will perform adequately over about a 92°C pavement temperature range between the summer highs and the winter lows. *Note*: This is pavement temperature and not air temperature. There are, however, many geographic locations in Oregon where the difference in high and low pavement temperatures will exceed the 92°C range. For these applications it is necessary to modify the asphalt binder to produce a "stretch" grade with an extended temperature performance range.

Modification is a manufacturing process which usually starts with softer base asphalt that will meet the required low temperature properties and then improves its high temperature stiffness by air blowing, acid modification, or polymer modification. These processes will add cost to the product.

Testing of Asphalt Properties. The Strategic Highway Research Program (SHRP) developed tests for measuring properties of liquid asphalts, many of which could not be measured previously. The tests, which determine whether the asphalt pavement will be prone to rutting and/or cracking, measure the durability properties, measure the high/intermediate temperature properties and measure low temperature properties. The following tests are used to determine the above-mentioned properties:

<u>DURABILITY PROPERTIES</u>.

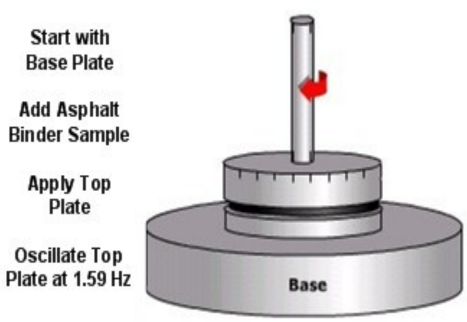
Rolling Thin Film Oven (RTFO). This device simulates the short-term aging that occurs during normal plant mixing and construction. A small amount of asphalt is poured into a bottle which is placed in a rotating oven rack for 75 minutes at 375°F. The rotating action causes the asphalt to coat the inside of the bottle in a very thin film. In addition, a stream of air is injected into the bottle during the oven process to enhance oxidation of the asphalt. The material is then recovered from the bottle and tested to determine the amount of hardening that occurred during the oven process. The specifications limit the amount of hardening during the process to preclude premature cracking of the asphalt.

Pressure Aging Vessel (PAV). This device simulates the long-term aging (5 to 10 years) that occurs while the pavement is exposed to elements during normal service. Small amounts of asphalt are place in thin layers in shallow metal pans and placed in a pressurized vessel at an elevated temperature (generally 300 psi and 210°F) for 20 hours. Again, the specifications limit the amount of hardening during the process to preclude premature age related cracking of the asphalt.

Pressure Aging Vessel (PAV)

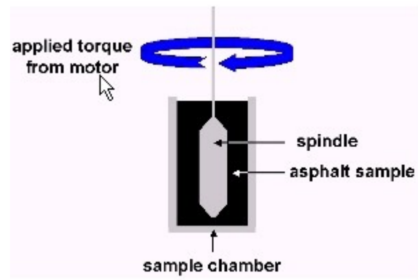
HIGH - INTERMEDIATE TEMPERATURE PROPERTIES.

Dynamic Shear Rheometer (DSR). This device measures the asphalt stiffness under cyclic torsional loading. It is intended to simulate the type of shear force a pavement would encounter under a vehicle traveling at 55 mph. An approximate dime size sample of asphalt is placed between to circular plates. The bottom plate is fixed and the top plate oscillates back and forth creating a shear force in the sample. The device measures the response of the sample to this sinusoidal loading of either fixed torque or fixed angular strain. This test is performed at the required high temperature for the grade of asphalt to preclude rutting and at intermediate temperatures (usually around 77°F) to preclude fatigue cracking.



Dynamic Shear Rheometer (DSR)

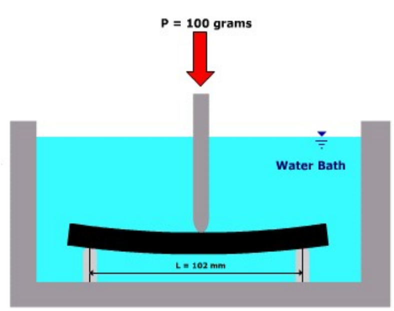
Rotational (Brookfield) Viscometer (RV). This device is used to measure the viscosity of the material at normal plant operating temperatures to insure there are no problems with handling, pumping, or mixing. A sample of the asphalt is placed in a test tube and heated to 275°F in a controlled temperature chamber. A small rotating spindle is immersed in the sample and the torsion required to rotate the spindle at 20 rpm is measured. Through the geometry of the spindle, the viscosity can be calculated.



Rotational (Brookfield) Viscometer (RV)

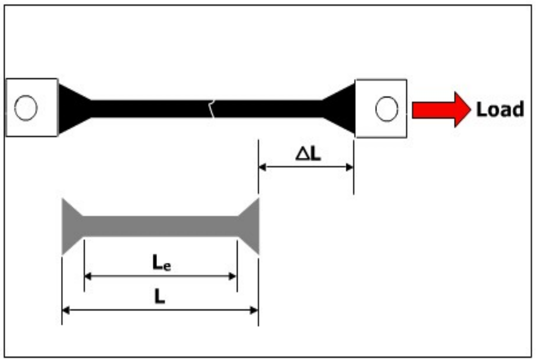
LOW TEMPERATURE PROPERTIES.

Bending Beam Rheometer (BBR). This device measures the creep stiffness of the asphalt at low temperature to preclude thermal cracking. A beam of asphalt (roughly the size of a stick of gum) is cooled to low temperature and simply supported on both ends. A known load is applied to the center of the beam and its deflections are measured over time. Using a constant load, a plot of the change in stiffness with time is generated. Two values come from the plotted data; the creep stiffness (S) at time equals 60 seconds and the slope (m) of the creep stiffness curve at time equals 60 seconds. The specifications set a maximum on creep stiffness (S) and a minimum on the slope (m).



Bending Beam Rheometer (BBR)

Direct Tension Tester (DTT). This device is an alternate test used in conjunction with the BBR when the material fails to meet the BBR requirements. Some asphalts exhibit large creep stiffness (S), yet remain ductile enough that they do not crack under normal thermal loading. Certain materials that exceed the creep stiffness (S) requirements of the BBR may be allowed if they meet the supplemental requirement of the DTT. Under this test a "dog bone" shaped sample of asphalt is loaded longitudinally under tension until it fails. Like the BBR, the test is run at low temperature. If the failure strain exceeds a specified minimum then the material is considered ductile and may be accepted under the specifications.



Direct Tension Tester

Classification of Asphalt Binders. The current system for specifying "hot mix" asphalt binders is the Superpave™ PG grading system developed by SHRP. PG stands for "performance graded" and reflects the testing discussed in the previous section. The system was devised to allow the user to select the appropriate PG grade based on the pavement service temperatures anticipated at the actual paving location.

PG grades are given as a set of two numbers (e.g. PG 64-22). For normal traffic, the two numbers represent the temperature range over which the binder will perform. The first number (64) represents the maximum average 7-day high temperature in °C that a pavement may achieve during its design life. The second number which includes the minus sign (-22) is the minimum single low temperature in °C that the pavement may achieve during its design life.

PG grades come in six degree increments and the common high temperature grades in Oregon are as follows:

64
70
76

The common low temperature grades in Oregon are as follows:

-22
-28
-34

Any high temperature grade may be paired with any low temperature grade (e.g. – PG 70-22 or PG 70-28).

Selecting the Correct PG Grade. The selection of the appropriate grade depends primarily on climate, traffic volume, and mix type (dense-graded vs. open-graded). However, for some applications, production costs and workability may also be considerations. Modified binders will typically cost more and therefore their added cost versus improved performance needs to be carefully evaluated.

Recommended PG Grades for Oregon. The PG specifications cover seven high temperature grades from 46 to 82 (in six degree increments) and seven low temperature grades from -10 to -40 (in six degree increments). In total there are 37 possible PG grades, however, because Oregon's climate does not require all 37 and to insure competitive prices, ODOT limits its list of grades to three high temperature grades and two low temperature grades. It is very important to select and specify binders from the same basic list used by ODOT. Those grades are as follows:

PG 64-22
PG 64-28
PG 70-22
PG 70-28
PG 76-22
PG 76-28

Of the grades listed generally only the PG 64-22 is a neat asphalt. The PG 64-28 and PG 70-22 both are at the 92°C range and depending on the supplier may be neat or modified. The remaining grades are generally modified asphalts.

The following guidelines are used by ODOT for selecting the appropriate grade for highway applications based on geography, traffic levels, and pavement type (e.g. – base course or wearing course):

Definitions:

Urban highway – A highway with slow moving traffic (less than 40 mph) or with traffic lights or other stops.

Rural highway – A highway outside of towns where traffic speeds normally exceed 40 mph and there are no traffic lights or other stops.

Dense-Graded Mixtures:

Western Oregon & Coastal Oregon below 2,500 ft. elevation (Willamette Valley and south to Cottage Grove, Columbia River Gorge east to Hood River, & Coast Range to Ocean)

Use PG 64-22 for:

Rural highways.

- Level 2 & 3 dense-graded base and wearing courses
- Level 4 base courses (below 4" depth)
- Urban highways.
- Level 3 & Level 4 base courses (below 4" depth)

Use PG 70-22 for:

Rural highways.

- All Level 4 dense-graded wearing courses
- Urban highways.
- Level 2, 3 & 4 dense-graded base and wearing courses

Southern Oregon below 2,500 ft. elevation (Cottage Grove south including Douglas, Josephine & Jackson Counties between the Coast Range and Cascades Foothills):

Use PG 64-22 or PG 70-22 for:

Rural Highways.

- Level 2 & Level 3 dense-graded base courses.
- Level 4 base courses (below 4" depth)

Use PG 70-22 for:

Rural Highways.

- Level 2, Level 3, & Level 4 dense-graded wearing courses

Urban Highways.

- Level 2, Level 3, & Level 4 dense-graded wearing courses

Urban (Critical) Highways.

- Level 3 base courses
- Level 4 base courses (below 4" depth)

Consider PG 76-22 for:

Urban (Critical) Highways.

- Level 3 Stop & Go Traffic wearing courses
- Level 4, I-5 Urban Designation Top 4" of wearing courses

Central & Eastern Oregon and Western/Southern Oregon above 2500 feet Elevation (Cascade & Siskiyou Mountains):

Use PG 64-28 for:

Rural Highways:

- Level 2 & 3 dense-graded base and wearing courses (< 3 million ESALs)

Urban Highways:

- Level 2 dense-graded base and wearing courses

Use PG 64-28 or PG 70-28 for:

Rural Highways.

- Level 3(> 3 million ESALs) dense-graded base courses
- Level 4 base courses (below 4" depth)

Urban Highways.

- Level 3 dense-graded base courses
- Level 4 base courses (below 4" depth)

Use PG 70-28 for:

Rural Highways.

- Level 3 (> 3 million ESALs) dense-graded wearing courses
- Level 4 dense-graded wearing courses
- Urban Highways.
- Level 3 & 4 dense-graded wearing courses
- Urban (Critical) Highways.
- Level 3 (> 3 million ESALs) dense-graded base courses. Consider for Ontario/Vale/Nyssa Stop & Go Traffic
- Level 4 base courses (below 4" depth)

Consider PG 76-28 for:

Urban (Critical) Highways.

- Level 3 dense-graded wearing courses. For Ontario/Vale/Nyssa Stop & Go Traffic
- Level 4 dense-graded wearing courses. For I-84 Urban Designation

Open-Graded Mixtures:

Note: For quantities of open-graded mixes below 2000 tons, the below listed "ER" designation may be waived.

Western Oregon to 2500 feet Elevation & Columbia River Gorge to Hood River:

Use PG 70-22 for:

- Level 2 open-graded mixes

Use PG 70-22ER for:

- Level 3 open-graded mixes.

Use PG 70-28ER for:

- Level 4 open-graded mixes.

Central and Eastern Oregon:

Use PG 70-28 for:

- Level 2 open-graded mixes

Use PG 70-28ER for:

- Level 3 & 4 open-graded mixes

Reliability Considerations. It should be noted that the above guidelines recommend a low temperature grade of -28 for central and eastern Oregon and those areas above 2500 ft. elevation in western Oregon. This is to mitigate thermal cracking during periods of cold temperatures.

However, in many locations -28 may be too conservative and may not provide the most economical binder for a given application.

Both high and low temperature grade recommendations are based on the probability that the specified pavement temperatures will not be exceeded during a typical 20-year design life for a pavement.

Reliability is the term used to describe the probability that an event won't occur. As an example, when a pavement temperature of -22 is assigned a 95% reliability it means that the weather history for that locations suggests that in 19 out of 20 years the pavement temperature will not drop below -22°C.

Designers are given the latitude to choose the design reliability for a given grade of asphalt binder. A designer may decide that a low volume rural road may only require a 50% reliability that the temperatures will exceed the grade selected during the design life. Conversely, for a high volume urban arterial, a designer may choose to design with 98% reliability.

	Cold Temperature Reliability		
City	**- 22° C**	**- 28° C**	**- 34° C**
Baker City	74%	97%	> 98%
Bend	92%	98%	--
Burns	68%	95%	> 98%
Klamath Falls	97%	> 98%	--
LaGrande	94%	98%	--
Lakeview	96%	> 98%	--
Madras	94%	> 98%	--
Pendleton	93%	98%	--
Ontario	92%	98%	--
The Dalles	98%	--	--

Table 2.1 Cold Temperature Reliability Levels for Selected Cities in Central and Eastern Oregon

Table 2.1 shows the actual reliability for three different low temperature grades (-22, -28, and -34) for several of the major communities in central and eastern Oregon.

Example: In Bend there is a 92% chance that the pavement temperature will not drop below -22 °C in any 20 year period. The reliability jumps to 98% that the pavement will never drop below -28 °C and is virtually guaranteed never to reach -34 °C.

ODOT selects 98% reliability for its facilities because of high traffic volumes. Local agencies and private owners may tolerate lower reliability because it may be more cost effective to accept some small increase in risk.

Workability and Other Considerations. Selecting the proper PG grade of binder purely on geography is appropriate for large scale public works applications which are designed to accommodate heavy traffic. However, for many private and other commercial applications, other considerations may impact the PG grade selection.

Workability is an important issue when choosing a neat versus modified asphalt, particularly polymer modified asphalts. Polymers make the hot mix "stringy" and taffy-like. This makes handwork very difficult. Therefore, jobs where matching objects such as manholes, inlet boxes, light pole bases, or areas of restricted access requiring significant handwork, should avoid using polymer modified asphalts.

When handwork becomes difficult, the resultant mix is often segregated creating a porous texture with high permeability. These areas tend to exhibit early loss of performance through stripping, raveling, or loss of underlying support.

Cost is another important issue for many small private or commercial applications. Modified asphalts will be more expensive due to manufacturing and handling costs. These added costs may not be offset by the added benefits they are intended to produce. Particularly concerns about rutting on private facilities that will never see significant heavy traffic.

Grade Bumping. The PG grading system is based on normal traffic operating at highway speeds (above 40 mph). If traffic is operating at slower speeds or has high volumes of heavy trucks, then AASHTO recommends bumping the high temperature grade by one or two increments. The recommendations are as follows:

Top 2 inches of pavement:

- Normal traffic volume operating between 12 to 42 mph; increase high temperature grade by one increment.
- Normal traffic volume operating below 12 mph; increase the high temperature grade by two increments.

or

- Heavy traffic above 10 million ESAL's; increase high temperature grade by one increment.
- Heavy traffic above 30 million ESAL's; increase high temperature grade by two increments.

Pavement below the top 2 inches:

- Heavy traffic above 30 million ESAL's; increase high temperature grade by one increments.

Note: The PG grades recommended under the ODOT guidelines may already have one or more "bumps" built into them for a given location. Recall there are 37 possible grades under the PG system, however, ODOT chose only 6 of them to keep costs down.

Many areas on the coast only require a PG 52, however the lowest grade readily available is a PG 64 which would be a double bump. Therefore, it is not necessary to specify additional bumps for slow or heavy traffic on the coast.

Conversely, southern Oregon generally requires a PG 64 and a combination of slow and heavy traffic may require bumping to PG 76. Check with ODOT or the APAO for availability prior to specifying a PG 76 grade binder.

Specifying an Elastomer Modified (ER) Binder. When a binder must be modified to meet a large temperature range (>92° C), the SuperPave™ system leaves it up to the manufacturer to select the modification method (e.g. air blowing, acid modification, etc.).

For some applications, however, it may be desirable to restrict the manufacturer to using an elastomeric polymer modification system only. This is generally the case when draindown is an issue such as with open-graded mixes. Elastomers are simply polymers that exhibit rubber like properties at room temperature. Elastomers are the most common type of polymer used in the modification of asphalt binders.

To preclude other types of modifications systems, the PG grade is given an "ER" designation (e.g. PG 70-22ER). The "ER" stands for elastic recovery and refers to a laboratory test which tests the rubber like properties of the binder.

ER grades have been shown to reduce fatigue cracking and reduce rutting. However, the added cost and workability issues should be weighed against any potential increase in performance when electing to use a polymer modified binder.

Impact of Recycled Asphalt Pavement (RAP) on Binder Grade Selection. The use of RAP in HMAC mixtures is widespread in Oregon and has been a huge success story. Improvements in plant technology and mix design processes have combined to make RAP a very important constituent in the production of HMAC.

RAP comes with its own asphalt binder which has its own set of binder properties. Any new oil added to the mixture will be impacted by the existing oil from the RAP. If the mixture contains a significant amount of RAP, then adjustments should be made to the PG grade selection to account for the blending of the two oils.

Generally oil on the RAP has been in service for many years and has stiffened with time. For low RAP percentages (20% or less) this effect is minimal and generally ignored when specifying the PG grade of the new oil to be added to the mix.

However, as percentage of RAP increases, it may be necessary to select a softer PG grade of the new oil to offset the effect of the aged oil in the RAP. The concern is primarily cold temperature cracking and loss of fatigue life if the mix becomes too stiff.

Current ODOT guidelines allow up to 30% RAP in dense-graded mixes with no requirements to alter the specified PG grade. ODOT however, typically is dealing with very thick pavement sections (> 6 inches) with relatively low deflections.

Most local agency and commercial work does not require very thick sections and therefore, using a softer grade of asphalt is appropriate when more than 20% RAP is to be used in the mixture. The softer grade of asphalt will offset any stiffening from the RAP oil and help to mitigate fatigue damage due to the higher deflections experienced in these typically thinner sections (< 6 inches).

- When using 20% or less RAP do not adjust the grade of binder recommended for your application.
- When using more than 20% RAP and "one grade bump" is warranted, do not "grade bump" use the grade originally required for that geographical location.
- When using more than 20% RAP and a "double grade bump" is warranted, make only a single "grade bump. It is recommended that rut testing be performed on these mixes.
- When using more than 20% RAP and no grade bumping is required, then lower the high temperature grade by one step. Do not go below a PG 64-22 grade.

Because the low temperature grade is conservative for most locations in Oregon, it is not recommended to drop the low temperature grade.

Example: A PG 70-22 is specified for a commercial project in which the producer wishes to use 25% RAP. No grade bumping due to traffic loading is required. The recommendation is to use oil that is one high temperature grade softer than specified or a PG 64-22.

2.2 AGGREGATES

Aggregates used in asphalt mixes are hard, inert materials such as crushed gravel and stone. Properly selected and graded aggregates are mixed with the asphalt cement to form asphalt mixes. Aggregates form the principal load carrying component of the mix and total 90 to 95 percent of the mixture by weight (75 to 85 percent by volume).

Types of Aggregates. Paving aggregates are often classified according to source or means of preparation. Following are brief descriptions of the various classifications.

Pit or bank-run aggregates. Both sand and gravel are pit or bank-run natural aggregates. They are usually screened to proper size and washed before being used in paving construction.

Processed aggregates. When natural or bank-run aggregate has been crushed and screened to make it suitable for asphalt mixes, it is considered a processed aggregate. Crushing typically improves the particle shape (by making the rounded particles more angular) and the surface texture (by making the surface rougher).

Quarry aggregates. Paving aggregates are also produced by removing sound rock from the face of the quarry (by blasting or other means) and then crushing and sizing the materials to produce the desired construction material. Quarry aggregates, because of their rough texture and angular shape, often result in higher stability mixes.

Synthetic aggregates. Aggregates produced by altering both the physical and chemical properties of the parent material are called synthetic (or artificial) aggregates. Although not widely used in Oregon, these aggregates can be produced specifically for use as aggregates (e.g., expanded clays) or are by-products of manufacturing and a final burning process (e.g., blast furnace slag).

Desirable Aggregate Properties. Selection of an aggre-gate material for use in an asphalt concrete pavement depends on the availability, cost, and quality of the material, as well as the type of construction for which it is intended. The suitability of aggregates used in asphalt construction are evaluated in terms of the following properties.

Size and grading. The maximum size of an aggregate is the smallest sieve through which 100 percent of the material will pass. The asphalt concrete use determines not only the maximum aggregate size, but also the desired gradation (distribution of sizes smaller than the maximum). The nominal maximum size is used to specify the aggregate gradation. It is the standard sieve at which 90-95 percent of the aggregate passes this dimension.

Durability. Toughness or hardness is the ability of the aggregate to resist crushing or disintegration during mixing, placing, compact-ing, and under traffic loading.

Soundness. Although similar to durability, soundness is the aggregate's ability to resist deterioration caused by natural elements such as the weather.

Particle shape and texture. The shape of aggregate particles influence the asphalt mixture's overall strength and workability as well as the density achieved during com-pac-tion. When compacted, irregular particles such as crushed stone tend to "lock" together and resist displace-ment.

Workability and pavement strength are influenced by surface texture. A rough, sand-- papery texture results in a higher strength than a smooth texture. Although smooth faced aggregates are easy to coat with an asphalt film, they are generally not as good as rough surfaces. It is harder for the asphalt to "grip" the smooth surface.

Cleanliness. Foreign or deleterious sub-stances make some materials unsuitable for paving mixtures.

Absorption. The porosity of an aggregate permits the aggregate to absorb asphalt and form a bond between the particle and the asphalt. A degree of porosity is desired, but aggregates that are highly absorbent are generally not used.

Moisture sensitivity. When the asphalt film separates from the aggregate because of the action of water, it is called stripping. Aggregates coated with too much dust also can cause poor bonding which results in stripping. Aggre-gates readily susceptible to stripping action usually are not suitable for asphalt paving mixtures unless an anti-stripping agent is used.

Appendix C provides requirements for each of these properties. It is important that all aggregate properties meet specifications to insure good pavement performance.

2.3 ASPHALT MIX TYPES

This guide is applicable to both dense-graded and open-graded asphalt mixes, mixtures of asphalt binder and aggregate. In this guide, asphalt mixes refer to hot plant mixtures of asphalt cement, aggregates, and additives as required. The applicable mixes range from 3/8” to 3/4" nominal size for both dense and open-graded mixes. Although other mix types are available and used in Oregon (e.g., 1” nominal size, Stone Matrix Asphalt, etc.), they are generally not appropriate for the pavements considered in this guide.

Table 2.2 summarizes the broadband limits for the mix types included in Section 00745 of the Oregon Standard Specifications for Construction. This table also includes a 3/8” open gradation which is not included in Section 00745. The dense gradations in Table 2.2 provide broad guidance for acceptable gradations. It is the job of the mix designer to develop a gradation that meets all of the criteria for a given application. Within these broadband limits, a designer can develop both fine and coarse textured dense-graded mixes. Table 2.3 provides a definition for coarse versus fine graded mixes.

In general, coarse graded mixes will have a more open looking surface texture, provide greater rut resistance and better frictional characteristics. Coarse graded mixes are best used in higher speed applications where heavy loads are anticipated

Fine graded mixes can also provide excellent stability and rut resistance if properly designed. Fine graded mixes will have a tighter surface texture and are well suited for parking lots, city streets and specialty pavement applications. Recommendations for appropriate mix types for a given application are given in Chapters 5.0 and 6.0 of this guide.

Table 2.2 Broadband Limits for Dense- and Open-Graded Mix Types

	Dense-Graded Mixes			Open-Graded Mixes			
Sieve Size	**3/4" Nominal Size**	**1/2" Nominal Size**	**3/8” Nominal Size**	**3/4" Open**	**1/2" Open**	**3/8” Open**	**3/4" ATPB**
1"	100			99-100			99-100
3/4"	90-100	100		85-96	99-100		85-95
1/2"		90-100	100	55-71	90-98	99-100	35-68
3/8"			90-100	32-50	49-64	90-100	14-36
#4				10-24	18-32	22-40	2-10
#8	23-49	28-58	32-67	6-16	3-15	5-15	0-5
#200	2-8	2-10	2-10	1-6	1-5	1.0-5.0	0-2
% Asphalt Cement	4-8	4-8	4-8	4-8	4-8	4-8	2.5-3.5

Table 2.3 Definition of Fine and Coarse Dense-Graded Mixtures

Mixture NMS	Coarse Graded	Fine Graded
1 1/2"	<35% Passing No. 4 Sieve	>35% Passing No. 4 Sieve
1"	<40% Passing No. 4 Sieve	>40% Passing No. 4 Sieve
3/4"	<35% Passing No. 8 Sieve	>35% Passing No. 8 Sieve
1/2"	<40% Passing No. 8 Sieve	>40% Passing No. 8 Sieve
3/8"	<45% Passing No. 8 Sieve	>45% Passing No. 8 Sieve
No. 4 Sieve	N/A (No standard Superpave gradation)	

2.4 SELECTING MIX TYPE

Basic Considerations. The user needs to consider a number of factors when selecting a mix type for a given application. Factors that must be considered include the following:

Surface appearance (texture). Depending on the application, the owner may want a smooth (walkways, recreational areas) or a rough (streets, highways) textured pave-ment surface. The finer dense-graded mixes (fine graded 3/8” to 1/2" nominal size) will produce tighter textural surfaces. They will also be less susceptible to segregation (localized coarse texture areas) caused by hand work (raking and shoveling the mix). For applications requiring significant amounts of hard work, a fine graded 3/8” or 3/4” mix is preferred.

Rut Resistance. Certain applications (com-mer-cial and industrial facilities) will require a highly stable mix to minimize rutting and shoving under heavy loads. Coarse graded 1/2" and 3/4" mixes are generally best for these applications. For others (e.g., recreational areas and private driveways), stability requirements may be less.

Drainage. Depending on the requirements, drainage of the pavement surface can be accomplished using either a dense- or open-graded mix. If a dense-graded mix is used, the surface must be sloped to allow the water to travel to drainage facilities. If open-graded (or porous) mixes are used, the water will pass through the pavement and must be collected or stored in underground drainage facilities. The asphalt treated permeable base (ATPB) broadband is given in Table 2.2. This mix has very high permeability and is used where rapid removal of water is required.

Permeability. Selecting the appropriate mix type, mix design and lift thickness combination is critical to performance. Mix type, design and lift thickness all have a direct effect on the ability of a contractor to compact asphalt in the field to appropriate densities, which in turn, will dictate the performance. Recent research has shown the relationship between mix types, in-place air voids and permeability.

This relationship is illustrated in Figure 2.1. As can be seen from this figure, a 3/4” mix is very permeable at 92 percent density. Whereas a 1/2” mix becomes impermeable at about 92 percent density and a 3/8” mix at even lower densities. It is very important for a mix to be impermeable. Permeable mixes will oxidize more rapidly, resulting in early cracking and loss of fatigue life. They are also more susceptible to moisture induced damage. For these reasons a 3/4" mix should not be used as a wearing surface for applications covered in this guide. The 3/4" mix may be used as a base coarse if placed in lifts of 2-1/2 inches or more and if covered with at least 2 inches of 1/2" or 1-1/2’ of 3/8” mix.

Lift Thickness. Maximum nominal aggregate size generally controls the minimum lift thickness that can be used.

It is very important to meet or exceed these minimum lift thicknesses. Research and experience has shown that optimum compaction occurs when the ratio of lift thickness (D) to Nominal Maximum Aggregate Size (NMAS) is equal to or great than 4. In no case should D/NMAS drop below 3. For single lifts over aggregate D/NMAS should be a minimum of 4. Lift thickness is also important in heat retention for compaction. Table 2.4 summarizes these recommendations.

Thick Lifts. Full depth or deep strength pavements should be built with the minimum number of lifts (maximum) lift thickness possible. This will generally result in the best compaction and the fewest lift lines. In most cases the practical upper limit for lift thickness is 4 inches. Modern rollers meeting Oregon DOT specification have no problem compacting a 4inch lift. Surface lifts should be limited to 3 inches or less (2 to 2-1/2” is ideal) to facilitate getting good smoothness and grade matches.

Finally, it should be noted that the selection and use of nonstandard mixes for small jobs should normally be avoided. They are simply not cost effective.

Guidelines. It is very important that the mix types be matched to the intended use. For example, mixes designed by ODOT for highways are not generally well suited for the uses described in this guide. Recommendations for mix type for the specific applications are given in Chapters 5.0 and 6.0.

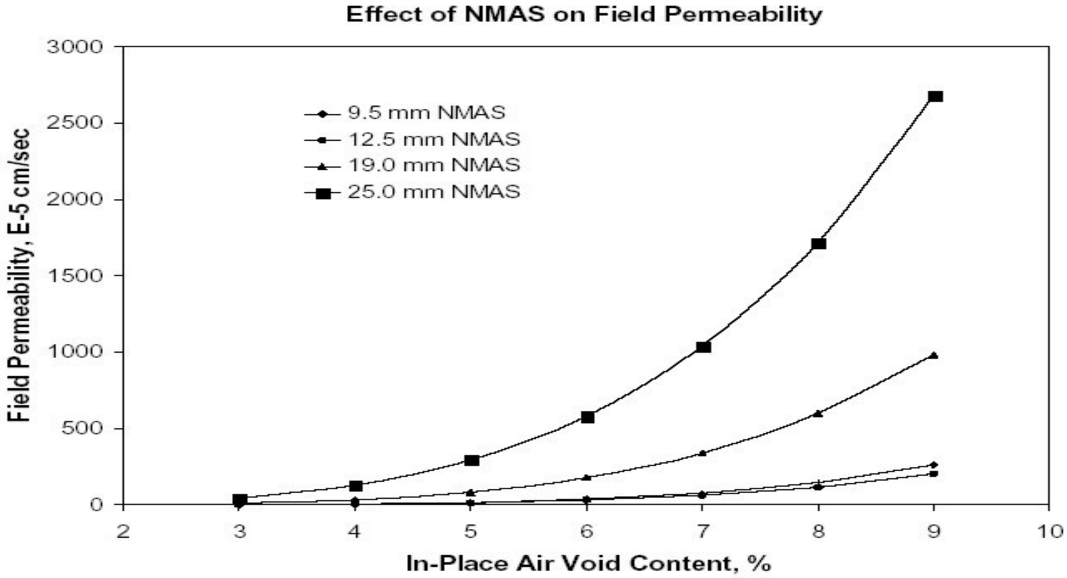


Figure 2.1 Effect on NMAS on Field Characteristics of HMA pavements

TABLE 2.4 Recommended Compacted Lift Thickness for Dense Graded Mixes

Mix Type (NMAS)	Recommended Lift Thickness D		
	Single or 1st Lift	Minimum	Optimum
3/8" Dense	1-1/2"	1-1/8"	1-1/2"
1/2" Dense	2"	1-1/2"	2"
3/4" Dense	3"	2-1/4"	3"

2.5 MIX DESIGN PROCEDURES

The object of producing a mix design is to determine the optimum blend of aggregates and asphalt for a specific source of these materials. To produce an asphalt mix design, asphalt cement and aggregate are blended together in the laboratory. The characteristics of each component, the relative proportion of these two materials and the air void content of the compacted mix determine the physical properties of the mix.

For the Oregon Standard Specifications for Construction, the mix levels are characterized as follows:

Level 1 HMAC (0-30,000 EALs). These mixes are for use with very low traffic and only limited exposure to trucks. They are usually used for private driveways, light parking lots, cul-de-sacs and recreational areas.

Level 2 HMAC (< 3 million EALs). These mixes are used in applications with moderate traffic volumes and moderate volume truck traffic. Applications would include country roads, residential, collector and minor arterial streets and light commercial parking lots.

Level 3 HMAC (3 – 30 million EALs). These mixes would be used in applications exposed to moderate to heavy truck traffic. Typical applications include major arterials, state highways and heavy commercial parking lots.

Level 4 HMAC (>30 million EALs). These mixes are for use in applications exposed to very heavy traffic. This would be used only on the highest volume state highways and on interstates.

A suitable mix design is very important to produce a well performing, long lasting pavement structure.

Asphalt mixtures should be properly designed to obtain the following desirable mix properties:

- Resistance to Permanent Deformation (Rutting) – The mix should not distort or displace when subjected to heavy traffic especially when temperatures are elevated.
- Fatigue Resistance – The mix should not crack when subjected to repeated loads over a period of time.
- Resistance to Low-Temperature Cracking – The mix should not crack during low or freezing temperatures.

- Durability – The mix must contain a sufficient amount of asphalt binder to ensure film coverage of all the aggregate. This will minimize picking or raveling of the mix.
- Resistance to Moisture Induced Damage – The mix should be resistant to stripping, which is the loss of adhesion between the aggregate and binder due to water intrusion.
- Skid Resistance – The mix should be designed to provide adequate resistance to skidding in order to permit normal turning and braking.
- Workability – The mix must be capable of being placed and compacted with reasonable effort.

Before discussing the methods of mix design, it is important to understand a few common definitions.

Effective Asphalt Content, P_{be}, is the total asphalt content of a paving mixture excluding the portion of asphalt lost by absorption into the aggregate particles. P_{be} is expressed as a percentage and is a measure of the "non-absorbed" or free asphalt available to bind the aggregate particles together. Generally, for typical Oregon mixes P_{be} should be in the 4.5 to 5.5 percent range. (Note: P_{be} is a percent of total mass. Effective asphalt as a percent of volume is typically 9 to 12 percent).

Air Voids, V_a, is the total volume of air pockets between the coated aggregate particles in a compacted mix. This is expressed as a percent of the bulk volume of the compacted mix. Air voids act as pneumatic "shock absorbers" to allow some expansion and contraction of the asphalt pavement without damaging the integrity of the material. Designing the correct air voids is an essential first step in constructing a well performing pavement. Typical Oregon mixes should be designed to have 4.0 percent air voids.

Voids in the Mineral Aggregate, VMA, refers to the volume of intergranular void space between the aggregate particles of a compacted mix. The value is expressed as a percent of the total sample volume. VMA is essentially the space between the aggregate particles that is available for the effective asphalt and the air voids. To accommodate 4.0 percent air voids and 9.0 to 12.0 percent effective asphalt (by volume), typical Oregon mixes should have 13.0 to 16.0 percent VMA.

Voids Filled with Asphalt, VFA, refers to the portion of the intergranular void space between the aggregate particles that is occupied by the effective asphalt. VFA is a measure of the relative proportion by volume of effective asphalt and air voids. In other words, how much of the space between the aggregate (VMA) is filled with asphalt and how much is air voids. Typical mixes in Oregon will have VFA's in the 70 percent range. This means the space between the aggregate is 70 percent filled with asphalt and 30 percent with air voids.

The goal of mix design is to determine the correct gradation to give the desired space between the aggregate (VMA). Then to determine the correct amount of asphalt to allow for absorption into the aggregate and to fill the available space leaving 4.0 percent air voids.

The key to understanding mix design is to recognize that the designer is attempting to model the mixture properties in a compacted state for your application two to three years after the pavement has been in service. For most applications, well designed asphalt pavement will continue to densify under traffic loading for the first two to three years. This process is known as secondary compaction and should gradually stop as the mix approaches the design air voids. This design system will only work if the designer has reliable information on the traffic loading predicted for a particular application.

The current method of mix design used in Oregon is the Superpave™ method. Details of the Superpave™ method can be found in the Asphalt Institute Manual SP-2.

It is important that the mix design be performed by technicians certified by ODOT's mix design certification program. Improper mix designs can result in early pavement problems.

Superpave™ Method. This method, developed as a part of the Strategic Highway Research Program, was adopted by ODOT beginning in the 1998 construction season for all dense-graded mix designs. The volu-metric mix design procedure includes the following steps, which are discussed in more detail below:

- Selection of component materials;
- Selection of the design aggregate structure;
- Selection of the design asphalt binder content;
- Evaluation of the mix for moisture sensitivity and mix stability.

The first step includes selecting the asphalt binder, aggregates and modifiers for the mix design. Sections 2.1 and 2.2 of this design guide provide details on choosing the correct asphalt binder, aggregate and whether modifiers will be necessary.

To select the design aggregate structure, trial blends are established by combining the gradations of individual stockpiles into a single gradation. The blended gradation is compared to the specification control requirements for the appropriate sieve. Table_2.2 gives the gradation limits for dense- and open- graded mixes in Oregon.

Once the aggregate structure is selected, specimens are compacted at varying asphalt binder contents. The mix properties are evaluated to determine the design asphalt binder content. Four different asphalt contents are required to perform a Superpave mix design.

The third step in the Superpave mix design method is to evaluate the moisture sensitivity of the proposed mix using AASHTO T283. Moisture sensitivity is measured by fabricating an even numbered set of compacted specimens at the design gradation and asphalt content (typically 6 or 8 specimens). These specimens are subdivided into two groups; a control group and a group to be conditioned. The control group is set aside and later tested in its original state. The conditioned set is placed in a 140°F water bath for 24 hours in an attempt to weaken the bond between the asphalt and the aggregate. Both sets are then measured for average tensile strength. The conditioned set must maintain at least 80 percent of the tensile strength of the control set.

Finally, ODOT uses AASHTO TP63 rut testing to evaluate Level 3 and 4 mixtures for stability. Mixture samples are subjected to 8000 repetitions with a 100 lb load to determine rut susceptibility.

One of the key components in the Superpave™ system is the gyratory compacter. The compaction effort or number of gyrations of compaction at design (N_{design}) for the Superpave™ compactor is varied to allow for different levels of compaction for different traffic loading. The various design gyrations used for Superpave™ are shown in Table 2.5 for different traffic loads.

Laboratory vs. Field Mix Compaction.

The gyratory compactor is also used during mixture production to compact asphalt concrete specimens in the laboratory. The purpose of any lab compaction process is to simulate, as closely as possible, the degree of density produced in the field by the rollers and secondary compaction under traffic. This simulation includes such factors as air void content, aggregate particle orientation and void distribution.

The compaction process in the laboratory is very quick, usually completed within 2 or 3 minutes. This is in direct contrast to actual roller operations in the field, which use a variety of roller combinations, roller passes, and roller patterns and in which final density levels might not be attained until 30 minutes or longer after the mix is placed by the paver. Also, during the laboratory compaction process, the mixture temperature is relatively constant. During construction, the temperature of the material is continually decreasing with time. In the laboratory, the compaction effort is usually applied to the mix at 284°F to 320°F. In the field, the mix may cool to 175°F or less before the compaction process is completed.

In the laboratory, the asphalt mix is compacted against a solid foundation, whereas in the field a variety of base types and stiffnesses are encountered. An asphalt mix can be placed as part of a newly constructed pavement as the first layer on top of a soft subgrade soil or as the surface course on a full depth asphalt concrete pavement structure. The material can be used as an overlay on a distressed asphalt pavement or as a resurfacing on a portland cement concrete (PCC) pavement. The ability to obtain a particular level of density in an asphalt mixture depends in part on the rigidity of the base being laid over and on the type of compaction equipment used. The differences between some pave-ment base conditions and laboratory base conditions can be significant. It may be necessary to use a test section to establish the compactive effort necessary to obtain specified density in the asphalt mix.

Summary.

Major differences between laboratory and plant mixes can exist in the gradation of the aggregates, the degree of hardening of the asphalt cement and the addition of fine aggregate from the emission control equipment. Therefore, the job mix formula produced in the laboratory should be treated only as an initial mix design, used primarily to pick an asphalt cement content.

The desired properties of the mix should be checked and verified using the plant produced, laboratory compacted asphalt mix. Tests should be run to determine the characteristics of the mix actually being manufactured (mix verification). This is discussed in more detail in Chapter 11.0 of this guide.

Traffic Load - EAL's (millions)	Compaction Gyrations - N_{design}
<0.3	65
0.3 - 3.0	65
3.0 - 30	80
> 30	100

Table 2.5 Recommended N_{design}

2.6 WHAT TO LOOK AT

The purpose of the mix design process is to select an asphalt type and content together with an aggregate gradation, which will yield the desired mix properties for the specific job application. As a user of the manual, you need not concern yourself with the details of the mix design process as long as it is performed by certified laboratory technicians. What you must be familiar with is what to ask for and what to look for in the mix design submitted. Table 2.6 shows the mix design criteria for the four mix design levels.

Summary. Upon completion of the mix design, make certain you receive the following:

1) Recommended job mix formula. This consists of the aggregate gradation and design asphalt content.
2) Mix must meet the design criteria given in Tables 2.3 and 2.5.
3) Recommended mixing and compaction temperatures for the asphalt mix must be provided.
4) Results of the tensile strength ratio (TSR). If the values are below the design criteria, an anti-strip additive should be recommended.
5) Results of the rut test for Level 3 and Level 4 mixtures

All of these items are contained in a mix design summary sheet (Table 2.7). In addition, make certain you obtain verification that the mix design was performed by a certified mix design technician. APAO has a list of certified technicians.

	Level 1	**Level 2**	**Level 3**	**Level 4**
Compaction Level	65 Gyrations	65 Gyrations	80 Gyrations	100 Gyrations
Air Voids, %	3.5	4.0	4.0	4.0
VMA, % minimum	1/2" – 14.0 3/8" – 15.0	3/4" - 13.0 1/2" – 14.0	3/4" - 13.0 1/2" – 14.0	3/4" - 13.0 1/2" – 14.0
VMA, % maximum	min + 2.0%	min + 2.0%	min + 2.0%	min + 2.0%
P No. 200/Eff. AC ratio	0.8 to 1.6	0.8 to 1.6	0.8 to 1.6	0.8 to 1.6
TSR, % minimum	80	80	80	80
VFA%	70-80 3/8" – 70-80	65-75 3/8" – 68-78	65-75 3/8" 68-78	65-75 3/8" 68-78

Table 2.6 Standards for HMAC Design Method Levels

If you have any questions with respect to the mix design don't hesitate to contact the APAO offices in Salem

2.7 REFERENCES

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Oregon Department of Transportation and American Public Works Association - Oregon Chapter, *Oregon Standard Specifications for Construction, Section 00745*, 2008.

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Table 2.7 Example Mix Design Summary Sheet

ODOT CONTRACTOR MIX DESIGN SUMMARY

PROJECT		MIX CLASS	
CONTRACT NO.		LEVEL (2,3,4)	
MIX PRODUCER		PROJECT MANAGER	
CMDT (print)		CMDT JMF MIX ID NO.	

AGGREGATE & OTHER CONSTITUENTS (RAP, BL. SAND, LIME, ETC.)

STOCKPILE SIZES							
SOURCE NUMBER							
STOCKPILE PERCENTAGE							
Bulk Specific Gravity (Gsb)							
Apparent Specific Gravity (Gsa)							

Design Developed with "dryback" Gmm (Y/N)? [ ]

MIXTURE AT DESIGN ASPHALT CONTENT

Maximum Specific Gravity (Gmm)	
Gyratory Bulk Gravity (Gmb)	
Air Voids, % (Va)	
VMA, %	
VFA, %	
Effective Asphalt Content, % (Pbe)	
P200 / Pbe Ratio	
Combined Aggregate (Gsb)	
Effective Specific Gravity (Gse)	
Combined Apparent Gravity (Gsa)	
Tensile Strength Ratio (TSR)	
TSR Compaction Blows	
VIR	
Absorbed Asphalt, % (Pba)	
APA Rut depth - mm	
Gmb Sample Weight @ JMF	
Number of Gyrations	
Draindown % (open graded)	
Date	
CMDT Signature	

JOB MIX FORMULA

Aggregate Gradation	
Sieve	
3/4" (19 mm)	
1/2" (12.5 mm)	
3/8" (9.5 mm)	
1/4" (6.3 mm)	
No. 4 (4.75 mm)	
No. 8 (2.36 mm)	
No. 16 (1.18 mm)	
No. 30 (0.60 mm)	
No. 50 (0.30 mm)	
No. 100 (0.150 mm)	
No. 200 (0.075 mm)	
Asphalt content, %	
Asphalt percent in RAP	
Antistrip, %	
Asphalt Brand	
Asphalt Grade	
Mixing temp. range	
Placement temp. range	
Asphalt SpGr (Gb) 77/77 F	
Asphalt SpGr (Gb) 60/60 F	

COMMENTS: BLEND CHOSEN? [ ] REASON? :

Chapter 3

Pavement Design Considerations

3.0 PAVEMENT DESGIN CONSIDERATIONS

3.1 DESIGN OVERVIEW

The flowchart shown in Figure 3.1 describes the pavement design process used in this manual. The flowchart identifies each of the principle components and the required inputs to complete the design. Each of the input areas is described more completely below. Before continuing, it is important that the users of this manual understand the limitations of the procedure described herein.

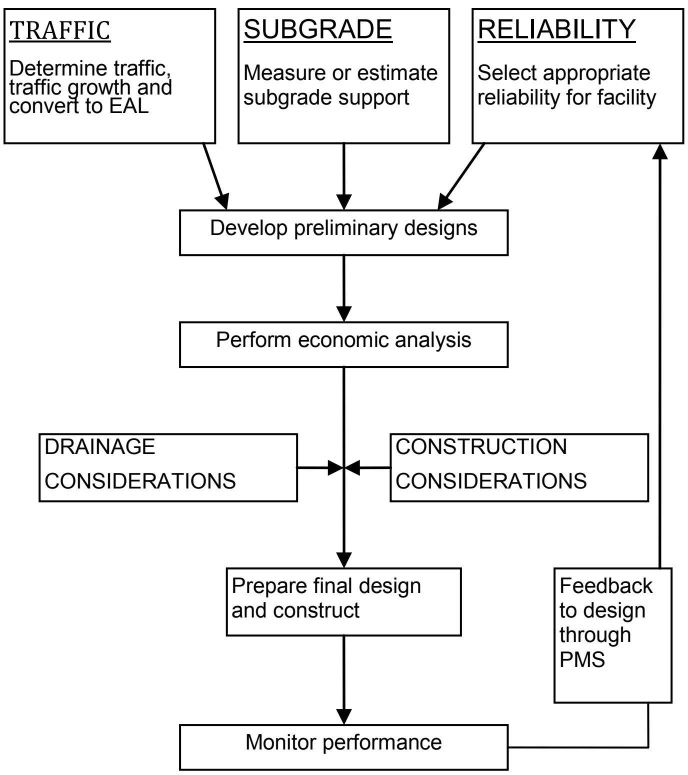


Figure 3.1—Flow Diagram for Pavement Design Process

Limitations. This guide is applicable to pavements carrying low to moderate traffic levels and considers several pavement types used in Oregon including:

- full depth asphalt pavements
- asphalt pavement surfaces with an untreated base course
- porous asphalt pavements that allow drainage of surface water.

Figures 3.2 through 3.4 illustrate the pavement types considered.

The full depth asphalt pavement is one in which asphalt mixtures are used for all courses above the subgrade. Such pavements are less affected by subgrade moisture and are conducive to staged construction. Full depth asphalt is used in all types of highway construction and where high volumes of traffic, particularly trucks, are anticipated.

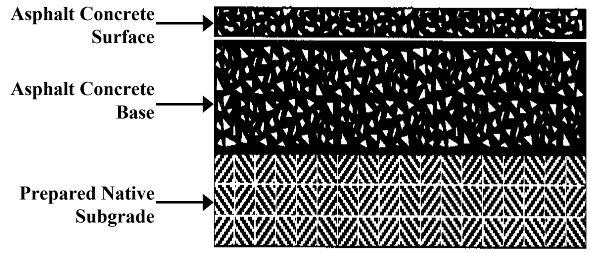


Figure 3.2—Full Depth Asphalt Pavement

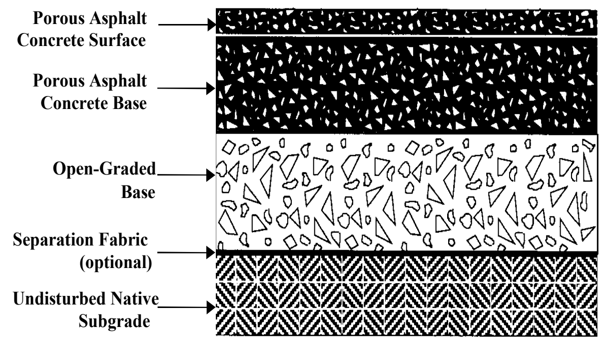


Figure 3.3—Conventional Asphalt Concrete Pavement

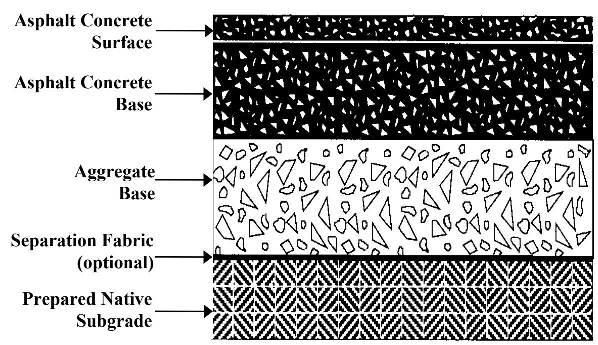


Figure 3.4—Porous Asphalt Concrete Pavement

Pavements with untreated aggregate base layers may be used where local aggregates and drainage conditions are suitable. The untreated aggregate base is placed and compacted on the prepared subgrade. In general, a dense-graded asphalt course and surface course are used to complete the pavement structure.

Bases constructed of compacted aggregates or asphalt-treated aggregate bases are considered; however, cement stabilized bases (CTB) are not covered in this manual. Transverse shrinkage cracks.

often occur in cement-treated bases and these cracks reflect through the asphalt surface layer. The exclusion of CTB should not prevent the designer from considering the use of low levels of cement (less than 3 percent) with fine-grained subgrade soils. This treatment may provide a good platform upon which to construct the base and subsequent layers.

Finally, the use of porous asphalt layers has been successful in urban areas and elsewhere. As shown in Figure 3.4, surface water passes through the asphalt layer. Use of porous pavements on highways is generally to reduce splash and spray. These types of surfaces are also widely used by ODOT, but they are placed on a dense impervious layer. The water passes through the porous mix and drains to the side on top of an underlying impervious asphalt mix. When properly designed and constructed, porous pavements have a load carrying capacity similar to a conventional pavement.

When used in urban areas to collect surface runoff, the pavement base serves as the reservoir for the collected water. These types of pavements are most feasible on parking areas with low truck traffic on sites with gentle slopes, permeable soils, and relatively deep water tables. The use of porous pavements may be particularly important in locations where landscape irrigation is anticipated. For these applications, the use of an engineering consultant is recommended.

Design Background. There are two basic approaches to structural design of HMA; Empirical and Mechanistic/Empirical (M/E). The most commonly used empirical method among agencies in the United States is the AASHTO procedure. The AASHTO procedure is the current standard in Oregon and is also used by ODOT. Mechanistic/empirical procedures have been in existence for many years, but have not been widely used in the past due to the extensive calculations required and lack of local calibration and testing. However, the rapid advancement of computer technology in the past 20 years has made mechanistic/empirical procedures much more practical. AASHTO recently released a new M/E design program called MEPDG-1. This program is being evaluated and calibrated by Oregon DOT for future use on ODOT projects. It will be phased in over time as state and local agencies acquire the training and develop the material inputs and local calibrations needed for full implementation. This guide uses the 1993 AASHTO Pavement Design Procedure to develop the structural design table. However, mechanistic/empirical analyses were performed as well to ensure optimum fatigue life would be achieved for each section. Following are brief discussions of the fundamental approaches of each design procedure.

AASHTO Procedure. The 1993 Pavement Design Guide is principally based on data collected from a large scale road test conducted in Ottawa, Illinois in the late 1950s.

The original design procedure (1959) has undergone several revisions over the last 40 years. The most substantial changes occurred with the release of the 1986 Guide. The 1993 Guide modified the procedures for rehabili-tating pavements, but did not make substantive changes to the "new" pavement design sections of the Guide.

The principal objective of the AASHTO pavement design procedure is to provide the public with smooth riding, functional, economical pavements over the design life of the facility. To meet this goal, the designer must know (estimate) the expected traffic and the material properties of each layer, including the subgrade. The designer must also accept that these values cannot be known absolutely and account for this uncertainty through the use of reliability factors. Each of these design inputs is discussed in more detail below.

Just as each of these design factors must be understood before proceeding with the design, it is important to understand how pavement performance and "failure" are defined under the AASHTO procedure. Pavement performance and failure are described using a present serviceability index (PSI). This concept attempts to track the ability of the pavement to serve the public, hence the term serviceability. Several surveys have shown that although many factors affect the public's perception of pavement quality, **smoothness** is the single most important factor. Therefore, smoothness may be assumed to be equivalent to PSI. With the passage of time and each heavy vehicle, the roadway becomes rougher. Ultimately the public defines failure by seeking alternate routes and demanding that the roadway be "fixed." This concept is illustrated in Figure 3.5.

As shown in the figure, immediately after construction the pavement has some initial service-ability

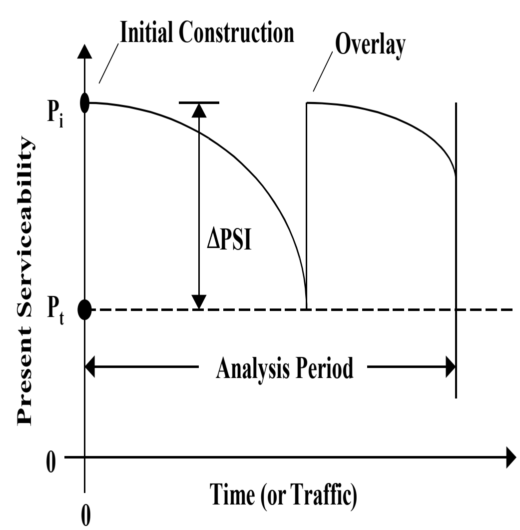
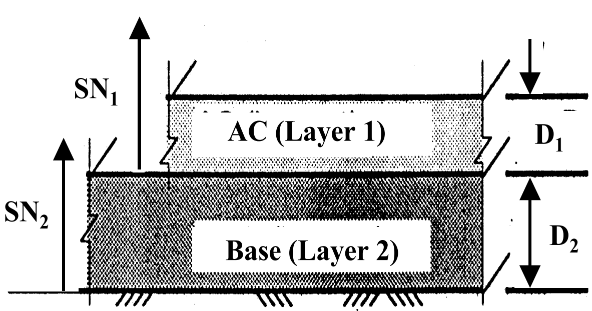


Figure 3.5 –Illustration of Serviceability Concept

serviceability decreases until some minimum tolerable value, p_t, is reached and an overlay is placed. The overlay restores the serviceability (smoothness) of the pavement and the process begins again. The thickness of the initial pavement and the overlay are determined from tolerable changes in PSI, the expected traffic and the material properties of each pavement layer.

When using the AASHTO procedure, individual layer thicknesses are not determined directly but rather are determined by first calculating a "structural number" (SN). This structural number describes the "strength" of all the material needed above a level to protect the layer below from damage. The "strength" of an individual layer is described using a layer coefficient, a_i. For example, the layer coefficient of asphalt is higher than an asphalt-treated base, which is higher than an untreated aggregate base. The use of a structural number allows several different combinations of base types and asphalt surfacing to be considered without completely recalculating the design.

Consider the simple pavement cross section shown in Figure 3.6. To protect the subgrade from damage due to the imposed loads, a structural number equal to SN_2 is required. This value is determined from the quality of the subgrade and the expected traffic loading. The protection could be made up of several different combinations of base and surfacing thicknesses. Similarly, the protection of the base layer requires surface layer strength equal to SN_1.



$$D_1 \geq \frac{SN_1}{a_1}$$

$$SN_1^* = a_1 \; D_1^* \geq SN_1$$

$$D_2 \geq \frac{SN_2 - SN_1^*}{a_2}$$

Example :

$$3.8'' = \frac{1.6}{0.42}$$

$$D_1^* = 4.0''$$

$$SN_1^* = 0.42 \; (4.0) = 1.68$$

$$D_2 \geq \frac{2.68 - 1.68}{0.14} \geq 7.1''$$

Figure 3.6—Simple Pavement Cross Section Illustration Structural Numbers

This structural number is calculated using the expected traffic loads and the quality (modulus) of the base. The thicknesses of each layer are determined by working from the top of the structure to the subgrade.

For the example shown in Figure 3.6, assume that SN_1 = 1.60 and SN_2 = 2.68. The thickness of the asphalt concrete, D_1, is calculated by dividing SN_1 by the layer coefficient of the asphalt, a_1. A typical layer coefficient for new asphalt concrete mix is 0.42. Since the thickness computation rarely results in practical layer thickness (e.g., AC thickness of 3.8 inches is not reasonable), rounding is used to specify the final thickness, D (e.g., 4.0 inches in our example). The product of a_1 and D yield a new SN. By subtracting this value from SN_2 and dividing by the layer coefficient of the base, a_2 (i.e., 0.14 for a good, well graded, highly fractured aggregate), the thickness of the base layer is determined. Again rounding would be applied to insure a constructible thickness (e.g., 7.0 inches).

Mechanistic/Empirical Procedures. The mechanistic/empirical method of design is based on the mechanics of materials that relates an input, such as a wheel load, to an output or pavement response, such as stress or strain, as shown in Figure 3.7. The response values are used to predict distress based on laboratory test and field performance data since theory alone is not sufficient to reliably design pavements. This procedure requires careful calibration to observed field data, in order to develop accurate transfer functions that relate the predicted stresses and strains to the specific distress types measured on in-service pavements. The mechanistic/empirical approach is primarily used to predict two distress types; fatigue cracking as a function of tensile strain at the bottom of the asphalt layer and permanent deformation (rutting) as a function of compressive strain at the top of the subgrade.

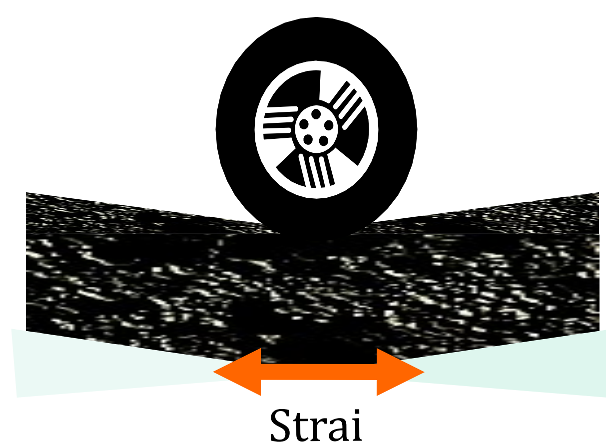


Figure 3.7—Strain Response to Wheel Load

Using a transfer function, the plot in Figure 3.8 can be developed to show the relationship between the fatigue life of the pavement structure and the tensile strain produced from a wheel load. It can be seen in Figure 3.8 that as strain increases the fatigue life is reduced.

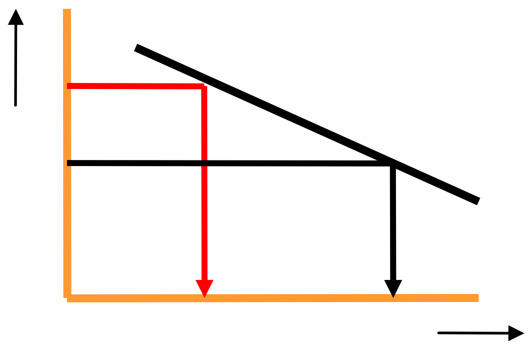


Figure 3.8—Fatigue Life as a Function of Tensile Strain

In a mechanistic analysis the designers must input material properties and thicknesses for each layer. The critical strain(s) under the design load can be predicted using layer elastic theory. For a fatigue analysis the designer determines the number of design loads the pavement can carry at the predicted strain level until a fatigue crack develops. At high strains this may be a relatively small number of loads; at low strains the number of loads to failure can be very large. In fact, recent research has shown that for strains below 100 micro strain the number of loads to failure is indefinite. This finding is the foundation of the perpetual pavement design concept, and allows the designer to develop a design that will never develop fatigue cracks at the bottom of the asphalt layer. Perpetual pavement design concepts are presented further in Appendix **Q.** Asphalt thickness and stiffness are the primary factors affecting fatigue life, however subgrade support is also a very important factor. Base aggregate depth and quality are less influential in the fatigue life estimates. Because fatigue life is more dependent on asphalt characteristics than aggregate base characteristics, placing only the minimum aggregate depth to achieve constructability normally results in the most cost effective, best performing section.

Using mechanistic/empirical methods allows improvement in the reliability of a design, the ability to evaluate the specific types of distress and it allows the designer to incorporate and account for new materials.

Users of this Design Guide have been spared most of the computations of the sort just described – however, the designer is responsible for thoughtful application of the design table, Table 3.4, given at the end of Section 3.2.

3.2 DESIGN IMPUTS

Many types of asphalt pavement structures exist, along with a number of different methods for designing the thickness of each element in any pavement. Fundamental to any design are the following:

- truck traffic,
- soil support capability,
- material properties of all layers.

Each element is important to the structural design process and the life of the final product depends on the close attention given to each element.

The degree of detail needed in a specific design situation is related to the intended use of the pavement. For example, the design of an interstate highway requires a careful estimate of traffic, including truck volumes and their weights. In contrast, the number of bicycles and their weights are not significant factors in the design of a bicycle path.

The effort expended characterizing the soil support should also be related to expected use of the facility. A detailed soil analysis for a residential street or small parking lot may not be deemed necessary, particularly if the designer has experience with other, similar pavements in the area. The designer must also consider the consequences of a subgrade failure when judging the need for detailed soil investigations. A pavement that is critically important to the function of the site (i.e., the main access to a distribution center) is a likely candidate for a more detailed investigation. The reliability of the design (discussed elsewhere) must be considered. Each of these factors is considered below.

The design life of a pavement is the time in years before rehabilitation is likely. By selecting the design life of a pavement, the designer is selecting the amount of truck traffic the facility is expected to carry. Unless otherwise indicated, this manual has a selected design life of 20 years for both commercial and non-commercial pavements.

Truck Traffic. The primary function of a pavement is to distribute and transmit wheel loads of vehicles to the supporting subgrade and therefore information about the traffic stream is required. Pavement must be designed to serve traffic needs over a period of years. Therefore, the volume of traffic and the various types of vehicles using the facility must be estimated for the anticipated life of the pavement.

The "design traffic" is determined based on the traffic volume on comparable types of pavement and the types and numbers of trucks expected to operate on the roadway over the life of the facility. The typical street is subjected to a wide variety of trucks each carrying different loads. The types of trucks and their loads vary daily and annually.

This variability is difficult to take into account directly, so pavement design engineers developed the concept of an equivalency. The use of equivalencies allows the designer to convert a mix of vehicles into a single number of equivalencies for design.

Equivalencies were developed based on axle weight rather than total vehicle weight because two trucks with the same gross vehicle weight will cause different damage to the pavement depending on how many axles support the load. Pavement designers agreed to use a standard equivalency, termed the equivalent axle load (EAL) for all designs. The EAL for a given axle (or group of axles) is defined as the relative damage done by the axle compared to the damage done by the standard axle passing over the same pavement. The standard axle is single axle with dual tires loaded to 18,000 lb. By summing the total number of EAL for all vehicles expected to use the facility over the life of the pavement, the traffic input to design is determined.

Although conceptually complicated, the conversion of a group of vehicles into a number of EAL is relatively straightforward once the process is understood. The 1993 AASHTO Pavement Design Guide provides equivalencies in tabular form for a wide range of axle groups and weights. Designers are encouraged to use this resource as needed. The equivalency for a given axle group can also be estimated using the "fourth-power law."

Consider the application of the fourth-power law to the delivery truck illustrated in Figure 3.9. Assume that the steering and rear axles on this vehicle have weights of 7,000 lb and 12,000 lb, respectively. The relative damage caused by this vehicle in terms of EAL is computed as follows:

Steering axle: $\left(\frac{7{,}000 lbs}{8{,}000 lbs}\right)^4 = .023$

Rear axle: $\left(\frac{12{,}000 lbs}{18{,}000 lbs}\right)^4 = .198$

Total Damage = .221

Thus, if the delivery truck passed over the pavement five times, it would do approximately the same damage as the passage of a single axle loaded to 18,000 lb.

Next consider the fully loaded moving van shown in Figure 3.9. Here the steering axle is loaded to 12,000 lb and each tandem axle group is loaded to 34,000 lb. Tandem axle groups are considered together because they act as a unit. A tandem axle group loaded to 33,000 lbs causes the same damage as a single axle loaded to 18,000 lbs; therefore 33,000 is the divisor when tandem axles are considered.

Steering axle: $\left(\frac{12{,}000 lbs}{18{,}000 lbs}\right)^4 = .198$

Rear axle: $2 \times \left(\frac{34{,}000 lbs}{33{,}000 lbs}\right)^4 = 2 \times 1.13 = 2.25$

Total Damage = 2.45

If the damage caused by this vehicle is compared to the small delivery van, it can be seen that the moving van causes more than ten times the damage of the small delivery truck. Although passenger cars make up the majority of the traffic volume, they do very little damage to the pavement structure. For example, a typical sport utility vehicle (GVW = 4500 lb) has a total EAL of 0.0005. Therefore, nearly 4,500 sport utility vehicles would have to pass over the pavement to do as much damage as one fully loaded moving van. For this reason, passenger cars and light trucks are not generally considered in pavement design.

Figure 3.9 provides the relative damage of a variety of fully loaded and empty trucks, busses, and other specialty vehicles. In many cases the detailed analysis procedures just described are not necessary. However, for projects in which many non-standard loads are expected, a detailed analysis is required. ODOT uses the above approach to consider damage by various vehicle classes. The load equivalency values they use to assess the damage in asphalt pavements for state high-ways is as follows:

Vehicle Class	EAL/Truck
2-axle	0.274
3-axle	0.603
4-axle	0.877
5-axle	1.781
6-axle	1.781
Busses	1.980

These factors assume a certain portion of the traffic travels empty.

Although not directly considered in this manual, designers should also be aware of the following additional traffic factors and should consult the AASHTO design guide or engage a pavement consultant:

Traffic speed (static vs. moving loads). Asphalt concrete is a viscoelastic material whose resistance to load is influenced by temperature and time of loading. Therefore time of loading (e.g., parked vehicles vs. highway speeds) must be considered. This is normally taken into account when the mix is selected for a given project.

	Fully Loaded			Empty		
	Rear Axle	Rear Axle	Front Axle	Rear Axle	Rear Axle	Front Axle
a) Dump Truck		○○	○		○○	○
Axle Wt, lb.		34,000	12,000		14,000	10,000
EAL		1.08	0.22		0.033	0.10
Total EAL			1.30			0.13
b) Garbage Truck		○○	○		○○	○
Axle Wt., lb.		38,000	12,000		16,000	10,000
EAL		1.68	0.22		0.057	0.10
Total EAL			1.90			0.16
c) Transit Bus		○	○		○	○
Axle Wt, lb.		22,000	13,000		18,000	8,000
EAL		2.20	0.35		1.00	0.041
Total EAL			2.55			1.04
d) Moving Van	○○	○○	○	○○	○○	○
Axle Wt, lb.	34,000	34,000	12,000	16,000	14,000	10,000
EAL	1.08	1.08	0.22	0.057	0.033	0.10
Total EAL			2.36			0.19
e) Concrete Transit Truck		○○	○		○○	○
Axle Wt, lb.		44,000	12,000		16,000	8,000
EAL		3.2	0.22		0.057	0.041
Total EAL			3.4			0.10
f) Small Fork Lift		○	○		○	○
Axle Wt, lb.		6,000	12,000		4,000	4,000
EAL		0.013	0.22		0.003	0.003
Total EAL			0.23			0.006
g) Small Delivery Truck		○	○		○	○
Axle Wt, lb.		12,000	7,000		4,000	4,000
EAL		0.22	0.022		0.004	0.004
Total EAL			0.24			0.008
h) Low-Boy, Equipment Delivery	○○	○○	○	○○	○○	○
Axle Wt, lb.	34,000	34,000	12,000	10,000	10,000	6,000
EAL	1.08	1.08	0.22	0.013	0.013	0.013
Total EAL			2.38			0.04
i) Construction Materials Delivery		○○	○		○○	○
Axle Wt, lb.		34,000	14,000		8,000	8,000
EAL		1.08	0.39		0.006	0.041
Total EAL			1.47			0.05
j) Recreational Vehicle, Class A Motor Home		○	○		○	○
Axle Wt, lb.		20,000	12,500		16,000	10,000
EAL		1.55	0.25		0.62	0.10
Total EAL			1.8			0.72

Figure 3.9—Typical Damage for Various Vehicles, EALs

Vehicle dynamics. Although not directly considered in most designs, vehicle dynamics play a role in the performance of asphalt pavements. When roughness develops in road-ways (i.e., at bridge ends), the dynamic loading caused by the roughness can create axle loads 10 to 30 percent higher than static loads.

Studded tires. These traction devices cause substantial damage to all roadways by hastening the loss of material from the wheel paths. Studded tire wear is not currently considered in pavement design.

Tire types and pressures. Equivalent axle loads (EAL) were developed in the late 1950s and early 1960s. Most trucks used bias belted tires inflated to 70 psi pressure at that time. Today most trucks use radial tires inflated to at least 100 psi.

If the designer believes that these factors are important to a particular design, a pavement engineer should be consulted.

To assist the designer, traffic is separated into six classes, I through VI, as shown in Table 3.1. An average daily truck traffic (ADTT), a range of EAL and example facilities fitting this category (street, highway, etc.) define each class.

Soil Support. The ability of the subgrade to support loads transmitted from the pavement is one of the most important factors in determining pavement thickness. The subgrade serves as a working platform to support construction equipment and as a foundation for the pavement structure that supports and distributes traffic loads. Thus, it is essential to evaluate the structural capability of the subgrade. Figure 3.10 shows the spread of a wheel load through the pavement structure and on to the subgrade. If sufficient pavement thickness is not provided, the applied loads could cause greater stresses on the subgrade than it can resist. This may result in deflection of the pavement, cracking and ultimately, failure.

Different types of soils have different abilities to provide support. A sandy soil, for example, will support greater loads without deformation than a silty clay soil. Thus, for any given traffic volume and weight of vehicles using the roadway, a greater pavement thickness must be provided on clay soils than on sandy soils. Three soil support levels are used in this guide.

Subgrade Classes. For the designs recommended in this manual, all soils have been divided into three classes: excellent (E), good (G), fair (F). Resilient modulus (M_R) design values are assigned to these different subgrade classes. A fourth soil class, poor (P), is included in the following discussion, but is not used in this guide due to the low modulus value. It is recommended that a poor soil undergo subgrade treatment or replacement before placing aggregate and asphalt. For more information on subgrade treatments refer to Chapter 4.0.

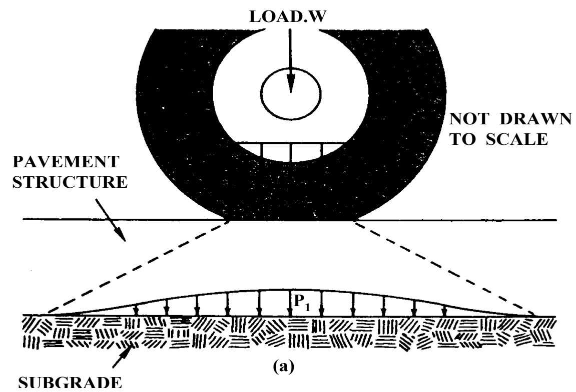


Figure 3.10—Spread of Wheel-Load through Pavement Structure

Excellent. Excellent subgrade soils retain a substantial amount of their load supporting capacity when wet. Included are the clean sands, sand-gravels, and those free of detrimental amounts of plastic materials. Excellent subgrade soils are relatively unaffected by frost provided they contain less than 15 percent passing a 75 µm (No. 200) mesh sieve. A soil classified as excellent will have a M_R value of 20,000 psi or greater. (CBR > 17)

Good. Good subgrade soils are those that retain a moderate degree of firmness under adverse moisture conditions. Included are such soils as loams, silty sands, and sand gravels containing moderate amounts of clays and fine silts. A soil classified as good will have a M_R value of at least 12,000 psi. (CBR > 8)

Fair. Fair subgrade soils are those that become quite soft and plastic when wet. Included are those soils having appreciable amounts of clay and fine silt (50 percent or more) passing a 75 µm (No. 200) sieve. The coarse silts and sandy loams may also exhibit poor bearing properties in areas where deep frost penetration into the subgrade is encountered for any appreciable periods of time. This also is true where the water table rises close to the surface during certain periods of the year. A soil classified as fair will have a M_R value of 7,500 psi. (CBR greater than 5)

Poor. Poor soils often perform poorly as pavement subgrades. Included in this soil group are most clays and very fine silts.

Level I (Very Light) Design EAL: up to 10,000 ADTT*: 1 per day over 20 years Examples: Parking lots, residential driveways Light traffic farm roads School areas and playgrounds Seasonal recreation roads Sidewalks and bicycle paths Golf cart paths Tennis courts	**Level IV** (Moderate) Design EAL: 100,000 to 250,000 ADTT: 14-35 per day over 20 years or 28-70 per day over 10 years Examples: Urban minor arterial and light industrial streets Rural major collector and minor arterial highways Residential streets with bus routes
Level II (Light) Design EAL: 10,000 to 50,000 ADTT: 2-7 per day over 20 years Examples: Residential streets Rural farm roads Parking lots of less than 500 stalls	**Level V** (High Moderate) Design EAL: 250,000 to 500,000 ADTT: 35-70 per day over 20 years or 70-140 per day over 10 years Examples: Industrial lots, truck stalls Bus routes and loading zones
Level III (Low Moderate) Design EAL: 50,000 to 100,000 ADTT: 7-14 per day over 20 years or 14-28 per day over 10 years Examples: Urban minor collector streets Rural minor collector streets Parking lots - more than 500 stalls	**Level VI** (Heavy) Design EAL: 500,000 to 1,000,000 ADTT: 70-140 per day over 20 years or 140-280 per day over 10 years Examples: Major urban arterial Major trucking distribution center Quarry/refuse disposal haul road

*Average Daily Truck (or Bus) Traffic - assumed EAL per truck = 2.0

Figure 3.1—Traffic Classification used in the Guide

However, to improve their performance, these soils should be stabilized. Lime, fly ash, asphalt cement, portland cement, and combinations of cement stabilizers also can be added to improve the subgrade support. The selection of stabilizing agent, the amount to use, and the application procedure depend on the soil classification and the subgrade support value desired. These should be determined through appropriate laboratory testing. A soil classification of poor will have a M_R of 5,000 psi or lower (CBR less than 3). Soils can be categorized into one of the design classes using a variety of techniques ranging from past experience to detailed laboratory testing. These techniques are described below. Regardless of the method used to characterize the soil, the designer must be aware that with increases in moisture contents of all fine-grained soils, strength and modulus are reduced. Thus, a soil tested at moisture contents representative of summer conditions may have only half that strength in winter.

Soil classifications. Soil is classified for road and street construction in order to predict subgrade performance on the basis of a few simple tests. Both the AASHTO and Unified Soil Classification (USC) systems are commonly used to classify soils. Once classified, the subgrade class can be determined.

According to the AASHTO system, a soil's load carrying capabilities can be classified into categories from A-1 through A-7. In general, the best highway subgrade soils are A-1 and the worst are A-7. The classification is based on the sieve analysis, plasticity index, and liquid limit of the soil being tested.

The USC system also relies on these same tests. Under this system, the best subgrade soils are well-graded gravel (GW) while highly plastic clays (CH) are the worst (see Fig. 3.11). The use of soil classification to estimate the soil support may be appropriate for projects in which the consequences of a failure are minimal (i.e., private driveways). Classification systems also can be used to compliment the designer's experience with a given soil type. However as the importance of the project increases or if the designer is unfamiliar with the soil types, additional testing is warranted.

Soil Type	Unified Soil Class	Percent Finer than 0.02 mm	Permeability	Frost Potential[1]	Typical CBR[2]	Typical M_r, psi[2]	Design Class
Gravels, crushed stone Little or no fines < 0.02 mm	GW, GP	0-1.5	Excellent	NFS	17	>15,000	Excellent
Sands, sand-gravel mix Little or no fines < 0.02 mm	SW, SP	0-3	Excellent	NFS	17	>15,000	Excellent
Gravels, crushed stone Some fines < 0.02 mm	GW, GP	1.5-3	Good	PFS	17	>15,000	Excellent
Sands, sand-gravel mix Some fines < 0.02 mm	SW, SP	1.5-3	Good	PFS	17	>15,000	Excellent
Gravelly soils Medium fines < 0.02 mm	GW, GP, GM	3-6	Fair	Low	8	7,500	Good
Sandy soils Medium fines < 0.02 mm	SW, SP, SM	3-6	Fair	Low	8	12,000	Good
Silty gravel soils High fines < 0.02 mm	GM GW-GM, GP-GM	6-10 10-20	Fair to Low	Medium	8	12,000	Good
Silty sand soils High fines < 0.02 mm	SP SW-SM, SP-SM	6-15	Fair to Low	Medium	8	12,000	Good
Clayey gravel soils High fines < 0.02 mm	GM, GC	Over 20	Fair to Low	Medium to High	5	7,500	Fair
Clayey sand soils High fines < 0.02 mm	SM, SC	Over 20	Low to Very Low	Medium to High	5	7,500	Fair
Very fine silty sands	SM	Over 15	Low	High to Very High	5 (Replace in severe frost areas)	7,500	Fair-Poor
Clays PI > 12	CL, CH		Very Low	High	3 (Replace in severe frost areas)	<5,000	Poor
All silt soils	ML, MH		Very Low	High to Very High	3 (Replace in severe frost areas)	<5,000	Poor
Clays PI < 12	CL, CL-CM		Very Low	High to Very High	3 (Replace in severe frost areas)	<5,000	Poor
Other fine-grained soils	OL		Very Low	High to Very High	<3 (Replace in severe frost areas)	<3,000	Very Poor
Highly organic soils	OH		Very Low	High to Very High	Replace in all cases		Very Poor

[1]NSF = not frost susceptible; PFS = possible frost susceptible

[2]CBR = California Bearing Ratios and M_r = Resilient Modulus values are minimum values expected for each subgrade class

Figure 3.11—Correlations Among Various Soil Tests and Classifications Systems (Modified after NAPA 1991)

Subgrade strength/modulus tests. The strength of soils underlying pavement is often determined using either California Bearing Ratio (CBR) or Hveem Stabilometer (R-value) test procedures. Details of these test procedures can be found in the AASHTO Test Methods Manual. The dynamic cone penetrometer (DCP) can also be used for measuring the soil strength. It can be directly related to the CBR value using empirical relationships. Any of these tests provides better characterization of the subgrade support than that provided by a simple soil classification. The use of strength testing is warranted as the consequences of pavement failure increase. Correlations between strength tests and subgrade classes are shown in Figure 3.11.

Finally, for those pavements for which failure would significantly impact the economics of the facility, laboratory testing for the resilient modulus, M_R, of the soil is warranted. Details of this test method are found in the AASHTO Test Methods Manual.

Whether classification, strength or modulus testing is used to select a subgrade class for design, users are reminded that soil properties vary with moisture content. Soils sampled and tested under conditions that represent summer conditions may not represent the typical soil properties for the year. The AASHTO Design Guide and this manual assume that average values of soil strength will be used.

Additional soil considerations. When poor subgrade soils are identified, the designer may increase the quality of subgrade support by stabilizing the soil or by removing the soil and replacing it with aggregate.

Common stabilization agents include lime and cement. The addition of either material increases the workability of the soil by decreasing the plasticity of the soil. Cement and lime treatment typically increase the modulus and strength of soils. The addition of lime to a highly plastic clay (CH) can result in a quality working platform upon which the base layers can be constructed. However, lime will not help when used with non-plastic soil (e.g., Willamette Valley silts). Additional informa-tion on stabilized soils can be found in Chapter 4.0 of this guide and in FHWA-SA-93-004, which is available from the Federal Highway Administration.

Construction on poor soils during wet winter months can also be accomplished by removing 12 to 24 inches of the soil and replacing it with coarse aggregate on a separation geotextile. The performance of the aggregate is enhanced through the use of a separation layer. The presence of this layer reduces the intrusion of fine particles from the subgrade into the base and by reducing the intrusion of fines, the strength of the base is maintained for longer periods. Some manufacturers claim that the use of these materials also may reduce the required base thickness. The AASHTO Design Guide does not allow for a reduction in base thickness for the use of geotextiles. Additional information on geotextile use can be found in Chapter 4.0.

Lastly, several classes of soils present special problems that warrant the retention of a pavement engineering consultant. The presence of organic or expansive soils or a high water table calls for special consideration that is best handled through a consultant.

Reliability. Reliability was incorporated in the AASHTO Guide beginning with the 1986 version. The 1993 Guide states, "The reliability of a pavement design is the probability that a pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the design period." Reliability allows designers to formally incorporate variability in the design process and, in turn, incorporates a degree of certainty.

Engineers have always recognized the variability in materials and construction. However, prior to the formal introduction of reliability into pavement design, the designer often selected design inputs (i.e., subgrade strength) that were lower than the expected average. By selecting a value lower than the expected, a "factor of safety" was introduced. This procedure often resulted in overly conservative designs. The process also precluded a systematic approach to improved designs because both successes and failures are masked by "engineering judgment." In addition, as the experience base retires and new materials are incorporated into pavements, these empirical approaches often fail. By using average values for all design inputs and then applying reliability (similar to a safety factor), the performance of pavements can be compared on a consistent basis allowing incremental improvements in pavement design.

Figure 3.12 illustrates how a number of pavements of the same design (i.e., same materials and thicknesses) might perform differently. For example (Fig. 3.12a), even though all the surface mix used in a given project came from the same plant and was placed and compacted using the same equipment, some variation is to be expected. Thus, the time (or EAL) to rehabilitation of these pavements form a normal distribution of "pavement lives." Despite the fact that all were constructed of the same materials on identical subgrades, some will fail prematurely and some will last longer than expected due to variations in thickness, materials and moisture conditions.

To avoid early failures, higher reliabilities are used in the design (i.e., arterials or interstates) as shown in Fig. 3.12b. Higher reliabilities result in thicker sections and higher initial costs result, but the pavement is less likely to fail earlier than expected. The higher cost may be warranted when an unexpected early failure would cause a temporary closure of the facility. Guidelines for selecting the appropriate level of reliability are as follows:

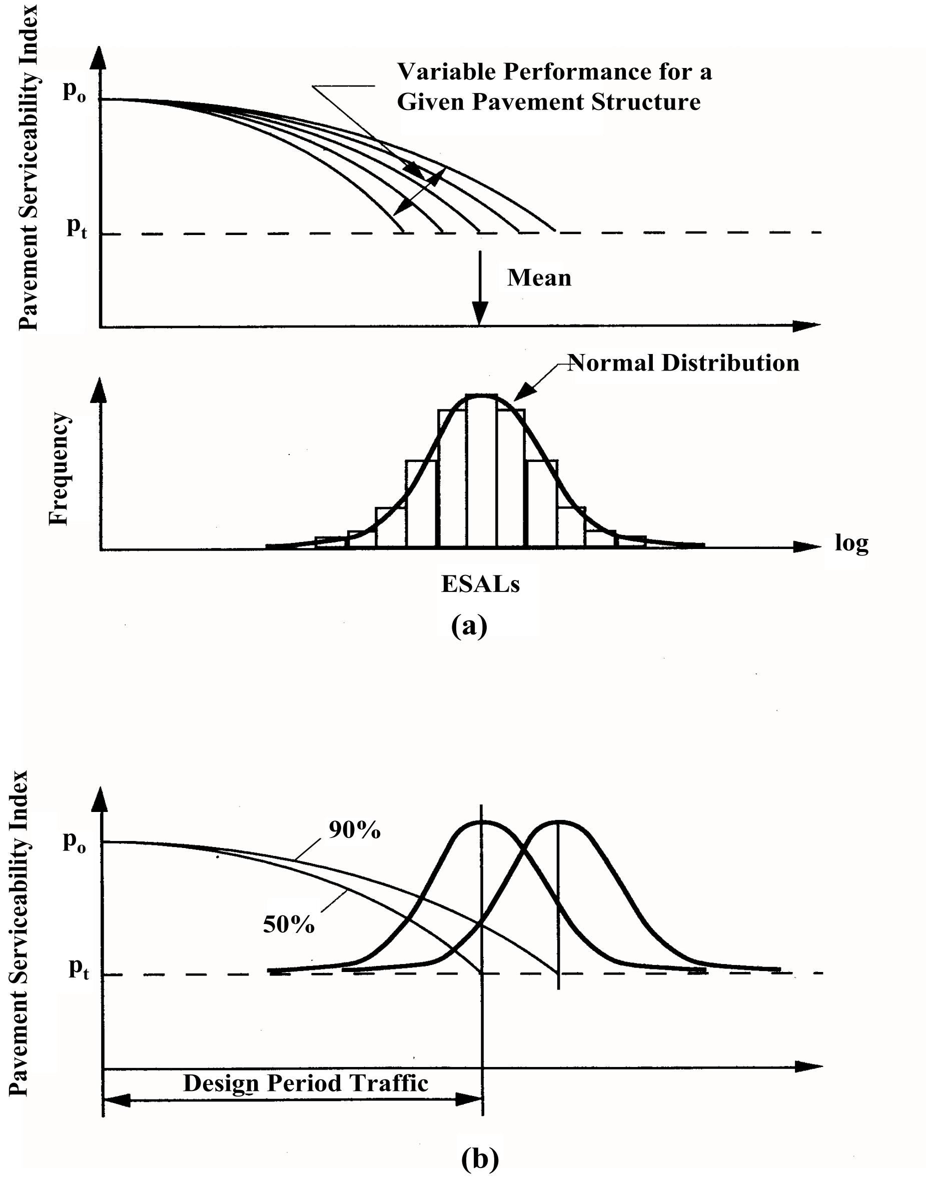


Figure 3.12 - Illustration of Pavement Performance for a Given Design (a) and How Reliability Affects Performance (b) (after Washington DOT, 1995)

Type of Facility	Reliability
Important Facilities - Disruptions during design life would cause significant inconvenience	90 %
Moderately Important Facilities - Some disruption during design life can be permitted	75 %
Low Importance Facilities - Disruption	50 %

For example, new facilities that have curbs and gutters should be designed for 90 percent reliability so that they may be maintained at grade without the need for reconstruction or thick overlays. County roads and most other facilities may be designed for 75 percent reliability. Fifty percent reliability is generally not recommended except for temporary facilities or when major rehabilitation is planned within the design period.

It must be remembered that most asphalt pavements will require maintenance and rehabilitation (overlays) periodically. Typical surface maintenance cycles begin in about the tenth year and last from three to seven years. Typical rehabilitation cycles might range from 15 to 20 years. The type of maintenance and rehabilitation required depends on the type of distress - structural vs. functional. This is discussed in more detail in Chapter 10.0.

Design Approach. The design approach used in this guide was developed using the AASHTO Guide Design for Pavement Structures. In addition, a mechanistic/empirical analysis was performed to ensure sections had adequate fatigue resistance and constructability. These methods provide a reasonable representation of the field conditions encountered during paving and pavement life cycle.

The first step to determining asphalt and aggregate layer thicknesses was to determine the structural number required for the given conditions using the procedures set forth by AASHTO. These procedures take into account soil type, serviceability loss (DPSI), standard deviation (S_o), reliability (Z_R) and traffic volume (W_{18}). The following assumptions were used in the structural number computations:

- Soil Resilient Modulus

Fair	M_R=5,000 psi
Good	M_R=10,000 psi
Excellent	M_R=15,000 psi

- Δ PSI=1.7
- S_o=0.44
- Reliability Factors

50%	Z_R=0.0
75%	Z_R=-0.674
90%	Z_R=-1.282

Next, aggregate base thicknesses were established for each soil type (i.e., fair, good, excellent), using layered elastic theory. In this analysis we varied the required aggregate thickness as a function of the soil modulus value associated with the particular soil type. A fixed deflection value was selected and used to determine the aggregate base thickness for each soil type. This procedure fixes the amount of deflection, created by identical loads, in all aggregate layers regardless of the sub-base soil condition. When fair soil is used as a sub-base, a thicker layer of aggregate is required to produce the same amount of deflection created when there is an excellent soil sub-base under the same loading conditions.

This procedure provides a uniform construction platform for paving. The following aggregate base thicknesses have been selected based on the above approach:

- Fair soil – 12”
- Good soil – 8”
- Excellent soil – 4”

By fixing the aggregate base thickness, the remaining structural support comes from the asphalt concrete thickness. As shown in Figure 3.8, fatigue damage is highly sensitive to horizontal tensile strain at the bottom of the asphalt layer. Increasing the AC thickness instead of the aggregate thickness to meet structural requirements lowers the tensile strain in the pavement, therefore reducing the risk of fatigue damage substantially and provides a more economical section. For example, consider the following two designs:

- Design 1: 8.0 inches AC
  12.0 inches aggregate base
- Design 2: 7.0 inches AC
  20.0 inches aggregate base

Both have the same structural number (SN = 4.1) and traffic loading, but the fatigue life for Design 1 is significantly more than Design 2. The number of single axle wheel passes until fatigue failure occurs for each design is:

- Design 1: 1,379,600
- Design 2: 860,000

In this example Design 1 provides a 60 percent increase in fatigue life and would cost less to construct than Design 2. It also utilizes less aggregate resource than Design 2 and would require less excavation.

In general the best performing and most economical design will result from this design approach. That is, select the minimum aggregate base thickness required for constructability and design the asphalt thickness to provide adequate fatigue and to provide the remaining structural protection for the subgrade.

This procedure varies a_2 depending on the stress state of the base layer. The aggregate base layer coefficient (a_2) was selected following AASHTO procedures. The stress state is dependent on both the asphalt concrete thickness and the soil resilient modulus; therefore, the base layer coefficient is also a function of the AC thickness and soil resilient modulus. A minimum base layer coefficient value of a_2=0.06 has been established. Table 3.2 shows the layer coefficients used for the thickness computations throughout the guide.

M_R	Asphalt Thick-	Layer Coeffi-
Fair Soil 5,000 psi	2-4 inches	0.08
	4-6 inches	0.06
	>6 inches	0.06
Good Soil 10,000 psi	2-4 inches	0.10
	4-6 inches	0.08
	>6 inches	0.06
Excellent Soil 15,000 psi	2-4 inches	0.11
	4-6 inches	0.09
	>6 inches	0.07

Table 3.2– Base Layer Coefficients

After determining the aggregate layer thickness and appropriate layer coefficient the structural contribution of the base can be calculated by using the following equation:

$$SN_2 = D_2 a_2$$

Since the layer coefficient is dependent on the asphalt layer thickness, which has not yet been determined, choosing the layer coefficient can sometimes become an iterative process. Several iterations may be necessary to determine the correct asphalt and aggregate layer thicknesses. However, using Table 3.4 will spare these kinds of calculations.

With the structural contribution of the aggregate base known, the asphalt thickness must provide the remaining pavement structure and is determined as follows:

$$SN = D_1 a_1 + D_2 a_2$$

By rearranging the previous equation and solving for the asphalt thickness:

$$D_1 = \frac{SN - D_2 a_2}{a_1}$$

The layer coefficient for new asphalt concrete mix used in Oregon, denoted a_1, is 0.42.

Rounding is used to specify the final thickness (e.g., if results give AC thickness of 3.8 inches, design thickness would be 4.0 inches), since the layer thickness computations rarely result in a practical asphalt layer thickness

The last step in the design process is to check that asphalt thicknesses meet the required minimums, which were created following standard ODOT procedures and standard practice. The minimums were calculated by using a base modulus (M_{RBase}) of 20,000 psi, instead of the soil modulus, to determine the structural number. Minimum asphalt thicknesses were determined by dividing the structural number by the layer coefficient for asphalt concrete ($a_1 = 0.42$).

$$\text{Minimum } D_1 = \frac{SN}{a_1}$$

Table 3.3 shows the minimum required asphalt thickness for different traffic and reliability levels. For Traffic Level I, the 3.0 inch minimum assumes a single lift if a 12.5mm or larger stone mix is used. If two lift paving is specified, the thickness needs to be increased to ensure the minimum lift thickness criteria from Chapter 2 is met.

The following is an example of the computations used for determining required aggregate and asphalt layer thicknesses. Assume the following conditions are present prior to construction:

- Fair soil conditions (M_R=5,000 psi)
- Traffic Volume: 100,000 – 250,000 EALs
- Required reliability of 90 percent

Using AASHTO design procedures and the given soil and traffic conditions: SN = 3.21 for this example. Because the soil classification is fair the aggregate layer thickness is fixed at 12 inches (e.g., D_1 = 12 inches). The next step is to determine the aggregate base layer coefficient. Given the high traffic volumes on fair soil, it can be assumed that the asphalt layer thickness will be greater than 4 inches, which corresponds to a base layer coefficient of a_2=0.06. The asphalt thickness can now be found using the following equation:

$$D_1 = \frac{SN - D_2 a_2}{a_1}$$

$$D_1 = \frac{3.21 - (12*0.06)}{0.42} = 5.93$$

With rounding, the final AC thickness is 6.0 inches. Therefore the final thickness design is 12 inches of aggregate base and 6.0 inches of asphalt concrete.

Table 3.4 is based on the procedures described above and is referenced throughout Chapters 5.0 and 6.0.

Traffic Level (EALs)	Reliability %	Minimum AC thickness
I Up to10,000	All levels	3.0
II 10,000 - 50,000	All levels	3.5
III 50,000 - 100,000	All levels	4.0
IV 100,000 - 250,000	50 75 90	4.0 4.0 4.5
V 250,000 - 500,000	50 75 90	4.0 4.5 5.0
VI 500,000 - 1,000,000	50 75 90	4.5 5.0 5.5

Table 3.3—Minimum AC Thickness

Traffic Level	Reliability %	Subgrade Class		
		Fair	Good	Excellent
a) Asphalt Concrete Over Aggregate Base, inches				
I Up to 10,000 EALs	All Levels	3.0/12.0	3.0/8.0	3.0/4.0
II 10-50,000 EALs	50	3.5/12.0	3.5/8.0	3.5/4.0
	75	3.5/12.0	3.5/8.0	3.5/4.0
	90	4.0/12.0	3.5/8.0	3.5/4.0
III 50-100,000 EALs	50	4.0/12.0	4.0/8.0	4.0/4.0
	75	4.0/12.0	4.0/8.0	4.0/4.0
	90	5.0/12.0	4.0/8.0	4.0/4.0
IV 100-250,000 EALs	50	4.5/12.0	4.0/8.0	4.0/4.0
	75	5.0/12.0	4.0/8.0	4.0/4.0
	90	6.0/12.0	4.5/8.0	4.5/4.0
V 250-500,000 EALs	50	5.5/12.0	4.0/8.0	4.0/4.0
	75	6.0/12.0	4.5/8.0	4.5/4.0
	90	7.0/12.0	5.5/8.0	5.0/4.0
VI 500-1,000,000 EALs	50	6.5/12.0	5.0/8.0	4.5/4.0
	75	7.0/12.0	5.5/8.0	5.0/4.0
	90	8.0/12.0	6.5/8.0	6.0/4.0

1 inch = 25 mm

Table 3.4 – Asphalt Concrete and Aggregate Design Thickness

Full Depth Asphalt Pavements. There are often times and situations where full depth asphalt pavements may be more practical than traditional asphalt pavement structures, such as during building construction. Full depth asphalt pavement structures have many advantages over conventional asphalt concrete structures including:

- Reduction of time required for construction
- Allowing construction in more adverse climatic conditions
- Reduction in the total depth of the pavement structure
- Reduction of the total depth of excavation required for the pavement structure
- Providing a stable, clean work surface during construction
- Providing a stable, clean work surface during construction.

Excellent and good subgrade conditions are ideal for full depth asphalt; however, a minimum of 100 mm (4 inches) of asphalt concrete is recommended. In some cases aggregate may be needed to provide material to fine grade and to provide a smooth surface to pave on.

If needed, 100 mm (4 inches) of aggregate is recommended as a minimum thickness for constructability purposes. Full depth asphalt can be built on fair soils only during the dry season and when the subgrade soils may be brought to optimum moisture conditions and compacted to specification density.

Full depth asphalts are designed using the same method discussed for alternative designs on the previous page. Full depth asphalt designs may be developed by using the appropriate a_2 values from Table 3.1 and a_1 equal to 0.42. This design needs to meet or exceed the structural number calculated from the thicknesses in the design table (Table 3.4) and the minimum asphalt thickness from Table 3.3. For example, a full depth asphalt design for Traffic Level V, good soil conditions and 75 percent reliability could be performed as follows:

$$SN_{required} = (5.5*0.42) + (6.0*0.08) = 2.79$$

Since an aggregate base is not used in full depth asphalt, the only contribution to the structural number is and asphalt cement.

$SN_{required} = 2.79 = D_1 a_1$

$D_1 = \frac{2.79}{0.42} = 6.64$ inches

This meets the minimum AC thickness requirements specified in Table 3.3. Therefore, the final thickness design is 7.0 inches of asphalt over the subgrade.

3.3 STAGE CONSTRUCTION

Planned stage construction consists of the construction of a road or street in two layers, by design, on an predetermined time schedule. Stage construction has been widely used in Oregon with varying degrees of success.

Stage construction should not be confused with maintenance and rehabilitation. In planned stage construction, the second lift, or stage, must be placed before the first stage shows any signs of distress.

Advantages of stage construction. The primary advantages of stage construction are:

- Placing a base lift early allows construction traffic to operate on a clean, dry surface avoiding disturbance of the base and subgrade.
- Any weak base or subgrade areas that were previously undetected can be corrected prior to placing the final stage.
- In a subdivision, the utility installations and surface damage which occurs during home construction can be corrected and "covered up" with the final stage.

Disadvantages of stage construction. The primary disadvantage of stage construction is that it increases the cost of the pavement by requiring more thickness, and an additional mobilization at the paving operation. In addition, it can create some problems with delamination or slipping between stage layers if they are not properly cleaned and prepared for paving.

Finally, if not properly designed, the first stage traffic can exceed the design life of the first stage, resulting in reduced service life for the finished pavement.

Design. Following is a design method which will allow stage construction without sacrificing long-term performance of the pavement. This method is based on "remaining life" concepts and Minor's accumulative damage hypothesis.In Minor's hypothesis the ratio of the anticipated number of design loads **n** to the number of loads to failure $\mathbf{N_f}$ must be less than one to prevent failure.

$$\frac{n}{N_f} \le 1$$

For staged construction, the equation becomes:

$$\frac{n_1}{N_{f1}} + \frac{n_2}{N_{f2}} \le 1$$

For this procedure we have chosen to limit the damage during the first stage to 60 percent. That means stage 2 must be designed to ensure the remaining 40 percent of pavement life is not consumed prior to the end of the design life. Therefore:

$$\frac{n_1}{N_{f1}} \le 0.6 \qquad N_{f1} = \frac{n_1}{0.6} = 1.67\, n_1$$

And:

$$\frac{n_2}{N_{f1}} \le 0.4 \qquad N_{f2} = \frac{n_2}{0.4} = 2.5\, n_1$$

Procedure. In this procedure:

n_1 = Stage 1 design ESAL: which are the total ESALs anticipated from initial placement of the first stage of asphalt to the time when the final thickness is placed.

n_2 = Stage 2 design ESAL: which is the total anticipated ESALs from when the final thickness of pavement is placed to the end of the design period.

N_{f1} = Design ESAL at 60 percent damage

N_{f2} = Design ESAL at 40 percent damage

d_1 = Thickness for Stage 1

d_F = Final required (total) thickness

d_2 = Thickness for Stage 2

$N_{f1} = 1.67\, n_1$

$N_{f2} = 2.5\, n_2$

$d_F = d_2 - d_1$

The following steps are required for the design:

- Determine the design ESAL for Stage 1 and Stage 2 (n_1 and n_2)
- Calculate N_{f1} and N_{f2}
  - $N_{f1} = 1.67\, n_1$
  - $N_{f2} = 2.5\, n_2$
- From Table 3.4 determine the asphalt thickness (d_1 and d_F) required for N_{f1} and N_{f2}
- For N_{f1} use 50% reliability (See Note 1)
- For N_{f2} use the normal project design reliability (usually 75 percent or 90 percent)
- The Stage 1 thickness is d_1
- Calculate the Stage 2 thickness from $d_2 = d_F - d_1$

Note: If N_{f1} is $\le$ 10,000 ESALs, set d_1 = 2.5 inches.

Often the Stage 2 thickness requirement will be 1.0 inches or less. It is important to observe minimum thickness requirements for Stage 2 paving as follows:

Mix Type	Minimum Thickness
9.5 mm	1.25 inches
12.5 mm	1.5 inches

Example Design. Given: Subgrade class is fair, 90 percent reliability.

Design ESALs = 90,000
Stage 1 traffic = 25,000 = n_1
Stage 2 traffic = 65,000 = n_2

$N_{f1} = 1.67\ (n_1) = 41{,}750$
$N_{f2} = 2.5\ (n_2) = 162{,}500$

From Table 3.4, 50 percent Reliability, Fair Soil
d_1 = 3.5 inches
From Table 3.4, 90 percent Reliability, Fair Soil
d_F = 6.0 inches
Stage 2 design thickness d_2
$= d_F - d_1 = 6.0 – 3.5 = 2.5$ inches

Note 1: If the pavement is built all in one stage rather than two, the asphalt thickness would be = 5.0 inches. Therefore, the result of choosing stage construction is an additional 1.0 inches of asphalt.

Note 2: 50 percent reliability is recommended for Stage 1 because: 1) the traffic for Stage 1 should be relatively predictable; 2) any deficiencies may be corrected prior to Stage 2; and, 3) higher reliability levels would result in an overly conservative total design thickness.

3.4 OTHER CONSIDERATIONS

Drainage. Pavement engineers recognize the importance of good drainage in the design, construction, and maintenance of any pavement. Probably no other single factor plays such an important role in determining the ability of a pavement to provide trouble free service.

The accumulation of water in the subgrade, or in an untreated aggregate base course, usually creates problems. When the soil is saturated, it is weaker. Some soils swell when water is added, which causes differential heaving. These factors weaken the pave-ment structure and its capability to support traffic loads.

Water in the pavement's asphalt layers can strip or separate the asphalt film from the aggregate.

Clearly, it is important to consider the drainage of a roadway. There are two basic categories of drainage – surface and subsurface. Surface drainage includes the disposal of all water present on the pavement surface, shoulder surface, and the adjacent ground when sloped toward the pavement. Subsurface drainage deals with water in the surrounding soil and in the pavement itself. Inadequate attention to either of these two drainage categories can lead to premature pavement failure.

Surface drainage. For surface drainage, the pavement and shoulders must be crowned or cross-sloped to facilitate the flow of water off of the roadway. Normally, the cross-slope moves the water to a curbed or inverted shaped gutter and then off of the pavement into a storm sewer or flume to a ditch. In parking areas or playgrounds, the cross-slope or crown may be inverted toward a center swale with a grated inlet for drainage interception.

Shoulders can best be drained if the entire shoulder width has an asphalt paved surface. If the shoulder is not asphalt, its cross-slope should be steeper in order to minimize seepage through the aggregate or grass shoulder.

Surface drainage from the pavement and from the adjacent land areas must be intercepted and disposed of. If a curbed section is provided, drainage is accumulated in the gutter area and intermittently discharged into either a pavement inlet or a ditch through a flume. The determination of inlet locations requires technical calculations and studies to maintain a tolerable spread of water on the pavement.

Drainage ditches are constructed along the edges of non-curbed roadways sections. Water flowing from the pavement and shoulder surfaces moves from the roadway into a rounded ditch area. The adjacent land is frequently sloped toward the ditch and can contribute significantly to the drainage flow.

Good design practices will provide cross-slopes both on the surface and in the underlying pavement courses and subgrade. In this way, water will not accumulate but will flow laterally to the sides.

Subsurface drainage. Subsurface water is water that percolates through, or is contained in, the layers beneath the surface. It usually is present as water that flows under the force of gravity or as capillary water that moves under capillary action in the soil.

Water may also rise from the underlying soil through the subgrade and into the base course. This water will move readily into an untreated aggregate base to a low point on the profile. If steep grades are present, and the subsurface water flowing in an untreated aggregate base to the low spot and is not intercepted, failure of the pavement structure will often result. Water in the pavement courses also may contribute to the stripping of asphalt films from the aggregate particles.

When water collects in the structural elements of the pavement, subdrains are required. Identification of these areas and determination of drain locations require the technical expertise and insight of an engineer. The choice of drain filter material and the design of the drainage system must be given careful attention by experts. Perforated and slotted pipe usually serve to move the free water from the trouble spot to a drainage area.

Frost Action. Freezing of subsurface soils can cause non-uniform heave of pavements in the winter and loss of strength in the spring. Only an overview of frost considerations is provided here; details of the problem and its solution can be found in Technical Manual 5-818-2, published by the Departments of Army and Air Force. Three factors influence the likelihood of frost damage in pavements. First, the soil must be frost susceptible. Silty soils with a sizeable portion of grain sizes less than 0.05 mm in diameter are likely to heave when frozen. Second, freezing temperatures must penetrate the soil. The depth of frost penetration varies in eastern Oregon from 40 to 100 cm (18 to 40 in.). Finally, water must be available.

ODOT (which uses a version of the above method) reduces the effects of frost action by assuring that the total thickness of non-frost susceptible materials in the pavement (surface, base, subbase) equal at least one-half the expected depth of frost penetration. This approach has been adopted for this guide. Typical frost depths are shown for selected Oregon cities below.

City	**Frost Depth** (inches)
Baker	48
Bend	30
Burns	30
Klamath Falls	18
Ontario	24
Pendleton	30

These data were taken from ODOT information and are available for other sites. Where information is not available or more detailed analysis is warranted, a consulting engineer or ODOT's pavements section should be contacted.

Construction Considerations. A number of construction factors can greatly affect the expected life of the pavement. Many of these factors are considered when construction specifications are developed. These include:

Subgrade preparation. The strength of the native soil is obtained by densifying it through compaction. A poorly compacted soil can result in early pavement failure. Adjustment of the moisture content is an integral part of the compaction process, and many problems (or delays) result from ignoring this fact. As a general guideline, moisture control should be maintained within 2 percent of optimum. Recommendations on moisture content limits should be provided through a soil report.

Variations in layer thickness. A variation in thickness, particularly in the surface layer can greatly affect pavement life. For example consider the three pavement sections placed on the same subgrade. Each pavement has a 200 mm (8 inches) aggregate base. The design surface thicknesses are 50, 100, and 150 mm (2, 4, and 6 inches), respectively. Assume that each pavement is constructed 13 mm (1/2 inch) less than the design thickness. As shown below, there is a significant reduction in pavement life for each pavement, but the reduction is most pronounced for the thinnest surface.

Design Thickness, mm	Actual Constructed Thickness, mm	Resulting Reduction in Life, %
50	37	56
100	87	44
150	137	34

Effect of compaction. The degree of compaction can also affect pavement life. Low compaction values in the base or surface layers will reduce pavement life. Generally, an increase in air voids (or a decrease in density) will reduce the ability of the asphalt mix to resist cracking resulting from repeated truck loadings. In addition, when asphalt mixes are placed at lower densities than specified, permanent deformation may occur in the wheel paths.

Effect of material quality. The specifications for a given job are developed to insure the use of quality materials and to control gradation, percent fracture, and durability of aggregate. Noncompliance with the specifications can reduce pavement life and this, in turn, often results in adjustment through the use of pay factors as discussed in Appendix C.

As noted above, minor variations in thickness have a significant effect on pavement life. The use of thicker asphalt layers (greater than 100 mm) offers several advantages over thin surface layers. For example;

- They are easier to compact because thicker sections retain heat longer and allow the contractor ample time to insure specified density are met.
- As shown above, minor variations in thickness are less harmful to pavement life when thicker sections are used.
- Thicker sections may extend the construction season since thicker sections retain heat better allowing contractors to meet density require-ments in cooler weather.

Soil conditions should be observed during the grading and subgrade preparation work. Any wet, soft, or spongy areas encountered at grade should be investigated and provisions made for their proper drainage. Even a minor rate of seepage may build up to a large quantity of water over a period of time if a means of escape is not provided. Such a soft spot usually forewarns of a structural failure at a later date – even shortly after traffic has used the new facility. After the pavement is in place, corrective measures are costly, create traffic problems, and can cause poor public relations.

Pavement Management Systems. This pavement design manual does not explicitly consider the management of pavement systems; however, a brief overview of the topic is warranted given the potential for improved pavement designs and cost savings that result from the use of such systems.

A pavement management system (PMS) is a decision support system, which is designed to be used to help make cost-effective decisions concerning the maintenance and rehabilitation of pavements (FHWA, 1992). Two levels of PMS are often identified; network-level and project-level. The network-level systems are designed to provide information to administrators and planners as they attempt to project future system costs and forecast system conditions under various funding scenarios. Project-level systems are used to assist designers in selecting the best maintenance or rehabilitation strategy for a given section under the existing funding constraints.

Pavement management systems require that data be collected from existing pavements. The performance (condition) of the pavement is particularly important. This information not only assists in the selection of appropriate rehabilitation and maintenance strategies, but can be used to evaluate the effectiveness of the original design. Therefore the feedback mechanism shown in Figure 3.1 is critical if improved, more cost-effective designs are to be developed.

Summary. The following checklist should be consulted as one begins the design process.

Site Conditions.

- Do the soil conditions, climate and topography indicate a need for:
    - ◊ stabilizing or replacing subgrade so
    - ◊ installing subdrains?
    - ◊ special measures to prevent frost heave?
    - ◊ improving pavement slope in some areas?
- Are specifications provided for:
    - ◊ undercutting and extra work?
    - ◊ grade tolerances, testing soil density and moisture?
    - ◊ acceptance of the work?

Base and Construction Options.

- Do local conditions and project needs favor any of the following base materials:
    - ◊ local materials – sand-clay base, limerock, etc.?
    - ◊ granular base?
    - ◊ hot mix asphalt base?
    - ◊ If stage construction is considered, how will the second stage be funded?
    - ◊ Is site paving a desirable option?
    - ◊ Single layer construction?
    - ◊ Should some concrete work be completed after paving?
    - ◊ Are estimates and cost comparisons based on local cost data

3.5 References

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Chapter 4

Subgrade Treatment

4.0 SUBGRADE TREATMENT

The subgrade is one of the most important factors influencing pavement performance. A poor subgrade will produce unworkable construction conditions and could result in early pavement failure. Thus, a well performing subgrade is essential. The design table in Chapter 3.0 of this guide applies to soils with a minimum resilient modulus value of 5,000 psi, which corresponds to a minimum CBR value of 3 (fair, good and excellent soils all meet or exceed these minimums). Poor soils, CBR less than 3, should be treated using one or more of the following methods:

- Stabilization
  - ◊ Lime-Modified Soils
  - ◊ Cement-Modified Soils
  - ◊ Emulsion-Modified Soils
- Moisture – Density and Water Control
- Cut and Cover
- Geotextile Use

The following sections describe each process in detail and provide guidelines for proper technique.

4.1 STABILIZATION

Subgrade stability refers to the soil strength and repeated loading behavior. Both of these properties influence the long-term performance of pavement structures. In order for the subgrade to be stable, it must:

- Prevent excessive rutting and shoving during construction
- Provide good support for placement and compaction of paving layers
- Limit pavement resilient deflections to acceptable limits
- Restrict the development of rutting in the subgrade during the service life of the pavement

The stabilization treatments covered in this guide include lime-modified, cement-modified and emulsion-modified soils.

Lime-Modified Soils. Many soil properties are improved with the addition of lime including strength, stiffness, plasticity and durability. When a lime-modified soil is used two factors must be considered, (1) the material must have sufficient strength to resist shear failure and (2) the layer must be of adequate thickness to prevent subgrade failure. Normally, that requires 9 to 12 inches of lime-modified soil.

Advantages of using a lime-modified soil include:

- High strength and durability
- The subgrade undercutting is minimized. In most cases the required depth of stabilization can be achieved without removing the existing soil.
- A relatively small amount of lime is needed in thisprocess; so transporting the material requires less effort than other methods of subgrade treatment.

Equipment requirements for lime-modified soil are minimal. Typically, a bulk delivery truck can spread the lime. If the soil if very wet special techniques may be needed (i.e., dozer-towed trailer dolly, high flotation tired spreader truck). A conventional rotary mixer can readily handle lifts up to approximately 12 inches.

Lime treatment is to be used for plastic soils where expansion potential combined with a lack of stability is a problem (i.e., plastic clays). Adding lime to non-plastic soils will not improve the subgrade. Additional information on the construction of stabilized soils can be found in FHWA-SA-98-004, which is available from the FHWA.

Design. If lime stabilization is chosen as the subgrade treatment, a qualified laboratory should perform the mix design, which determines the unconfined compressive strength of the lime-modified soil. The design should include several composite points, which evaluate the unconfined compressive strength of the lime mixture at various lime contents (based upon percent of dry soil weight). The composite points should be performed until the pH value of the soil reaches the minimum target value of 12.4. The mix design should include any necessary mellowing periods (typically 48 hours), the number of required mixing periods and the density of the compacted specimens

If asphalt is not placed immediately after stabilization, the final construction specifications should include a requirement to maintain a moist layer for at least seven days after compaction. This can be accomplished through frequent watering or an applied moisture barrier. Section 00344 of the Oregon Standard Specifications for Construction is applicable where the subgrade is to be improved using lime.

Cement-Modified Soils. Like lime-modified soils, adding cement to a soil can improve the strength, stiffness, plasticity and durability. Laboratory testing is used to determine the proper cement content, compaction and water requirements of the modified soil.
In-place mixtures follow four basic steps; spreading, mixing, compacting and curing. After the road has been shaped to grade and the soil has been loosened, the proper amount of cement is spread on the subgrade. Mixing machines then thoroughly mix the cement and the required amount of water with the soil.

Advantages of using a cement-modified soil include:

- High strength and durability
- Low initial cost
- Approximately 90 percent of material is already in place, keeping handling/hauling costs to a minimum
- Cement-modified soils continue to gain strength with time
- High resistance to seasonal moisture changes and freeze/thaw cycles

Cement treatment should be considered only for soils that exhibit a plasticity index (PI) of 10 or less. Materials can be almost any combination of sand, silt, clay, gravel or crushed stone. However, granular soils are preferred because they pulverize more easily and require less cement to achieve the required strength and durability.

Due to permanent hydration and cementation, cement-modified soils have more strict time constraints in which to work the material. Subgrades stabilized with cement are susceptible to transverse cracking, which results in reflective cracking at the pavement surface.

Additional information on the construction of stabilized soils can be found in FHWA-SA-98-004, which is available from the FHWA.

Design. If cement stabilization is chosen as the subgrade treatment, a qualified laboratory should perform a mix design. The mix design should determine the unconfined compressive strength of the cement-modified soil mixture. The design should include several composite points, which evaluated the unconfined compressive strength of the cement mixture at various cement contents (based upon percent of dry soil weight).

The laboratory report should include the as-tested density of the test specimens.

Section 00344 of the Oregon Standard Specifica-tions for Construction is applicable where the subgrade is to be improved using cement.

Emulsion-Modified Soils. Another option for subgrade stabilization is to use an emulsion-modified soil. Although this method has not been widely employed in Oregon projects, it is an acceptable, sufficient stabilization technique for some soil types.

Design. Emulsion-modified soils are a viable alternative when the subgrade soils are sandy and do not have an excessive amount of material finer than the #200 sieve. Emulsified asphalt stabilization increases the load bearing capacity, firmness and resistance to displacement of the soil. The Asphalt Institute provides guidelines for blending and some general specifications in *A Basic Asphalt Emulsions Manual* (MS-19). The stabiliz tion process is a simple procedure, where the asphalt emulsion is mixed in-place by a traveling mixer or with a blade. Adding imported aggregate and/or milled asphalt can strengthen the stabilized material.

Proper mixing and coating for stabilization depends on the proper amount of pre-wetting of the sandy material before applying the emulsion. A qualified laboratory should establish the amount of water, and the type and amount of emulsion. A laboratory can also determine whether or not to add an aggregate and if so how much aggregate to add.

If it rains before the mixture is compacted and cured, traffic should be kept off until it cures and necessary compaction or re-compaction can be accomplished. The minimum amount of water necessary for mixing should be used to disperse the asphalt emulsion. Over-mixing may cause the emulsion to strip from the sand particles or break prematurely. For faster curing, place the emulsion sand mixture in several thin layers rather than a single thick layer. For optimal results placement should be done at 70 °F or above. Do not seal emulsion-modified soils too soon. Entrapped mixing water and distillates may create problems.

4.2 MOISTURE – DENSITY AND WATER CONTROL

Moisture – Density Control. The strength and stiffness of fine grained soils (clayey and silty soils) are largely affected by moisture content and density. When these soils are wet of optimum, moisture is the primary factor influencing stability. For excessively high moisture content conditions, it is difficult to achieve a good working platform for construction and adequate support for the finished pavement. Typical specifications require that soil should be compacted to at least 95 percent of maximum dry density (AASHTO T-99). Do not assume that soils compacted near optimum water content to at least 95 percent of maximum dry density will provide adequate subgrade stability. Moisture content is typically specified as a maximum moisture content or a permissible moisture content range. Special provisions should be modified as needed to address problems for a specific project

The use of density control is widely used for construction as a means of improving the subgrade strength. The use of moisture control is also accepted, but is generally only a qualitative requirement. There are several problems with using moisture–density control, including:

- Differences in the densities and physical properties of samples compacted by laboratory impact methods and soil compacted by field construction equipment.
- An acceptable density does not assure a stable subgrade. The density is a function of the soil type and no matter how much compactive effort is used, it is impossible to achieve a stable subgrade with certain soils, especially if they are wet of optimum.
- Effective moisture-density control is usually only possible during an extended warm and dry period (typically July through September in Oregon).

Water Content Control. To control excess moisture, it is recommended that proper drainage of the grade be provided and that the top 8 inches of the subgrade be dry. Drainage will remove surface water in the area but will not significantly reduce the water content in fine-grained materials. Drying is typically, accomplished through evaporation. Disking or tilling decreases the size of soil lumps, increasing the amount of soil exposed for evaporation. Three conditions arenecessary for evaporation; (1) there must be a heat supply, (2) there must be a vapor pressure gradient to the atmosphere and (3) there must be a continuous supply of water from the soil (hence, the need for tilling).

It is possible to place the soil at the optimum water content, but it can be difficult to maintain that moisture condition. Field experience and theory indicate that heavy repeated loading of a system with a dry soil layer located above a wet soil layer will cause a moisture content increase and thus a reduction in stability. This is referred to as “pumping”. Soils with a high silt and fine sand content are highly susceptible to pumping. They are also very moisture sensitive and should be treated with methods other than moisture-density control and water control.

4.3 Cut and Cover

This method refers to covering the soft subgrade with a thick layer of granular material or to removing a portion of the soft material and replacing it with granular material. The granular layer distributes the wheel loads over the subgrade and serves as a working platform for construction equipment. Figure 4.1 can be used to approximate the granular material depth needed. This figure is only applicable to soils with a CBR value of 3 or less.

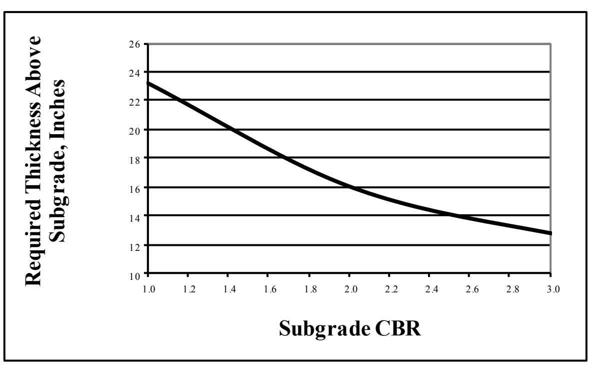

Figure 4.1 Guideline for Granular Material Thickness above Supgrade

The granular material must provide sufficient strength to prevent shear failure and rutting. The use size, better gradation and proper fines content all contribute to increased shear resistance.

There are several advantages to using the cut and cover method including:

- Cut and cover is a simple procedure not requiring any special equipment.
- This method can be used for large scale treatments or spot treatments.

If suitable backfill material is available, this method is relatively inexpensive.

It is standard practice in Oregon to use a geotextile (discussed in further detail in the next section) along with the cut and cover method. After the existing soil is removed, the geotextile is placed followed by the layer of granular material. It is highly recommended to use these two treatments in conjunction.

4.4 GEOTEXTILES

Geotextiles are a permeable synthetic material made of textiles, usually polymers such as polyester and polypropylene. The primary function of the geotextiles covered in this guide is separation, which refers to the placement of a geosynthetic between two dissimilar materials. Geotextile fabrics are placed between the aggregate base course and the subgrade. Separation is important to maintain the design thickness, stability and load-carrying capacity of the aggregate base.

The failure of a road system is often caused by the contamination of high strength aggregate materials by weaker subgrade materials (see Figure 4.2). This contamination occurs as a result of upward pumping of subgrade material by the applied live loads. Using a geotextile keeps the full aggregate thickness intact, providing full support for many years.

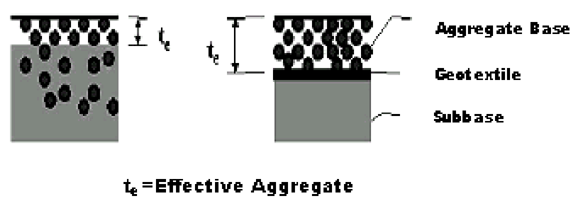

Figure 4.2 – Geotextile Use

There are two types of commonly used geotextiles: woven and nonwoven. Woven geotextiles are very strong, do not elongate or stretch much when a force is applied and are made of synthetic fabric by weaving yarns together. Nonwoven geotextiles are highly permeable, increase in strength as the thickness increases and are able to stretch and take the shape of the adjacent surface. Typically, either woven or nonwoven geotextiles can be used for separation purposes. If a woven product is used, it should be at least 4-oz./sq. yd, while if a nonwoven product is used, it should be at least 8-oz./sq. yd. for survivability during construction.

Geotextiles combine a low initial cost with highly predictable long-term performance in paving applications. The primary advantages of using geotextiles include:

- reducing the intensity of stress on the subgrade and preventing the base aggregate from penetrating into the subgrade during construction.

- preventing subgrade fines from pumping or otherwise migrating up into the base over the design life.
- preventing contamination of the base materials, which may allow more open-graded, free draining aggregates to be considered in the design.
- maintaining the roadway design section and\the base course material integrity, ultimately increasing the life of the roadway.

Material Properties. The properties listed below are tested prior to use of the geotextile to ensure that construction and hydraulic criteria are met.

- Good Tensile Strength (Grab Test)
- Puncture Resistance (Rod or Pyramid Puncture)
- Burst Resistance (Burst Strength)
- Flow Capacity (Permitive)
- Piping Resistance (Apparent Opening Size AOS)

Selecting Geotextiles. Selecting a geotextile depends to a large degree on the survivability criteria. The selection of the geotextile in roadway paving applications is generally governed by the anticipated construction stress. The geotextile must survive the construction operations if it is to perform its desired function. The AASHTO M288 specification for geotextiles provides three classifications of materials.

The classifications are related to strength properties that are meant to provide a certain level of survivability during construction. Table 4.1 shows the recommended usage:

Class	Recommended Usage
1	Specified to use in severe or harsh construction conditions where there is a greater expected potential for damage to the geotextile, i.e., use of large, angular
2	Specified for the use in more typical sur-
3	Typically not recommended for use in road construction - would probably be

Table 4.1 – Geotextile Classifications and

Geotextiles are assumed to provide no structural support, therefore, no reduction is allowed in aggregate thickness required for structural support. Aggregate savings are achieved through a reduction in the stabilization aggregate required for construction but not used for structural support. The value of a geotextile is in separation and improved constructibility.

Cost Considerations. Cost tradeoffs should be evaluated for different construction and geosynthetic combinations. This should include subgrade preparation and equipment control versus geosynthetic survivability Typically, higher-cost geotextiles with a higher survivability on the existing subgrade will be less expensive than the additional subgrade preparation necessary to use lower-survivability geotextiles.

Geotextile Testing. The various standards for testing the geotextiles are listed in Annual Book of ASTM Standards, Volume 4.08 (geosynthetics) and Volume 4.09 (geotextiles and geomembranes). A few important test methods are listed below:

- Standard Test Method for Deterioration from Exposure to Ultraviolet Light and Water: ASTM Test Method D 4335.
- Standard Test Method for Effects of Temperature Stability of Geotextiles: ASTM Test Method D 4594.
- Standard Test Method for Tensile Properties of Geotextiles by Wide-Width Strip Method: ASTM Test Method D 4595.
- Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Method): ASTM Test Method D 4632.
- Standard Test Method for Determining Apparent Opening Size of a Geotextile: ASTM Test Method D 4651.
- Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products: ASTM Test Method D 4833.
- Standard Test Method for Abrasion Resistance of Geotextiles (Sand Paper/Sliding Block Method): ASTM Test Method D 4833.

Specifications. Section 00350 of the Oregon Standard Specifications for Construction is for all geosynthetics used in construction for ODOT projects. Section 02320 covers the geotextile requirements. The geotextile and level of certification must be included in the pavement design recommendation. The level of certification for subgrade geotextiles is either “A” or “B.” Level “A” is used for projects where a large quantity of geotextile material is used or where quality assurance is critical.

Field Inspection Checklist.

- Read special provisions and specifications
- Sample and test project requirements
- Check material properties
- Check roll storage damages
- Check roll and lot numbers
- Sample for comparison and approval
- Check each roll for flaws and non-uniformity
- Sample and test randomly
- Observe installation for compliance
- Check all seams for flaws
- Check after placement for damages
- Check future shipment

4.5 REFERENCES

Colorado Asphalt Pavement Association, *Guideline for the Design and Use of Asphalt Pavements for Colorado Roadways*.

Federal Highway Administration, *FHWA Geosynthetic Design and Construction Guidelines*, 1995.Illinois Department of Transportation, *Subgrade Stability Manual*, March 1, 1982.

Minnesota Local Road Research Board, *Geosynthetics: Use in Streets and Highways*, January 1999. CD-ROM.

Oregon Department of Transportation Pavement Services Unit, *ODOT Pavement Design Guide,* July 2002.

Chapter 5

Urban Streets, Rural Roads, Driveways and Parking Lots

5.0 URBAN STREETS, RURAL RAODS, DRIVEWAYS AND PARKING LOTS

As discussed in Chapters 2.0 and 3.0, several factors need to be considered in the design and construction of any facility; however, the basic steps are similar and include:

I) Mix selection. This consists of selecting the appropriate binder, mix type, and mix design criteria.
2) Structural design. The steps used to determine pavement thickness include:
   - Determine the type and frequency of vehicles that will use the facility, particularly the expected truck traffic. This should consist of construction as well as operational traffic.
   - Clearly delineate traffic patterns for trucks and estimate EALs for the design period, normally 20 years. Another important consideration is identifying areas where trucks are operating slowly, turning, or parking. These areas will most likely require a one-grade increase in the asphalt binder.
   - Using soil data from the project, select a subgrade class (excellent, good, fair) based on information provided in Chapter 3.0.
   - Select the reliability level based on the level of performance risk you are willing to take. The higher the reliability level, the lower the performance risk.
   - Using the selected traffic level, subgrade class and reliability level, select a design thickness from Table 3.4. Note, the surface thicknesses provided are the minimum recommended values.

This chapter presents the factors to consider in the design of streets, driveways and parking lots and provides specific recommendations for mix selection and thickness designs for these types of facilities. At the end of the chapter are detailed design examples.

5.1 LOCAL AND RESIDENTIAL STREETS

Design Considerations. The primary objective of residential and subdivision street design is to provide safe, efficient vehicular access to residential homes, schools, playgrounds and other neighborhood activities. This section addresses some basic considerations that should be evaluated in the design and construction of such streets.

Many localities have established certain standards and requirements for residential streets. All applicable sections of local requirements should be considered. However, the information contained herein is provided as an additional reference for design and construction requirements.

Residential street design standards can control the movement of traffic and help establish desirable traffic patterns. The speed at which motorists drive the routes they select can be influenced by street configuration. Residential streets and roads by design are low speed, low traffic and short trip facilities. Truck traffic should be limited to only vehicles that provide residential services such as trash pickup, heating oil delivery, moving vans, etc. All designs must be sufficiently flexible to accommodate the particular needs and geography that exist in various parts of Oregon.

The pavement structure of many subdivision and residential streets are initially underdesigned and result in pavement failure taking place prior to the completion of the housing in the area. Damage is often caused by the initial overloading of the pavement by construction vehicles.

This is especially true if stage construction is used without properly designing the first stage to account for all of the anticipated construction traffic. Example I at the end of this chapter illustrates the recommended stage construction design approach.

The thickness designs given in Table 3.4 are average compacted thickness recommendations. Any reduction of the pavement thickness values for base or surface thicknesses may result in early pavement failure

Traffic analysis. All asphalt pavements must be designed using proper loading data to insure adequate pavement performance. In residential street design, these data should be based on vehicular traffic estimates for the pavement's design life. These estimates should include accurate counts of vehicles by type, weight and number.

This design manual considers residential streets to be light duty streets with traffic, both present and future, limited almost entirely to passenger cars plus normal service trucks (moving vans, trash trucks, home heating oil delivery, school buses, etc.).

Soil support. The ability of the native subgrade soil to support loads transmitted through the pavement is one of the most important factors in determining pavement thickness. For example, the California bearing ratio (CBR) test provides a simple dependable index of a soil's load bearing capacity. It is widely used by many highway departments as well as other governmental agencies on both the state and federal levels

As discussed in Chapter 3.0, the strength of the subgrade soil should be established through testing procedures from one of the following:

- Have a reputable material testing laboratory conduct a subgrade soils test of the project and determine CBR values. Tests should be performed at the anticipated moisture content in service. Use of field devices (e.g., DCP) that correlate to CBR are acceptable.
- Contact the local office of ODOT (or local city and county engineering offices) for information on results of strength tests made by the department on soils in the immediate area.

Mix Selection. Various mix types have been used for local residential streets. For most applications it is recommended that a 9.5 or 12.5 mm dense-graded mix be used. The binder grade recommendations are as follows:

- Western Oregon -PG 64-22
- CentralJEastern Oregon -PG 64-22 or PG 64-28
- Coastal Oregon -PG 64-22
- Southern Oregon – PG 64-22

The mix design method should be the Superpave method (Level 1 or 2)

Thickness Recommendations. The values for pavement thickness given in Table 3.4 are minimum compacted thickness for work accomplished during the dry construction season. Any reduction in the thickness values for base and surface layers may result in premature pavement failure and/or a shorter pavement life. The designs are based on average conditions. Higher reliability levels reduce the risk of failure. If construction takes place during a wet period (producing a soft subgrade), a working platform (usually aggregate over fabric) is required to operate equipment over the wet subgrade.

The designs thicknesses are appropriate for situations where the full asphalt layer thickness is placed (no stage construction). If stage construction is used, additional asphalt layer thickness may be required, depending on the extent of the damage incurred during construction. Please refer to Example I at the end of the chapter for an illustration of this concept and the design procedure outlined in Chapter 3.

Drainage Provisions. It is important to keep water away from the subgrade soil. If the soil becomes saturated, a substantial decrease in strength and stability will result, making the overlying pavement structure susceptible to breakup under imposed loads. Both surface and subsurface drainage must be considered.

Water present in the pavement layers is the most common cause of early pavement failures. Therefore, all drainage must be carefully designed and should be installed in the construction process as early as is practicable.

Provisions should be made to intercept all groundwater from springs, seepage planes, streams and utility trenches. Another major source of water is irrigation, either landscaping or agricultural. Care must be taken to reduce the effects of this water source as well.

Residential streets should have minimum cross slopes of 2 percent and longitudinal grades of 0.3 percent to insure proper surface water run-off and drainage. The pavement should also be constructed in a manner that will not permit water to collect at the pavement edge.

For streets or roads without side ditches, it is recommended that an edge drain system be installed to remove water beneath the pavement. In addition, areas of very high natural permeability may require an underdrain system to carry water away from the pavement structure.

Construction Guidelines. Guidelines for constructing asphalt pavements are given in Section 5.8 of this chapter. Appendix C provides sample specifications for public works projects. Appendix D provides sample specifications for private projects.

5.2 COLLECTION AND ARTERIAL STREETS

Design Considerations. Collector or feeder streets carry traffic from the residential streets to the arterial routes and provide direct access to subdivisions from arterial streets and roads. Generally, they have moderate amounts of low speed traffic and include some bus and truck traffic. As with residential street design, most localities have adopted design standards for the construction of collector streets. All applicable local and state codes, standards and specifications should be complied with when designing and constructing these streets.

Arterial streets provide the highest operating speeds and highest levels of traffic service. They serve major corridors of traffic and are usually multiple lane in urban areas. They are typically high volume facilities that connect major activity centers. Although arterials frequently carry very large traffic volumes and heavy truck traffic, pavement designs recommended herein are limited to facilities with a maximum of one million EALs. Design of asphalt concrete pavements for higher volume facilities or unusual truck loadings requires considerable expertise and detailed analysis. The information contained in this section should serve as a starting point in the proper planning and design of collector and arterial streets.

Traffic analysis. All asphalt pavements must be designed using proper loading data to insure adequate pavement performance. In collector/arterial street design these data should be based on vehicular traffic estimates for the pavement's design life including construction traffic. These estimates should be based on accurate counts of vehicles by type, weight and number.

This design manual considers these streets to be medium to heavy-duty streets with traffic, both present and future, mostly passenger cars but with some truck and bus traffic.

Soil support. As discussed earlier in this chapter, the strength of the subgrade soil should be established through testing procedures from one of the following:

- Have a reputable material testing laboratory conduct a subgrade soils test of the project and determine CBR values at expected moisture contents under traffic. Use of field devices (e.g., DCP) that correlate to the CBR are acceptable.
- Contact the local office of ODOT (or local city/ county engineering offices) for information on CBR results or modulus tests made by the department on soils in the immediate area.

Mix Selection. Various mix types have been used for collector/arterial streets. For most applications it is recommended that a 12.5 *rom* dense graded mixture be used. A 19.0 mm dense graded mixture may be used for the base course layer, but is not recommended for the wearing course. The binder grade recommendations are as follows:

- Western Oregon -PG 64-22 or PG 70-22
- Central/Eastern Oregon - PG 64-22, PG 64-28, or PG 70-22 or PG 70-38
- Coastal Oregon -PG 64-22
- Southern Oregon -PG 70-22 or PG 76-22

The decision between PG XX-22 and XX-28 should be based on a thermal crack probability consideration. See Table 2.1 for guidance.

The decision to increase the binder grade from PG 64-xx to PG 70-xx or from PG 70-xx to PG 76-xx should be based on the level and type of traffic and on the RAP content. For higher volume intersections and other locations with heavy static loads (such as a bus stop), the higher binder grade should be used. In most locations in Oregon a PG 70-xx is adequate; however, in the most severe high temperature climates, a PG 76 -xx may be required. Medford and Grants Pass are two examples where a PG 76-xx may be necessary in high volume intersections. For further guidance on selecting binder grades you may contact APAO.

The mix design method should be the Superpave method (Level I or 2).

Thickness Recommendations. The values for pavement thickness given in Table 3.4 are average compacted thicknesses for work accomplished during the dry construction period. Any reduction in the thickness values shown for base and surface layers may cause premature pavement failure and/or a shorter pavement life. If the pavement is constructed during the wet winter period, a working platform is required as discussed earlier in this chapter.

Full-depth alternates should be strongly considered in these applications, particularly in urban areas where utilities may be close to the surface, where aggregate resources are not readily available or where disposal costs are high. Additional benefits of the fuil-depth pavements include:

- reduces construction time
- reduces total depth of pavement structure
- virtually eliminates dust and mud in the construction site.

The recommended design thickness must also be adequate to withstand the potential for frost heave as discussed in Chapter 3.0. The total thickness should equal one-half the expected frost depth to prevent frost heave.

Drainage Provisions. It is most important to keep water away from the subgrade soil. Ifthe soil becomes saturated, it will lose strength and stability and make the overlying pavement structure susceptible to breakup under imposed loads. Both surface and subsurface drainage must be considered. All drainage must be carefully designed and should be installed in the construction process as early as is practicable. Provisions should be made to intercept all groundwater from springs, seepage planes and streams. When used, curb and gutter sections should be set to true line and grade. Marshy areas will require special consideration and should be addressed during the planning stage. These streets should have a minimum transverse grade of two percent (2%) to insure proper surface water run-off and drainage. The pavement should also be constructed in a manner that will not permit water to collect at the pavement edge.

Areas of very high natural permeability may require an underdrain system to carry water away from the pavement structure. Storm drainage should be designed using a minimum storm frequency of ten.

Construction Guidelines. Guidelines for constructing asphalt pavements are given in Section 5.8 of this chapter. Appendix C provides guide specifications for public works projects. Appendix D provides sample specifications for private projects.

Design Considerations. Low-volume rural roads consist of local roads and collectors whose primary functions are to provide access to abutting properties and from there to arterial routes. Speeds on these facilities will vary from low to high depending on the geometric standards for which the facility is designed. Truck traffic is usually low, consisting of some school busses and heavy trucks. Most traffic consists of vehicles providing local service such as heating oil and gasoline, local farm traffic and farm vehicles.

Mix Type Selection. Mix types recommended for secondary roads could include either a 12.5 mm dense-- or open-graded mixture. A 19.0 mm dense-graded mixture may be used for the base course layer, but is not recommended for the wearing course. The binder grade recommendations are as follows:

- Western Oregon -PG 64-22
- CentralJEastern Oregon -PG 64-22 or PG 64-28
- Coastal Oregon -PG 64-22
- Southern Oregon -PG 64-22

The mix design method should be the Superpave method (Level 2).

Thickness Recommendations. Recommended pavement thicknesses are given in Table 3.4 for various summertime subgrade conditions using both full-depth and composite pavements. These values are minimum compacted thicknesses. The recommended design thickness must also be adequate to withstand the potential for frost heave. The total pavement thickness should equal one-half the expected frost depth to prevent frost heave.

Drainage Provisions. As for streets, it is important to keep water away from the subgrade soil; otherwise it becomes saturated, loses strength and stability, which results in early distress in the pavement layer. Both surface and subsurface drainage must be considered, carefully designed, and installed in the construction process as early as possible.

For rural roads, provision should be made to intercept all groundwater from springs, seepage planes and streams. Rural roads should have a minimum transverse grade of two percent (2%) to insure proper surface water runoff and drainage. The pavement cross-section should be constructed in a manner that will not permit water to collect at the pavement edge.
Areas of high natural pemleability may require an underdrain system to carry water away from the pavement structure.

All storm drainage should be designed using a minimum storm frequency of 10-years. The system must have hydraulic characteristics to accommodate the maximum expected flow from the 10-year storm.

Construction Guidelines. Guidelines for constructing asphalt pavements are given in Section 5.8 of this chapter. Appendix C provides guide specifications for public works projects. Appendix D provides sample specifications for private projects.

5.4 DRIVEWAYS AND PRIVATE ROADWAYS

Design Considerations. A residential driveway must be properly constructed in order to be a good investment. The information contained in this chapter is intended as a general guide for the homeowner on the design and construction of asphalt concrete residential driveways. These driveways are simple and econom-ical to build and a driveway that is correctly designed and constructed will give many years of service with little or no maintenance.

The homeowner's decision to pave this driveway is sometimes made many years after the home is constructed and frequently incorporates an existing crushed stone or gravel driveway. There are certain special considerations for this type of paving and are specifically addressed in this chapter as is resurfacing existing asphalt driveways.

Mix Type Selection. The recommended mix is a 9.5 or 12.5 mm dense-graded mix. The binder grade recommendations are as follows:

- Western Oregon -PG 64-22
- Central/Eastern Oregon -PG 64-22 or PG 64-28
- Coastal Oregon -PG 64-22
- Southern Oregon -PG 64-22

The mix design method should be the Superpave method (Level l).

Thickness Recommendations. Recommended pavement thicknesses for very light traffic are given in Table 5.1 for various subgrade conditions using composite pavements (asphalt over an aggregate base). These values are average compacted thicknesses for the dry construction season. Assume the asphalt will be placed in one lift. For applications with greater levels of truck traffic, use Table 3.4.

Traffic Level	Reliabillity %	Subgrade Class		
		Fair	Good	Excellent
1 Up to 10,000 EAL's	All Levels	2.5/12.0	2.5/8.0	2.5/4.0

Table 5.1 Asphalt Concrete and Aggregate Design Thickness for Driveways and Private Roadways

Drainage Provisions. Good drainage is important for pavement durability and long life. The surface of the driveway should blend to the contour of the existing ground so that the surface water runs over it or away from it in its natural course. In flat areas, the driveway should have a minimum slope of 2 percent (or a crown not less than Y4 inch per foot) so that all surface water will drain off. Drainage from roof downspouts, patios and walkways should, if feasible, be piped well away from the edge of the driveway. In some cases, pipe cross drains may be needed to take the water under the driveway. Under no circumstances should water be allowed to stand on the pavement or at the pavement edges.

Generally an underdrain system is not required on full-depth asphalt pavements, even over poor soil or in certain other undesirable drainage conditions. However, an underdrain system may be required if the driveway pavement is constructed on an untreated aggregate base

Construction Guidelines. Detailed guidelines for constructing asphalt pavements are given in Section 5.8 of this chapter. Appendix D provides sample specifications.

5.5 LIGHT COMMERCIAL PARKING LOTS

Design Considerations. The parking lot is the first -and the last - part of a building complex to be viewed by the user. It is the gateway through which all customers, visitors and employees pass. This first impression is very important to the overall feeling and atmosphere conveyed to the user. Users also include pedestrians, bicyclists, skateboarders, etc. These users are also greatly affected by the quality and uniformity of the pavement surface.

Developers want their new facilities to be attractive, well designed and functional. Though many hours are spent on producing aesthetically pleasing building designs, the same design consideration for the parking area is often overlooked. Pavements in parking areas that are initially under-designed can experience excessive maintenance problems and a shortened service life. Poorly performing pavements are also not as safe for the users.

When properly designed and constructed, parking areas can be an attractive part of the facility that is also safe, and most important, usable to the maximum degree. In addition, parking areas should be designed for low maintenance costs and easy modification for changes in use patterns. Parking lots must be designed to carry the construction traffic, vehicles operating over the facility (automobiles, light trucks, and fork lifts) as well as the other users described above.

Mix Selection. Parking lots should be designed using a 9.5 or 12.5 mm dense-graded mixture. A 19.0 mm dense-graded mixture may be used for the base course layer, assuming minimum lift thickness requirements can be met. The binder grade recommendations are as follows:

- Western Oregon -PG 64-22 or PG 70-22
- Central/Eastern Oregon – PG 64-22, PG 64-28, or PG 70-22, PG 70-28
- Coastal Oregon – PG 64-22
- Southern Oregon – PG 64-22 or PG 70-22

The mix design method should be the Superpave method (Level 2).

Thickness Recommendations. Design thicknesses given in Table 3.4 are minimum values calculated for the volume and type of traffic that will use the facility and on the load-supporting capability of the underlying soils. They are also based on construction occurring during the dry construction season. For construction during the winter season, a working platform will be required.

Although not recommended, the design thickness for 50 percent reliability has often been used in the past, with variable results. Owners are encouraged to design these facilities for at least 75 percent reliability.

Special truck lanes are sometimes required to expedite traffic to loading areas, trash dumpster sites and equipment areas. Design thicknesses for these lanes or pavement areas should be increased to accommodate the expected EALs.

Drainage problems are also a major cause of pavement failures. Their significance warrants a special section on drainage that should be reviewed before selecting a pavement design either from this guide or from any other source

Drainage Provisions. Drainage problems are frequently a major cause of parking area pavement failures. It is critical to keep water away from the subgrade soil. If the subgrade becomes saturated, it will lose strength and stability, making the overlying pavement structure susceptible to breakup under imposed loads.

Drainage provisions must be carefully designed and should be installed early in the construction process. Recommendations (or guidelines) for surface slopes should include the following:

- Parking areas (including pedestrian crosswalks) should have a minimum slope of 2 percent and a maximum of 5 percentv.
- Handicap accessible areas. These areas should have a l% minimum and 2 percent maximum slope.
- Shopping cart areas. These areas should have slopes ranging from 1.5 to 3 percent. Greater values will cause the carts to roll away.
- Limit sheet flow on pavement surface to a maximum of 60 m (200 feet).
- Limit drainage swales to 30 m (100 feet) maximum.
- Avoid collection of surface water in truck operating areas.
- Drain away from the pavement structures. This includes water from roof drains, landscape runoff, HVAC systems, etc.

It is particularly important that landscape water not collect in or on the pavement structure. Turf areas are generally the greatest source of landscape water. Full-depth curbs or edge drains should be considered to prevent landscape water from finding its way into the pavement structure. A common problem is flat or reverse finish elevations. Adequate (minimum) gradient is often more important than the use of curb and gutter.

Drainage "bowls" should be avoided. The use of tilted planes draining to the edges is recommended. Other drainage factors that need to be considered include:
Edge constraints. Several types of edge con-straints have been used in parking lots. They include nothing, header boards, extruded curbs, curb and gutter, and full depth curbs.

Use of extruded curbs on the edge of the pavement offer no edge constraint but somewhat better drainage opportunities (e.g., removal of water to locations other than the edge of the pavement).

Full-depth curbs or curbs and gutter offer significant edge constraint and the best opportunity to collect surface water without harming the pavement.

Future overlays. If no provision is provided for future overlays, this will affect the surface drainage considerably. Generally, new designs match curb and gutter, walkways, building elevations, etc. An unplanned 2 inch overlay on the pavement sometime in the future can greatly disrupt the surface drainage pattern.

Construction Guidelines. Guidelines for construction of asphalt pavements are given in Section 5.8 of this chapter. Detailed guide specifications are given in Appendix D.

5.6 HEAVY COMMERCIAL PARKING LOTS

Design Considerations. Typically, the major difference in the design of light and heavy commercial parking facilities is the type and frequency of truck traffic operating on the facility. The general design considerations provided for light commercial also apply to heavy commercial.

Mix Selection. Parking lots can be designed using either 12.5 or 19.0 mm dense-graded mixes. Where high stability is required, harder asphalt should be specified. The binder grade recommendations are as follows:

- Western Oregon -PG 70-22
- Central/Eastern Oregon -PG 70-22 or PG 70-28
- Coastal Oregon -PG 64-22
- Southern Oregon -PG 70-22 or PG 76-22

Thickness Recommendations. Design thicknesses given in Table 3.4 are minimum values calculated for the volume and type of traffic expected to use the facility and on the load-supporting capability of the underlying soils. They are also based on construction occurring during the dry construction season. For construction during the winter season, a working platform will be required.

Special truck lanes are recommended to expedite traffic to loading areas, trash dumpster sites, and equipment areas. These areas require greater thick-nesses to accommodate the increase in expected EALs. Impact loads at dumpster sites can cause the pavement to wear out. For this area, a consideration should be given to a one grade increase in asphalt binder.

Drainage problems are also a major cause of pavement failures. Their significance warrants a special section on drainage that should be reviewed before selecting a pavement design from this guide or from any other source.

Drainage Provisions. Drainage problems are frequently a major cause of parking area pavement failures. It is critical to keep water away from the subgrade soil. If the subgrade becomes saturated, it will lose strength and stability, making the overlying pavement structure susceptible to breakup under imposed loads

Drainage provisions must be carefully designed and should be installed early in the construction process. Recommendations (or guidelines) for surface slopes include the following:

- Parking areas (including pedestrian crosswalks) should have a minimum slope of 2 percent and a maximum of 5 percent.
- Handicap accessible areas. These areas should have a 1% minimum and 2 percent maximum slope.
- Shopping cart areas. These areas should have slopes varying from 1.5 to 3 percent. Greater values will cause the carts to roll away.
- Limit sheet flow on pavement surface to a maximum of maximum of60 In (200 feet).
- Limit drainage swales to 30 m (l00 feet) maximum.
- Avoid collection of surface water in truck operating areas or at trash dumpster sites.
- Drain away from the pavement structures. This includes water from roof drains, landscape runoff, HVAC systems, etc.

It is particularly important that landscape water not collect in or on the pavement structure. Turf areas are generally the greatest source of landscape water. Full--depth curbs or edge drains may be required to prevent landscape water from finding its way into the pavement structure. A common problem is flat or reverse finish elevations. Adequate (minimum) gradient is often more important than the use of curb and gutter.

Drainage "bowls" must be avoided. The use of tilted planes drainage to the edges are recommended. Other drainage factors that need to be discussed include:

Edge constraints. Several types of edge con-straints have been used in parking lots. They include nothing, header boards, extruded curbs, curb and gutter, and full depth curbs.

No edge constraints or wooden header boards (e.g., 2x4s or 2x6s) offer little in terms of edge support or drainage. In fact, water will likely seep under the pavement causing early distress at the edge of the pavement.

Use of extruded curbs on the edge of the pavement offer no edge constraint but somewhat better drainage opportunities (e.g., removal of water to locations other than the edge of the pavement).

Full-depth curbs or curbs and gutter offer significant edge constraint and the best opportunity to collect surface water without harming the pavement.

Future overlays. If no provision is provided for future overlays, this will affect the surface drainage considerably. Generally, new designs match curb and gutter, walkways, building elevations, etc. An unplanned 50 mm overlay on the pavement sometime in the future can greatly disrupt the surface drainage pattern.

Construction Guidelines. Guidelines for construction of asphalt pavements are given in Section 5.8 of this chapter. Guide specifications are given in Appendix D.

5.7 INDUSTRIAL AREAS

Log sort yards, port facilities and heavy industrial parking facilities are excellent sites to use heavy-duty asphalt pavements. These facilities often require in-depth soils investigations as well as special pavement design expertise to determine pavement designs for the unusual load conditions. This guide is not intended to be used for projects of this type. It is recommended that the owner/architect retain a consultant to design the pavement structure for industrial areas.

5.8 CONSTRUCTION PRACTICES FOR STREETS, DRIVEWAYS AND PARKING LOTS

Streets, Driveways and Parking Lots.

Subgrade preparation. Because the subgrade must serve both as a working platform to support construction equipment and as the foundation for the pavement, it is very important to see that it is properly graded and compacted. The finished surface should be smooth, uniform and free of localized weak spots. The best way to evaluate the adequacy of support is to proof-roll. Proof-rolling can be performed with a loaded water or other truck. A properly prepared subgrade will not deflect excessively under the load of a loaded truck. The truck's tires should not leave deep tracks in the surface. In addition to proof-rolling, some specifications may call for monitoring density in-place with a nuclear density gauge.

All underground utilities should be protected or relocated prior to grading. All topsoil should be removed and low quality soil must be improved by adding asphalt or other suitable admixtures such as lime or granular materials.

The areas to be paved should have all rock, debris and vegetation matter removed. Grading and compac-tion of the area should be completed in such a manner as to prevent yielding areas or pumping of the soil. The subgrade should be compacted to a uniform minimum density of 95 percent of AASHTO T-180. This will ensure a stable working platform.

Should a weak spot be discovered, the material should be removed and replaced with either 9 to 12 inches compacted crushed stone or 6 inches compacted asphalt concrete plant-mix. Make certain the "bathtub" effect is avoided by providing adequate drainage outlets. In case of an extremely poor subgrade, it may be necessary to remove the upper portion of the subgrade and replace it with select material. When finished, the graded subgrade should not deviate from the required grade and cross section by more than 1/2 inch in 10 feet

Base construction (asphalt). Prior to placement ofthe asphalt concrete base course the subgrade should be graded to the established requirements, adequately compacted and all deficiencies corrected. The asphalt concrete base course should be placed directly on the prepared subgrade in one or more lifts, spread and compacted to the pavement thickness indicated on the plans or established by the owner. Compaction of asphalt mixtures is one of the most important construction operations contributing to the proper performance of the completed pavement, regardless of the thickness of the course being placed. This is why it is so important to have a properly prepared subgrade against which to compact the overlying pavement. The asphalt concrete should meet the specifications for the mix type specified.

Base construction (aggregate). The subgrade must be graded to the required contours and grade in a manner as will insure a hard, uniform, well compacted surface. All subgrade deficiency corrections and drainage provisions should be made prior to constructing the aggregate base. The crushed aggregate base course should consist of one or more layers placed directly on the prepared subgrade, spread and compacted to the uniform thickness and density as required on the plans or established by the owner. Minimum crushed aggregate thickness is 4.0 inches. All crushed aggregate material should be of approved type and suitable for this type of application.

Prime coat. In the past it was common to use an application of low viscosity liquid asphalt (MC-70 or RC-250) over untreated bases or aggregate stone base prior to placing the bituminous concrete course, typical application rates are 0.3-0.4 g/yd2• The use of prime and its benefit differ with each application and are not currently in common practice in Oregon. Any requirements for prime should be discussed with the paving contractor. A common problem with prime coats is associated with weather conditions and curing.

Asphalt surface course. Material for the surface course should be hot plant-mix placed in one or more lifts to the true line and grade as shown on the plans or set by the owner. The plant-mix material should conform to the guide specifications for hot mix bituminous concrete. The asphalt surface should not vary from established grade by more than 1/4 inch in 10 feet when measured in any direction. Any irregularities in the surface of the pavement course should be corrected directly behind the paver. Rolling and compaction should start as soon as the hot-mix material can be compacted without displacement and continued until thoroughly compacted and all roller marks disappear.

Desirable minimum lift thickness is 2 inch. Thin lifts cool rapidly and are difficult to compact. The designer is encouraged to use thicker lift thicknesses where possible.

Curb and gutter. Designed to provide roadway drainage, curb and gutter also delineates the roadway edge. Gutter widths vary from 1 to 2 feet with a 1-1/2 feet width being most common. Vertical curbs range between 5.0 and 8.0 inches in height with a 6.0 inch highcurb preferred.

One of the most common errors in pavement design is not specifying the appropriate grades to insure that water does not collect on the pavement. A common problem is flat or reverse fmish elevations. Adequate gradient is often more important than the use of curbs and gutters. Many residential and subdivision streets also place the elevation of the pavement below that of the curb and gutter. As water is the biggest enemy of any pavement, these "dry curbs" will result in poor pavement performance and shorter pavement life. It is suggested the AC surface be placed flush with or up to 1/4 inch above the gutter edge.

Pavement failures also often occur around catch basins. Reasons for this can include not finishing to the level of the basin and/or inadequate compaction. This results in accumulation of water in the vicinity of the basin and early failures in the form of cracking and/or settlement. To minimize this problem, the AC surface should be placed flush with or up to 1/4 inch above the catch basin.

Basis of payment. Unless otherwise specified compensation for the construction of bituminous concrete residential streets and roads should be at the contract unit price of asphalt material complete in place. This could be by ton, area paved (yd2) or linear lfeet. This should be full compensation for all labor and equipment required to produce, transport, place and compact the bituminous concrete.

Existing Driveways. Paving existing aggregate driveways. The required asphalt pavement thickness for surfacing an existing gravel or aggregate driveway may be taken from Table 5.1. The aggregate layer should be evaluated for its suitability. Most existing aggregate surfaces are not suitable due to contamination; hence, additional aggregate should be added to provide a working platform on which to pave.

If needed, existing aggregate driveways should be graded and treated with a non-toxic commercial soil sterilant prior to paving. (Note: Check with the DEQ to determine which sterilants are permitted.) Also, a determination of the depth of existing stone must be made. Should that determination reveal an aggregate depth less than required minimum thickness shown in the table for aggregate base material, additional stone

Resurfacing existing asphalt driveways. After many years of service the homeowner may want to repair and resurface the asphalt driveway to correct original construction errors, oxidation, cracking and automobile fuel or oil spillage. All weak areas should be repaired with proper patches prior to resurfacing. Areas where fuel spillage and other petroleum products have softened the asphalt pavement must be removed and patched. Structural patches should be designed and constructed with full-depth asphalt concrete to insure strength equal to or exceeding that of the existing pavement. Careful and correct preparation of the existing pavement, prior to the construction of smoothing or strengthening overlays, is essential for good construction and maximum overlay performance. Requirements for correct preparation of existing pavements for overlays vary with the pavement age, condition and use. For this reason it is recommended that a competent asphalt driveway contractor be consulted for required pavement repairs and overlay thickness. It is recommended, however, that the existing surface be thoroughly cleaned, a tack coat be placed and the asphalt concrete overlay have a minimum compacted thickness of 1-1/2 inch. Caution: Overlays placed over seal coats containing coal tar are susceptible to delamination. These seal coats need to be removed prior to the application of the overlay.

5.9 REFERENCES

The Asphalt Institute, *Full-Depth Asphalt Pavements for Parking Lots, Service Stations and Driveways.* IS –91, December 1981

National Stone Association, *Design Guide for Parking Areas,* Fifth Edition, January 1994

NAPA, the Design of Hot Mix Asphalt for Heavy Duty Pavements. Q15-11, 1995

American Association of State Highway and Traffic Officials. *AASHTO Guide for Design of Pavement Structures.* 1993

The Asphalt Institute. *How to design Full-Depth Asphalt Pavements for Streets.* IS—96, December 1981

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DESIGN EXAMPLE 1—CITY STREET

Introduction

A residential street in eastern Oregon (LaGrande) was selected for this example. The traffic considera-tions are typical of many residential areas, however the soil type and environmental conditions may not be typical of other areas in Oregon. It must be remembered that this design is intended to serve as an example of the design process presented in this manual and is not intended for use.

Background

This pavement, to be constructed in a new sub-division, will consist of two travel lanes plus curbside parking and will serve 50 single-family homes. A re-view of the subdivision layout shows that this roadway will not function as a collector and therefore only traffic associated with the homes (and their construction) need be considered. Because of the relatively heavy truck traffic associated with the construction of a subdi-vision and the relatively light traffic following comple-tion of the homes, staged construction should be con-sidered.

A review of the records for the LaGrande area shows that typical summer temperatures are 95°F and winter temperatures are 10°F. Annual precipitation averages less than 16 inches. The expected depth of frost pene-tration is 30 inches (ODOT).

Binder Selection

The appropriate binders for LaGrande can be selected based on the information in Chapter 2. For this light traffic condition and climate, a high temperature grade of 64°C is perfect. The low temperature selection should be based on the level of thennal cracking risk one is willing to accept. From Table 2.1 we can see that going from a -22°C to a -28°C binder only increas-es our probability from 94 percent to 98 percent. For this project it is not justified since the -28 product will cost more and be harder to work with. Therefore, a -22°C binder is recommended. The final binder grade is a PG 64-22.

Mix Selection

For an urban street application a 12.5 mm or a 9.5 mm mix is appropriate. We recommend a 12.5 mm mix because we have had good success and the local con-tractors are accustomed to using it. A 9.5 mm would require a special mix design adding unnecessary cost to the project.

Structural Design

Traffic Estimates. Traffic estimates are required for both the construction phase and the "operational" phases of the pavement. Each of these are discussed below:

Construction Phase. Construction traffic can be estimated based on a single-family housing (SFH) unit basis as shown, assuming typical frame con-struction. Changes in construction types or subdi-visions containing multiple--family housing would require that these values be revised.

Type of Vehicle	No. of Trips per SFH	EAL per Vehicle	To-tals
Transit Mixer	4 load-ed 4 empty	3.10 2.0	12.4 8.0
Materials Delivery (5 axle)	3 load-ed 3 empty	2.36 1.5	7.1 4.5
Materials Delivery (3 axle)	5 load-ed 5 empty	1.3 0.8	6.5 4.0
Materials Delivery (2 axle)	3 load-ed 3 empty	0.2 0.05	0.6 0.15
Landscaping (3 axle)	3 load-ed 3 empty	1.3 0.8	6.5 4.0
Total per SFH			54
Total Construction EAL for 50 SFH			2690

Operational Traffic. Following the comple-tion of construction, typical operational characteristics control the types of vehicles using the pavement. As noted previously, only heavy traffic need be considered when deter-mining the thickness of the pavement layers. Again the approach will be to estimate the types of trucks using the facility on a per unit basis; however, some vehicle types will be aggregated for the entire subdivision (i.e., trash pick up).

Total Traffic. Following the recommendations of Chapter 3.0, the design life of the facility is 20-years. Although traffic is expected to grow over the life of the project for many facilities, the an-ticipated traffic will remain constant for the 20-year design period in this residential area. Combining the construction and opera-tional EAL count yields a total of about 9,200 or traffic level I

Type of Vehicle	No. of Trips per SFH per Year	EAL per Vehicle	Total Over 20 Years
Moving Van (5 axle)	0.25	3.10	775
Recycling Pick Up (1 trip per week for subdivision) (3 axle)	52	1.3	1,352
Utility Service Truck (3 axle)	0.25	1.3	325
Trash Pick Up (1 trip per week for subdivision) (3 axle)	52	1.9	1,976
Small Delivery Vehicle (2 axle)	10	0.2	2,000
Total Operational EAL for 50 SFH			6,428

Subgrade Support. Based on a site visit, the designer has determined that the soil is fairly uniform throughout the subdivision. Contacts with the City Engineer and local ODOT representatives have confirmed that the soil is sandy clay (SC). Test results from an adjacent ODOT project show the soil has a CBR of 5. Using Figure 3.11, the soil modulus would be estimated to be about 7500 psi or a fair subgrade class.

In this circumstance, additional testing is not warranted for two reasons. First, the soil was found to be fairly uniform throughout the project. If significant variation was noted, then testing would likely have been necessary. Second, the project will be constructed in stages that allow problem areas to be identified and corrected prior to placement of the final stage thus minimizing the likelihood of premature, localized failures during the operational phase.

Reliability. For traffic level 1 only, reliability is not a selection criteria because the asphalt thicknesses are in the minimum levels. If reliability was an option, we would recommend 75 or 90 percent.

Final Recommendation. The recommended pavement design for this project taken from Table 3.4 is: Asphalt over aggregate base -3.0 AC over 12.0 inch base. This structural design is appropriate for the one-stage construction alternate during the dry construction.

An additional consideration is the likely depth of frost penetration at this location. For example, ODOT documents show that the typical depth of frost penetration in LaGrande is approximately 75 em (30 inches). Following ODOT recommendations, the total pavement thickness must be at least one-half this thickness (15 inches). In this case the design meets this criteria.

Staged Design

If stage construction is a consideration, a staged design should be completed following the procedures in Section 3.3. For this project:

N_{fl} = 1.67(n_1) = 1.67 (2690) = 4,492

N_{f2} = 2.5 (n_2) = 2.5 (6428) = 16,070

d_1 -can be found from Table 3.4, Traffic Level II, Fair Soil

d = 3.0; however as noted in Section 3.3 for N_f < 10,000 d_1 = 2.5 inches

d_f-is determined from Table 3.4, Traffic Level II, Fair Soil, 75% Reliability

d_f = 3.5

$d_2 = d_f - d_1 = 3.5 - 2.5 = 1.0$

If a 9.5 mm mix were being used and Stage 2 paving will take place during the summer paving season, then d2= 1.0 inches is acceptable; however, we have chosen a 12.5 mm mix.

For 12.5 mm mix and/or paving outside the warm season, the minimum thickness for Stage 2 should be

Final Stage Design:

Stage 1 2.5 inches
Stage 2 1.5 inches

Total 4.0 inches

The result of choosing stage construction is to increase the total asphalt thickness from 3.0 inches to 4.0 inches.

DESIGN EXAMPLE 2— PARKING LOT

Introduction

A shopping center parking lot in Portland was selected for this example. The layout of the shopping center allows the separation of heavy truck traffic from the automobile traffic. Tenants in the shopping center consist of a major grocery store and four smaller lease facilities. It must be remembered that this design is intended to serve as an example of the design process presented in this manual and is not intended for use.

Background

This shopping center fronts on an urban minor arterial. City records show that the one-way average daily traffic (ADT) is 5,I00 with 4 percent trucks. Recent traffic classification data are available from the city and are used in the calculations.

A review of the Portland area records shows that typical summer temperatures are 25°C (77°F) and winter temperatures are 2°C (35°F). Annual precipitation averages about 110 cm (43 inches).

The use of a staged construction process is appropriate for this project. Construction of the access drives and parking areas by placing the base and a single lift of asphalt concrete creates a dry working platform upon which the building trades can stage their activities. The thickness of the first stage pavement is governed by the expected construction traffic and minimum thickness requirements for construction, whichever is greater. As the project nears completion, any areas of base weakness can be corrected and a new lift of asphalt concrete placed.

Mix and Binder Selection

A PG 64-22 or PG 70-22 may be used on this project. The PG 70-22 will provide increased rutting resistance in the heavy truck areas and is a good choice for commercial/industrial applications. For the base lift, a 12.5 or 19.0 mm mix is recommended. For the surface course, use a 12.5 mm mix (Table 2.6).

The mix design criteria for the project is recommended as Level 2, with a design air void content of 4 percent (Table 2.6).

Traffic Estimates. Traffic estimates are required for both the construction phase and the "operational" phases of the pavement. Each of these are discussed below.

Construction Phase. Construction traffic can be estimated based on type of construction and the total area (assumed to be 50,000 sq. ft.). Tilt up construction was assumed for this example. Other equipment types could include cranes, earthmovers, backhoes, etc., and would require that these values be revised.

Type of Vehicle	No. of Trips for Shopping Ctr (50,000 ft2)	EAL per Vehicle	Total
Transit Mixer	190 loaded 190 empty	3.10 2.0	969
Materials Delivery (5 axle)	25 loaded 25 empty	2.36 1.5	96
Materials Delivery (3 axle)	65 loaded 65 empty	1.3 0.8	136
Materials Delivery (2 axle)	45 loaded 45 empty	0.2 0.05	11
Total Construction Phase EAL			1,214

Operational Traffic. Following the completion of construction, typical operational character-istics control the types of vehicles using the pavement. As noted previously, only heavy traffic need be considered when determining the thickness of the pavement layers. Again the approach will be to estimate the types of trucks using the facility. However, because the shopping center layout allows the separa-tion of most of the heavy vehicles from the auto traffic, two designs will be completed. First, the delivery/receiving areas.

In this example, the owner has requested a design life for the facility of only 10 years. Additionally, the designer should take into account potential growth in traffic over the 10-year period. Annual growth rates of 3 percent represent the upper limit in many urban areas and will be used for this design.

Delivery Areas. The first-year truck traffic may be projected based on the type of facility (grocery and small retail) and the total square footage of retail space or on the total expected vehicle traffic generated by the retail establishments. For this example, the retail space is expected to generate 3,650 vehicles per day (or 1,825 one-way). Furthermore, it is assumed that 4 percent of the total traffic will be trucks (similar to proportion on the collector). Therefore, the total daily truck traffic is 73 (1825*(0.04) = 73).

Vehicle	Distribution[1] %	EAL Per Truck[2]	Average Daily Truck Traffic[3] (ADTT)	Annual EAL[4] (Year
2-axle	53	0.274	39	3,900
3-axle	12	0.603	9	1,981
4-axle	12	0.877	9	2,881
5-axle	18	1,781	13	8,451
6-axle	5	1.781	4	2,600
Total Operational EAL			73	19,813

[1]Taken from ODOT truck classification data

[2]From ODOT average EAL per vehicle, see Chapter 3

[3]Taken from ODOT traffic count data – ADT of 5,100 with 4 percent trucks (one-way) and the estimated total vehicular traffic of 1,825

[4]Annual EAL = ADTT*EAL per truck*365 days/year

Accounting for the 3 percent growth over the 10-year design life:

- Design Traffic = 19,813*{[(1+0.03)IO-l]/0.03} = 227,000
- Combining the construction and operational EAL count yields a total of about 228,200 (Traffic Level III).

Automobile Parking Areas. Although a minimal structure would likely be sufficient to serve the automobile areas (Traffic Level I), it should be expected that about 25 percent of the truck traffic may wander into the auto parking area over the life of the facility. This corresponds to 56,750 EAL (0.25 * 227,000).

The construction traffic is added to this amount to yield the total design traffic for this area.

> Total Design EAL: 56,750 + 1,214 = 57,964 or about 58,000 EAL (Traffic Level II)

Subgrade Support. Based on a site visit the designer has determined that the soil is fairly uniform throughout the subdivision. Contact with the structural engineer responsible for the shopping center design indicates that the soil was classified as CL, clay of low plasticity. Soil modulus test results are available from two locations on site. The average modulus was 5,000 psi, (CBR=3) which is typical of CL soils (see Figure 3.11). Using these data, the designer selects a modulus value of 5,000 psi, or a poor subgrade class.

Soils in the poor category should be treated by one of the methods described in Chapter 4.0. In this case, the cut and cover procedure will be used. The granular base thickness is selected based on Figure 4.1. For CBR=3 the required thickness is 13 inches. The asphalt thickness will be selected from Table 3.4.

Reliability. The recommended reliability for this project is 90 percent. The consequence of failure (e.g., the number of people impacted by premature failure) is fairly high since the roadways serve businesses and the short design life (10 years) should be coupled with high reliability.

Auto Area	AC over Aggregate Base	4.0/12
Truck Area	AC over Aggregate Base	4.0/17.0

Final Recommendation. The recommended pavement designs for this project taken from Table 3.4 are:

Staged Construction. The estimated construction traffic in this case is a small percentage of the total traffic and only 12 percent of the traffic Level I EAL. If you apply Minor's hypothesis, it is apparent that the total (final) thickness will not need to be increased to account for the small amount of damage done during construction.

The Stage I thicknesses will be selected based on minimums, and elevation control. The table below shows the options.

Area and Pavement Component		Stage 1	Stage 2	Total Thickness, inches
Auto Area	AC	2.5	1.5	4.0
	Base	13.0	-	13.0
Truck Area Option 1	AC	3.5	2.5	6.0
	Base	13.0	-	13.0
Truck Area Option 2	AC	4.5	1.5	6.0
	Base	13.0	-	13.0

CHAPTER 6

Specialty Pavements

6.0 SPECIALTY PAVEMENTS

This chapter presents information on the design and construction of specialty pavements and is intended as a general guide only. Due to the multitude of designs and applications, individual structural design details are limited. The types of facilities considered in this chapter include the following:

- Bikeways, paths, trails and walkways
- Playgrounds (or recreational areas)
- Tennis courts
- Running tracks
- Special environmental uses

For each application, general design considerations are first presented followed by recommendations for mix selection and thickness designs, drainage consid-era-tions and construction guidelines.

The thickness recommendations presented herein are the consensus of values recommended by the Asphalt Institute, the U.S. Tennis Court and Track Builders Association and the experience of local industry.

6.1 BIKEWAYS, PATHS, TRAILS AND WALKWAYS

Design Considerations. Bicycle trails and path-ways are generally constructed in much the same manner as asphalt paved sidewalks. However, they are usually built wide enough to permit a small vehicle to safely pass another (8 feet). Golf cart paths require the same pavement thickness as bike paths and a minimum pavement width of 5 feet; how-ever, widths of 8 feet are encouraged to accommodate convention-al construction equipment and to allow maintenance vehicles to operate on the paths.

The pavements are not usually designed to with-stand repeated loads from these type vehicles but need to be designed to withstand an occasional load applica-tion without undue damage. Additional widen-ing on sharp curves is also recommended as a safety meas-ure. To minimize golf shoe spike wear, the pave-ment should be designed with a higher than normal asphalt content.

Thickness Recommendations. Bicycle trails and path-ways are generally placed in one lift, therefore making it impractical to use more than one asphalt mix type. Also, since such pavements carry only occasion-al vehicular traffic, the recommended thickness is gen-erally based on the minimum practical require-ments. Table 6.1 provides the recommendations for these types of facilities. As indicated, the recommended pavement thickness will vary depending on the strength of the soil and the types of materials used in the pavement structure.

The asphalt concrete over aggregate base alternate has the major advantage of constructibility, particularly over soft subgrades. The full-depth alternate is best suited for those situations where the subgrade is firm and gradable.

The asphalt layer for bikeways and playgrounds can be placed in one lift. The asphalt layer for tennis courts and running tracks should be placed in two lifts to en-sure the smoothness tolerances for these types of facil-ities.

Mix Selection. Mix selection for these type facilities must take into account the required surface condition. If smooth surfaces are required, then the 9.5 mm dense-graded mix is recommended. If a rougher tex-ture is desired, then the 12.5 mm dense-graded mix would be preferred. The binder grade recommenda-tions are as follows:

- Western Oregon – PG 64-22
- Central/Eastern Oregon – PG 64-22, PG 64-28
- Coastal Oregon – PG 64-22
- Southern Oregon – PG 64-22

The mix design method should be either the Marshall method (50 blows – 2 to 3 percent air voids) or the Su-perpave method (Level 1).

Drainage Provisions. It is important to keep water away from the subgrade soil. If the soil becomes satu-rated it will reduce the strength and stability, causing the overlying pavement structure to become suscepti-ble to breakup under imposed loads or freeze-thaw cycles.

Both surface and subsurface drainage must be con-sidered. All drainage must be carefully designed and should be installed in the construction process as early as is practicable. Bicycle and golf cart paths should follow the contour of the terrain so that surface water runs off and away from the pavement. Flat bicycle and golf cart paths should have a minimum slope of 2 per-cent and be constructed in such a manner that water will not collect at the pavement edge or under the pave-ment within the aggregate base. Areas of very high natural permeability may require an underdrain system to carry water away from the pavement structure. Note: Underdrains are usually not necessary when full-depth asphalt is used for the base and surface courses.

Construction Guidelines. The following guidelines are applicable for these types of facility.

Subgrade preparation. Because the subgrade must serve both as a working platform to support construction equipment and as the foundation for the pavement structure, it is very important to see that the subgrade is properly compacted and graded. A visual examination usually reveals the adequacy of evaluation.

However, field or laboratory tests to evaluate the load-supporting characteristics of subgrade soils are desirable. If these tests are not available, designs may be chosen based on careful field evaluations (through visual classifications and proof rolling the subgrade with a loaded dump truck) and/or experience in the area on previous projects.

All underground utilities should be protected or relocated prior to grading. All topsoil should be removed and low-quality soils must be improved by adding suitable admixtures such as lime or granular materials. The areas to be paved should be treated with a soil sterilant to inhibit future flora growth after all rock, debris and vegetation matter have been removed. (Note: Check with DEQ to determine whether the soil sterilant can be used in your area.)

Another common problem is the uplifting and cracking of pavements from tree roots. Often trees are placed too close to the pavement (or vice versa) or an inappropriate tree is specified. Root (or edge) barriers should be considered in these locations. These barriers do not work if the existing tree root is already under the pathway. They work best for new plantings.

Grading and compaction of the area should be completed in such a manner as to prevent yielding areas or pumping of the soil. (A large truck driven over the area will give an indication of any “soft spots”). Should a weak spot be discovered, the material should be removed and replaced with either 6 inches compacted crushed stone or 3 inches compacted bituminous concrete plant-mix. In case of an extremely poor subgrade, it may be necessary to remove the upper portion of the subgrade and replace it with select material. When finished, the graded subgrade should not deviate from the required grade and cross section by more than 1/2 inch in 10 feet. The top 6 inches of the subgrade should be compacted to 95 percent of AASHTO T-99.

Base construction (asphalt). For the full-depth alternate, prior to placement of the asphalt concrete base course the subgrade should be graded to the established requirements, adequately compacted and all deficiencies corrected. The asphalt base course should be placed directly on the prepared subgrade in one or more lifts, spread and compacted to the pavement thickness indicated on the plans or established in the contract. Compaction of asphalt mixtures is one of the most important construction operations contributing to the proper performance of the completed pavement, regardless of the thickness of the course being placed. This is why it is so important to have a properly prepared subgrade against which to compact the overlying pavement.

Base construction (aggregate). The subgrade must be graded to the required contours and grade in a manner as will insure a firm, stable, uniform, well compacted pavement structure. Normally, the top 6.0 inches of the subgrade should be compacted to 95 percent of AASHTO T-99. All subgrade deficiency corrections and drainage provisions should be made prior to constructing the aggregate base. The crushed aggregate base course should consist of one or more layers placed directly on the prepared subgrade; spread and compacted to the uniform thickness and density as required on the plans or established by the owner. *Absolute minimum crushed aggregate thickness is 4.0 inches*. All crushed aggregate material should be of an approved type and suitable for this type of application.

Tack coat. Prior to placement of successive pavement layers the previous course should be cleaned and a tack coat of diluted emulsified asphalt applied (normally a CSS-1) at the rate of 0.05 to 0.10 g/yd^2.

Type of Facility	Subgrade Type		
	Fair	Good	Excellent
a) Asphalt Concrete over Aggregate Base, inches			
Bikeways, Paths, Trails, Walkways	2.5/6.0	2.5/5.0	2.5/4.0
Playgrounds and Recreational Areas	2.5/6.0	2.5/5.0	2.5/4.0
Tennis Courts	3.0/6.0	3.0/5.0	3.0/4.0
Running Tracks	3.0/6.0	3.0/5.0	3.0/4.0

Table 6.1 Recommended Minimum Pavement Thickness for Specialty Pavements

Asphalt surface course. Material for the surface course should be asphalt concrete placed in one or more lifts to the true line and grade as shown on the plans or set by the owner. The asphalt concrete material should conform to the guide specifications given in Appendix D. Any irregularities in the surface of the pavement course should be corrected directly behind the paver. Rolling and compaction should start as soon as the material can be compacted without displacement and continued until thoroughly compacted and all roller marks disappear.

6.2 PLAYGROUNDS/RECREATIONAL AREAS

Design Considerations. There are many pavement types that are suitable for playgrounds, basketball courts, and other play courts. They include conventional asphalt concrete mixes as well as proprietary products, which are often used for color treatments and area demarcations.

The most important design considerations for these types of facilities include the following:

- smooth surfaces requiring a fine mix
- low maintenance - a high asphalt content mix will allow for long life; when maintenance is required, coatings can be applied to rejuvenate or seal the facility's surface
- good drainage - to eliminate ponding and puddles

The pavement surface could be either full-depth asphalt concrete or asphalt concrete over aggregate base. The advantages of the different alternates were discussed previously under Section 6.1.

Thickness Recommendations. The thickness recom-mendations for these facilities are given in Table. 6.1.

Mix Recommendations. The preferred mix for this type of facility is the 9.5 mm dense-graded. The binder grade recommendations are as follows:

- Western Oregon – PG 64-22
- Central/Eastern Oregon – PG 64-22, PG 64-28
- Coastal Oregon – PG 64-22
- Southern Oregon – PG 64-22

The mix design method should be either the Marshall method (50 blows – 2 to 3 percent air voids) or the Superpave method (Level 1).

Drainage Provisions. It is important to keep water away from the subgrade soil. If the soil becomes saturated it will lose strength and stability and make the overlying pavement structure susceptible to breakup under imposed loads. Both surface and subsurface drainage must be considered. All drainage must be carefully designed and should be installed in the construction process as early as is practicable. Playgrounds and flat sidewalks should have a slope of 1½ to 2 percent and be constructed in such a manner that water will not collect at the pavement edge. Areas of very high natural permeability may require an underdrain system to carry water away from the pavement structure. (Note: Underdrains are usually not neces-sary when full depth asphalt is used).

Construction Guidelines. The following guidelines are applicable for these types of facility.

Subgrade preparation. Because the subgrade must serve both as a working platform to support construction equipment and as the foundation for the pavement structure, it is most important to see that the subgrade is properly compacted and graded. A visual examination will usually reveal the adequacy of evalu-ation. However, field or laboratory tests to evaluate the load-supporting characteristics of subgrade soil are desirable. If these tests are not available designs may be chosen based on careful field evaluations and/or experience in the area on previous projects.

All underground utilities should be protected or relocated prior to grading. All topsoil should be removed and low-quality soil must be improved by adding suitable admixtures such as lime or granular materials. The areas to be paved should be treated with a soil sterilant to inhibit future flora growth after all rock, debris and vegetation matter have been removed.

Another common problem is the uplifting and cracking of pavements from tree roots. Often trees are placed too close to the pavement (or vice versa) or an inappropriate tree is specified. Root or edge barriers should be considered in these locations. These barriers do not work if the existing tree root is already under the pathway. They work best for new plantings.

Grading and compaction of the area should be completed in such a manner as to prevent yielding areas or pumping of the soil. (A loaded dump truck driven over the area will give an indication of any "soft spots"). Should a weak spot be discovered the material should be removed and replaced with either 6 inches compacted crushed stone or 3 inches compacted bituminous concrete plant-mix. In case of an extremely poor subgrade, it may be necessary to remove the upper portion of the subgrade and replace it with select material. When finished, the graded subgrade should not deviate from the required grade and cross section by more than 1/2 inch in 10 feet.

Base construction (asphalt). For the full-depth alternate, prior to placement of the bituminous concrete base course the subgrade should be graded to the established requirements, adequately compacted and all deficiencies corrected. The asphalt concrete base course should be placed directly on the prepared subgrade in one or more lifts, spread and compacted to the pavement thickness indicated on the plans or established in the contract. Compaction of asphalt mixtures is one of the most important construction operations contributing to the proper performance of the completed pavement, regardless of the thickness of the course being placed. This is why it is so important to have a properly prepared subgrade against which to compact the overlying pavement.

Base construction (aggregate). The subgrade must be graded to the required contours and grade in a manner as will insure a firm, stable, uniform, well compacted pavement structure. All subgrade deficien-cy corrections and drainage provisions should be made prior to constructing the aggregate base. The crushed aggregate base course should consist of one or more layers placed directly on the prepared subgrade; spread and compacted to the uniform thickness and density as required on the plans or established by the owner. *Absolute minimum crushed aggregate thickness is 4 inches*. All crushed aggregate material should be of an approved type and suitable for this type of application.

Tack coat. Prior to placement of successive pavement layers the previous course should be cleaned and a tack coat of diluted emulsified asphalt applied at a rate of 0.05 to 0.10 g/yd^2.

Asphalt surface course. Material for the surface course should be placed in one or more lifts to the true line and grade as shown on the plans or set by the architect or engineer. The plant-mix material should conform to the specifications for hot-mixed bituminous concrete of the type specified. Any irregularities in the surface of the pavement course should be corrected directly behind the paver. Rolling and compaction should start as soon as the hot-mix material can be compacted without displacement and continued until thoroughly compacted and all roller marks disappear.

6.3 TENNIS COURTS

Design Considerations. An asphalt-paved tennis court, properly designed and constructed, makes an excellent sporting facility. The asphalt surface provides good traction for the players, consistent ball bouncing and clear demarcation of boundary lines. Proprietary products are usually used for the uppermost surfaces to insure good drainage and no ponding. Asphalt tennis courts should require little maintenance over their design life. Details of the geometric design and layout of tennis can be found in the publications of the U.S. Tennis Court and Track Builders Association.

Thickness Recommendations. Recommended mini-mum pavement thicknesses for tennis courts are given in Table 6.1.

Mix Recommendations. Recommendations for mix types for tennis courts include the use of a 12.5 mm mix for the base and a 9.5 mm mix for the surface. The binder grade recommendations are as follows:

- Western Oregon – PG 64-22
- Central/Eastern Oregon –PG 64-22, PG 64-28
- Coastal Oregon – PG 64-22
- Southern Oregon – PG 64-22

The mix design method should be the Superpave method (Level 1).

Drainage and Slope Provisions. Proper drainage is of the utmost importance in the construction of a good court. In sandy or gravelly soil, underdrainage may not be required, but in areas of predominantly clay or fine silty soils, a perimeter drain (French drain) consisting of a perforated pipe or clay tile backfilled with crushed stone in a 2 to 3 foot deep ditch around the court(s) is recommended. The perimeter drainage ditch should have adequate slope and outlets to prevent the retention of water between the facility.

In order to properly drain, the finished court surface(s) should have a minimum slope of 1 inch in each 10 feet on a true plane from end to end drainage from the net. The 12 inch difference in elevation from one end to the other is not noticeable by the players. The surface should not slope away in two directions from the net. Specific drainage recommendations can be found in the construction manual developed by USTCTBA.

Construction Guidelines. The following guidelines are applicable for these types of facility.

Subgrade preparation. A soil examination should be made to determine its suitability as a founda-tion material. Trees and other vegetation including their root systems must be removed from the site and the soil treated with a sterilant that will effectively inhibit future flora growth. Because the earth subgrade must serve both as a working platform to support construction equipment and as the foundation for the pavement structure, it is important to see that the subgrade is properly compacted and graded. All topsoil should be removed and low-quality soils must be improved by adding admixtures such as lime or granu-lar materials.

The site should be excavated and filled to provide the finished grades shown on the plans or established by the owner. Any soft, yielding material should be replaced with a suitable material in not greater than 6 inch lifts and compacted to a density of 95 percent of AASHTO T-99 at optimum moisture. Good compaction is particularly important in tennis court construction as subsequent subgrade settlement may cause cracking in the court surface. The subgrade should be shaped to true and even lines so as to insure a uniform thickness of base course.

Base construction (asphalt). For the full-depth alternate, the asphalt concrete should meet the specifications for the type of mix specified. The specified thickness of asphalt base should be placed in one lift on the prepared subgrade. The material should be compacted to the required uniform density by rolling with a powered steel wheel tandem roller with static weight of 5 to 10 tons or by other equipment producing equivalent density. The finished base should conform to the true lines and grade as established on the plans or by the owner with a variance of not more than 1/4 inch when measured with a 10 foot straight edge.

Base construction (aggregate). The crushed aggregate base should be placed and compacted to a uniform thickness and required density with a maximum grade variance of 1/4 inch in 10 feet measured in any direction. All aggregate material should conform to the specifications. Compaction in the construction operation is most important to the performance of the completed asphalt pavement, regardless of the thickness of the course being placed. Compaction should be accomplished by rolling with a 5 to 10 ton powered steel wheel roller or other equipment capable of producing equivalent density. Under no circumstances should the compacted aggregate thickness be less than 4 inches.

Tack coat. Prior to placement of successive pavement layers the previous course should be cleaned and a tack coat of diluted emulsified asphalt applied at a rate of 0.05 to 0.10 g/yd^2.

Asphalt surface course. Material for the surface course should be a Hot-Plant Mix placed in one or more lifts to the true line and grade shown on the plans or set by the owner. The Plant-Mix material should conform to the specifications for the bituminous mix specified. The asphalt surface should not vary from established grade by more than 1/8 inch in 10 feet when measured in any direction.

Color finish course (optional). The use of a color finish on asphalt tennis court surfaces is becoming increasingly popular. Favorite colors are grass green and tile red, or a combination of both. Prior to the addition of any color course the entire surface should be flooded with water and allowed to drain. Any depression holding water deeper than 1/16 inch should be patched. There are a wide variety of color surfaces and manufacturers, available for tennis court construction. Color surface manufacturer's specifications should be followed for the addition of any color or texture surfaces.

Playing lines. A minimum of 30 days waiting time following construction is recommended before the application of playing lines. A latex striping paint should be used and placed no thicker than necessary for delineation, accurately located and marked in accor-dance with the rules of the United States Lawn Tennis Association.

Tennis court overlays. There are many reasons for overlaying of an existing tennis court such as badly oxidized or aged surface, poor drainage or poorly constructed base.

Each of these conditions and their severity should be considered in determining the required overlay pavement thickness.

Since there are many possible considerations in determining the most sound and economical procedures to follow in resurfacing a tennis court, it is strongly recommended that a qualified asphalt paving contractor, experienced in tennis court construction, be consulted. Whatever is done, it is necessary to ensure compatibility with any coating that might be on the surface of the existing court.

6.4 RUNNING TRACKS

Design Considerations. Asphalt running tracks are widely used and can be tailored to suit most requirements of athletes and coaches. The tracks themselves can be designed for the correct amount of resilience to insure optimal performance.

An all-weather running track should meet the following minimum requirements:

- it should be durable, resilient and resistant to weather conditions
- it must resist shearing and twisting forces and running shoe damage
- the surface must be uniform and smooth for good drainage
- it must possess the requisite coefficient of friction for athletic shoes
- longitudinal and transverse slopes must be in strict accordance with the requirements for the type of facility intended

The same requirements are appropriate to the construc -tion of runway approaches for the pole vault, high jump and long jump pads.

Thickness Recommendations. The thickness recom-mendations for running tracks are given in Table 6.1.

Mix Recommendations. The selection of mix type depends on whether a proprietary running surface is used. For most applications, it is recommended that a 12.5 mm mix be used for the base and a 9.5 mm mix be used for the surface. The binder grade recommendations are as follows:

- Western Oregon – PG 64-22
- Central/Eastern Oregon – PG 64-22, PG 64-28
- Coastal Oregon – PG 64-22
- Southern Oregon – PG 64-22

The mix design method should be either the Marshall method (50 blows – 2 to 3 percent air voids) or the Superpave method (Level I).

Drainage Provisions. Good surface and subsurface drainage are necessary to properly support the paving structure. The basic objective of the surface drainage system is to ensure that the only water that falls on the track surface is that which comes from rain; all other sources should be directed around the surface. The objective of the subsurface drainage system is to prevent excessive moisture buildup underneath the soil, especially in frost areas so that frost susceptibility of the soil is minimized. Specific drainage recommenda-tions can be found in the *Track Construction Manual* developed by the U.S. Tennis Court and Track Builders Association.

Construction Guidelines. The following guidelines are applicable for these types of facilities.

Subgrade preparation. Because the subgrade must serve both as a working platform to support construction equipment and as the foundation for the pavement structure, it is most important to see that the subgrade is properly compacted and graded. A visual examination will usually reveal the adequacy of evalu-ation. However, field or laboratory tests to evaluate the load-supporting characteristics of subgrade soil are desirable. If these tests are not available, designs may be chosen based on careful field evaluations and/or experience in the area on previous projects.

All underground utilities should be protected or relocated prior to grading. All topsoil should be removed and low-quality soil must be improved by adding suitable admixtures such as lime or granular materials. The areas to be paved should be treated with a soil sterilant to inhibit future flora growth after all rock, debris and vegetation matter have been removed.

Another common problem is the uplifting and cracking of pavements from tree roots. Often trees are placed too close to the pavement (or vice versa) or an inappropriate tree is specified. Root barriers should be considered in these locations.

Grading and compaction of the area should be completed in such a manner as to prevent yielding areas or pumping of the soil. (A loaded dump truck driven over the area will give an indication of any "soft spots"). Should a weak spot be discovered the material should be removed and replaced with either 6 inches compacted crushed stone or 3 inches compacted bituminous concrete plant-mix. In case of extremely poor subgrade, it may be necessary to remove the upper portion of the subgrade and replace it with select material. When finished, the graded sub-grade should not deviate from the required grade and cross section by more than 1/2 inch in 10 feet.

Base construction (asphalt). For the full depth alternate, prior to placement of the asphalt concrete base course the subgrade should be graded to the established requirements, adequately compacted and all deficiencies corrected. The asphalt concrete base course should be placed directly on the prepared subgrade in one or more lifts, spread and compacted to the pavement thickness indicated on the plans or estab -lished in the contract. Compaction of asphalt mixtures is one of the most important construction operations contributing to the proper performance of the completed pavement, regardless of the thickness of the course being placed. This is why it is so important to have a properly prepared subgrade against which to compact the overlying pavement.

Base construction (aggregate). The subgrade must be graded to the required contours and grade in a manner as will insure a firm, stable, uniform, well compacted pavement structure. Normally, the top 6 inches of the subgrade should be compacted to 95 percent of AASHTO T-99. All subgrade deficiency corrections and drainage provisions should be made prior to constructing the aggregate base. The crushed aggregate base course should consist of one or more layers placed directly on the prepared subgrade; spread and compacted to the uniform thickness and density as required on the plans or established by the owner. *Absolute minimum crushed aggregate thickness is 100 mm (4 inches)*. All crushed aggregate material should be of an approved type and suitable for this type of application.

Tack coat. Prior to placement of successive pave -ment layers the previous course should be cleaned and a tack coat of diluted emulsified asphalt applied at a rate of 0.05 to 0.10 g/yd^2.

Asphalt surface course. Material for the surface course should be placed in one or more lifts to the true line and grade as shown on the plans or set by the architect or engineer. The plant-mix material should conform to the specifications for hot-mixed bituminous concrete of the type specified. Any irregularities in the surface of the pavement course should be corrected directly behind the paver. Rolling and compaction should start as soon as the hot-mix material can be compacted without displacement and continued until thoroughly compacted and all roller marks disappear.

Special considerations. It is particularly important that the longitudinal and transverse slopes specified in the *Track Construction Manual* be adhered to. In addition, the geometrics (e.g., curves, widths, etc.) need to be followed very carefully.

6.5 SPECIAL ENVIRONMENTAL USES

Asphalt mixes have been used for a number of environmental related applications including:

- Pond liners. Asphalt mixes are used exten-sively to contain fresh water, as well as waste water.
- Containment for toxic materials. Used both as a liner as well as a cap to contain highly toxic materials.

Asphalt mixes have numerous attributes in these applications including:

- Asphalt mixes can be designed to be imper-meable so liquids cannot penetrate.
- Asphalt mixes are also puncture proof and conform to irregular surfaces.
- Asphalt mixes can be designed to withstand moderate settlements that might be experi-enced in caps and landfills.
- Asphalt mixes can be designed to provide long-term durability.
- Asphalt mixes are resistant to most toxic materials. They are, however, subject to degradation when exposed to petroleum products such as motor oil, kerosene, gasoline and the like.

When designing a facility such as these, the owner is strongly encouraged to retain a consultant experi-enced with these applications.

6.6 REFERENCES

NAPA, *Asphalt for Environmental Liners*. PS-17.

Oregon Department of Transportation, *Oregon Bicycle and Pedestrian Plan*. June 14, 1995.

The Asphalt Institute, *Asphalt Pavements for Athletics and Recreation*. PS-18, Lexington, KY.

U.S. Tennis Court and Track Builders Assoc., *The Tennis Facilities Construction and Maintenance Manual*. 1997, Ellicott City, MD.

U.S. Tennis Court and Track Builders Assoc., *Track Construction Manual*. 1996, Ellicott City, MD.

Chapter 7

Design of Porous Pavements for Commercial Facilities

7.0 DESIGN OF POROUS PAVEMENTS FOR COMMERCIAL FACILITIES

7.1 INTRODUCTION

Porous asphalt pavements are increasingly in demand because they offer site planners and public works officials the opportunity to minimize impervious surfaces and manage stormwater in an environmentally friendly way.

Impervious surfaces such as roofs and pavements create runoff, so that dirt and debris are washed into streams and waterways. At the same time, water has often been regarded as the “enemy” of asphalt. Great efforts are taken to assure that water does not enter the roadway material, especially in areas with numerous freeze/thaw cycles.

Ironically enough, porous asphalt offers the opportunity to address both of these problems in many parking lot and paved area applications. With the proper design and installation, porous asphalt parking areas can provide cost-effective, attractive parking lots with a life span of twenty years or more, and at the same time, provide stormwater management systems that promote infiltration, improve water quality, and ***eliminate*** the need for a detention basin. While this almost sounds too good to be true, the technology is really quite simple.

The secret to success is to provide the water with a place to go, usually in the form of an underlying, open-graded stone bed. As the water drains through the porous asphalt and into the stone bed, it slowly infiltrates into the soil. The stone bed size and depth must be designed so that the water level never rises into the asphalt. This stone bed, often eighteen to thirty-six inches in depth, provides a tremendous subbase for the asphalt paving. Even after twenty years, porous lots show little if any cracking or pothole problems. The surface wears well, and while slightly coarser than standard asphalt, it is attractive and acceptable – most people parking on the lot will not notice (or believe) that it is porous.

Porous asphalt does not necessarily require additives or proprietary ingredients, although polymers and/or fibers can be used to prevent draindown and to improve durability and shear strength. Constructing a permeable surface does not require the contractor to have special paving equipment or skills. With the proper information, most asphalt plants can easily prepare the mix and general paving contractors can install it. A porous pavement is defined as one that allows water to drain all the way through the pavement structure.

This article will discuss the background and costs of porous pavement, cite examples of successful installations, explain how it works, and explore design considerations. It will also discuss issues including soil and subsurface conditions, infiltration, water quality, construction, and maintenance.

7.2 BACKGROUND

First developed in the 1970s at the Franklin Institute in Philadelphia, porous asphalt pavement consists of standard bituminous asphalt in which the aggregate fines (particles smaller than 600 um, or the No. 30 sieve) have been screened and reduced, allowing water to pass through the asphalt (Figure 1).

Figure 7.1 Water Pass

Underneath the pavement is placed a bed of uniformly graded, clean- washed aggregate with a void space of 40 percent. Stormwater drains through the asphalt, is held in the stone bed, and infiltrates slowly into the underlying soil mantle. A layer of geotextile filter fabric separates the stone bed from the underlying soil, preventing the movement of fines into the bed (Figure 2).

Porous pavement is especially well suited for parking lot areas. Several dozen large, successful porous pavement installations, including some that are now 20 years old, have been developed by Cahill Associates (CA) of West Chester, Pennsylvania, mainly in Mid-Atlantic states. These systems continue to work quite well as both parking lots and stormwater management systems. In fact, many of these systems have outperformed their conventionally paved counterparts in terms of both parking lot durability and stormwater management.

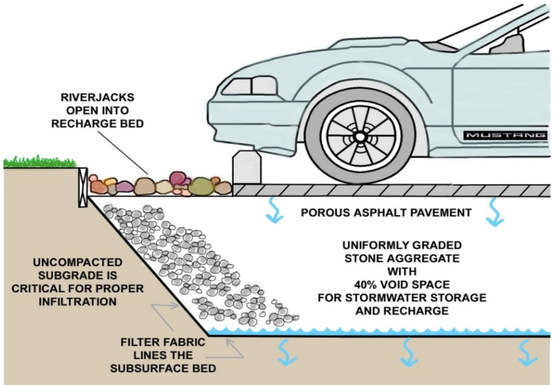

Figure 7.2 – Cross-Section

Cost

Porous pavement does not usually cost more than conventional pavement. On a yard-by-yard basis, the asphalt cost is approximately the same as the cost of conventional asphalt. The underlying stone bed is usually more expensive than a conventional compacted subbase, but this cost difference is generally offset by the significant reduction in stormwater pipes and inlets. Additionally, because porous pavement is designed to “fit into” the topography of a site, there is generally less earthwork and are no deep excavations.

When the cost savings provided by eliminating the detention basin are considered, porous pavement is generally an economically sound choice. On those jobs where unit costs have been compared, the porous pavement has always been the less expensive option. Current jobs are averaging between $2,000 and $2,500 per parking space for parking, aisles, and stormwater management.

A recent installation at the University of North Carolina in Chapel Hill included parking lots where some sections were constructed from porous asphalt and some sections used porous concrete. The cost differential was approximately 4:1 – that is, the porous concrete pavement cost four times as much as the porous asphalt pavement. All other installations cited in this article are asphalt pavements.

7.3 INSTALLATIONS OLD AND NEW

One of the first large-scale porous pavement/recharge bed systems that CA designed is located in a corporate office park in the suburbs of Philadelphia (East Whiteland Township, Chester County). This particular installation of about 600 parking spaces posed a challenge because of both the sloping topography and the underlying carbonate geology that was prone to sinkhole formation. The site also is immediately adjacent to Valley Creek, designated by Pennsylvania as an Exceptional Value stream where avoiding nonpoint source pollution is of critical importance.

Constructed in 1983 as part of the Shared Medical Systems (now Seimens) world headquarters, the system consists of a series of porous pavement/recharge bed parking bays terraced down the hillside connected by conventionally paved impervious roadways. Both the top and bottom of the beds are level, as seen in Figure 3, hillside notwithstanding. After twenty years, the system continues to function well and has not been repaved. Although this area is naturally prone to sinkholes, far fewer sinkholes have occurred in the porous asphalt areas than in the conventional asphalt areas, which the site manager attributes to the broad and even distribution of stormwater over the large areas under the porous pavement parking bays.

Figure 7.3 – Benched Parking Bays

Other early 1980s sites, such as the SmithKline Beecham (now Quest) Laboratory in Montgomery County, Pennsylvania, and the Chester County Work Release Center in Chester County, Pennsylvania, also used the system of “terracing” the porous paved recharge beds down the hillside to overcome the issues of slope. At the DuPont Barley Mills office complex in Delaware, the porous pavement was constructed specifically to avoid the construction of a detention basin, which would have destroyed the last wooded portion of the site. More recently (1997), the porous parking lots at the Pennsylvania State Berks Campus were constructed to avoid destroying a wooded campus hillside. The Pennsylvania State Berks lots, also on carbonate bedrock, replaced an existing detention basin and have not experienced the sinkhole problems that another campus detention basin has suffered.

7.4 HOW IT WORKS

The porous asphalt mix has a lower concentration of fines than traditional asphalt, as shown in Table 1, accomplished by straightforward screening. In all other manufacturing aspects, porous asphalt is the same as conventional asphalt and can be mixed at a standard asphalt batch plant. With fewer fines, the asphalt is porous and allows water to drain though the material through virtually imperceptible openings (To the untrained eye, porous pavement properly prepared is difficult to distinguish from conventional pavement.).

There are several variations of the mix, including gradations developed by various state transportation departments seeking a pavement that also can be used to reduce noise and skidding. For the purposes of stormwater management, we have found the best performance from the mix indicated in Table 1.

US Standard Sieve Size	Percent Passing
3/8"	95
#4	35
#8	15
#16	10
#30	2

Percent bituminous 5.75% to 6.0% by weight

Table 7. 1 – Standard Porous Asphalt Mixes

The underlying stone recharge bed consists of a uniformly graded (i.e., screened) 1.5- inch to 2.5-inch clean -washed stone mix, such as an AASHTO No. 3. Depending on local aggregate availability, both larger and smaller size stones have been used. The important requirement is that the stone be uniformly graded (to maximize void space) and clean washed. The void space between the stones provides the critical storage volume for the stormwater. Stones that are dusty or dirty may clog the infiltration bed and must be avoided.

The stone bed is usually between eighteen and thirty-six inches deep, depending on stormwater storage requirements, frost depth considerations, and site grading. This depth provides a significant structural base for the pavement. As a result, porous asphalt exhibits very few of the cracking and pothole formation problems encountered in conventional pavement.

The bottom of the recharge bed is excavated to a level surface and is not compacted. This allows water to distribute and infiltrate evenly over the entire bed bottom area. Compaction of the soils will prevent infiltration, so it is important that care be taken during excavation to prevent this. The bottom of the bed cannot be placed on fill material unless that fill material is stone. A layer of non-woven geotextile at the bottom of the bed allows the water to drain into the soil while preventing the soil particles from moving into the stone bed. The steps involved in a typical porous asphalt installation are shown on page 7-9.

Very often, the underlying stone bed can also provide stormwater management for adjacent impervious areas such as roofs and roads. To achieve this, we convey the stormwater directly into the stone bed and then use perforated pipes in the stone bed to distribute the water evenly (Figure 4).

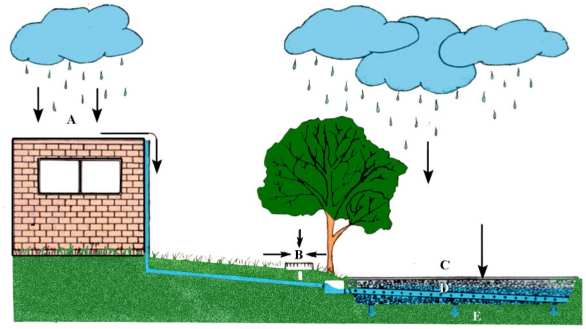

Figure 7.4 – Roof Leaders

Roof leaders can be connected directly to the subsurface infiltration bed.

- Precipitation is carried from roof by roof drains to storage beds.
- Stormwater runoff from impervious areas and lawn areas is carried to storage beds.
- Precipitation that falls on pervious paving enters storage bed directly.
- Stone beds with 40 percent void space store stormwater. Perforated pipes distribute stormwater from impervious surfaces evenly throughout the beds.
- Stormwater exfiltrates from storage beds into soil and recharges the groundwater.

Figure 7.5 – Perforated Pipes

7.5 DESIGN CONSIDERATIONS

In the late 1970s and early 1980s, as we designed our first systems, we were uncertain how well the porous asphalt would hold up over time and use. In these first systems, we designed the parking spaces with porous pavement but constructed the aisles and connector roadways with conventional asphalt. We extended the stone stormwater storage/infiltration bed under the entire parking area, however, including the areas with impervious paving.

Over time, we have found that the porous asphalt material has held up as well as, or better than, the conventional asphalt, largely due to the solid sub-base provided by the stone storage/infiltration bed. In subsequent designs we have paved the entire surface in the porous asphalt. We have found that sufficient asphalt content is essential to pavement durability (5.75 percent to 6.0 percent bituminous asphalt by weight). In sites where a lower asphalt content was used, some surface scuffing and/or raveling can be observed on the pavement surface. In different situations, we have tried various commercial additives intended to improve strength or performance in cold weather, but in general have avoided any proprietary mixes or additives.

We have also taken the "belt and suspenders" approach to all of our systems. If the pavement were to be paved over, forgotten, or clogged, stormwater still must reach the stone bed below the pavement. Often, we have used an unpaved stone edge, as shown in Figure 6, for this purpose. We have also used catch basins that discharge to perforated pipes in the bed.

Figure 7.6 – Repaved, Unpaved Stone Edge

Additionally, in case the bed bottom clogs (which has not happened yet), we have always designed the underlying bed systems with a "positive overflow." During a storm event, as the water in the underlying stone bed rises, it must never be allowed to saturate the pavement. We have used a catch basin with a higher outlet than inlet to provide positive release. In this way, the bed also serves as an "underground detention basin," eliminating the need for a separate basin.

The stormwater component of the system should be designed by an engineer proficient in hydrology and stormwater design. Essentially, the bed acts as an underground detention basin in extreme storm events, albeit one that also reduces volume. A storm can be "routed" through the bed using the same calculation methods employed to route detention basins to confirm peak rate mitigation.

As a final design consideration, infiltration systems also work best when the water is allowed to infiltrate over a large area. We usually use a rule of thumb and design to a ratio of 5:1 impervious area to infiltration area. That is, the runoff from five acres of impervious area would require a one-acre infiltration bed. Because parking tends to consume so much of our landscape relative to other impervious surfaces, meeting this ratio is rarely a problem.

With the proper design and installation, porous asphalt parking areas can provide cost-effective, attractive parking lots with a life span of twenty years or more, and at the same time, provide stormwater management systems that promote infiltration, improve water quality, and ***eliminate*** the need for a detention basin. While this almost sounds too good to be true, the technology is really quite simple.

The secret to success is to provide the water with a place to go, usually in the form of an underlying, open-graded stone bed. As the water drains through the porous asphalt and into the stone bed, it slowly infiltrates into the soil. The stone bed size and depth must be designed so that the water level never rises into the asphalt. This stone bed, often eighteen to thirty-six inches in depth, provides a tremendous subbase for the asphalt paving. Even after twenty years, porous lots show little if any cracking or pothole problems. The surface wears well, and while slightly coarser than standard asphalt, it is attractive and acceptable – most people parking on the lot will not notice (or believe) that it is porous.

7.6 SOIL AND SUBSURFACE CONDITIONS

Obviously, suitable soil conditions are required for infiltration. The designer must evaluate a number of factors, including soil type, infiltration rate, depth to bedrock, and depth to water table. Some of the guidelines that we have used in design are shown below.

The most important factor is that the location of the porous pavement infiltration system be considered early in the design process. Traditionally, engineers have designed stormwater systems that collect and convey runoff to the lowest point. By the time you have done this, you are likely to be at the wettest location on the site, next to the stream or wetlands or in poor soils. Infiltration systems perform best on upland soils. Some of our more recent designs integrate a mixture of large and small infiltration systems throughout the site, including porous pavement, to avoid conveying stormwater any distance.

Here is a summary of design guidelines for subsurface infiltration.

- Avoid piping water long distances. Look for infiltration opportunities within the immediate project area.
- Consider past uses of the site and appropriateness of infiltration design and porous pavement.
- Consider the source of runoff. Incorporate sediment reduction techniques as appropriate.
- Perform site tests to determine depth to seasonal high water table, depth to bedrock, and soil conditions, including infiltration capabilities. Design accordingly. Maintain three feet above high water table and two feet above bedrock.
- Avoid excessive earthwork (cut and fill). Design with the contours of the site. Maintain a sufficient soil buffer above bedrock.
- Do not infiltrate on compacted fill.
- Avoid compacting soils during construction.
- Maintain erosion and sediment control measures until site is stabilized. Sedimentation during construction can cause the failure of infiltration systems.
- Spread the infiltration over the largest area feasible. Avoid concentrating too much runoff in one area. A good rule of thumb is 5:1 impervious area to infiltration area (i.e., 5 acres of impervious area to 1 acre of infiltration area). A smaller ratio is appropriate in carbonate bedrock areas.
- The bottom of the infiltration area should be level to allow even distribution.
- The slope on which the porous pavement is placed should not exceed 5 percent. Use conventional pavement in steep areas that receive vehicular traffic
- Provide thorough construction oversight.

Before any infiltration system is designed, soil investigation must be done. This consists of two steps. First, a simple "deep hole" six to eight feet in depth (Figure 7) is excavated with a backhoe and the soil conditions are observed. While some designers prefer an auger, we believe that there is no substitute for physically observing and describing the soil horizons. Next, infiltration measurements are performed at the approximate bed bottom location. We have used both simple percolation tests, which are not very scientific, as well as infiltrometer readings. We do not consider infiltration rates between 0.1 inch per hour and 0.5 inch per hour too slow; rather, this means that infiltration will occur slowly over a two- to three-day period, which is ideal for water quality improvement.

Underlying geology must also be considered in areas such as those underlain by carbonate formations. In that situation, more detailed site investigation may include borings and ground-penetrating radar. Contrary to popular belief, properly designed infiltration systems do not create sinkholes. A number of our systems, including older systems, are located in carbonate areas. In several situations, we have successfully installed porous pavement infiltration systems adjacent to areas where detention basins had previously created sinkholes.

Figure 7.7 – Deep Hole Excavation

7.7 WHEN INFILTRATION IS LIMITED

Despite the need for infiltration, not all sites and soils are suitable. In those situations, we have designed porous pavement systems to reduce impervious surfaces or as part of a water quality improvement program. The porous pavement parking lots recently constructed at the John Heinz National Wildlife Refuge near the Philadelphia Airport are located in a wet, low-lying site that has been subject to fill over the years. The soils are not well drained. In this situation, a trench was excavated to a lower gravel layer to facilitate infiltration, but the parking lots primarily serve to avoid the creation of new impervious surfaces at this valuable wildlife refuge.

At the Ford Motor Company Rouge River Facility in Dearborn, Michigan, the use of porous pavement is an important part of Ford's commitment to sustainability. The original manufacturing plant was constructed in a low-lying, wet area and has been subject to a century of industrial use. In 1999, Ford constructed a porous parking lot designed to slowly drain to a series of planted wetland swales (Figures 8 and 9).

The stormwater stored in the beds beneath the porous pavement supports the vegetated swales by discharging slowly to the planted areas. The system is specifically designed to improve water quality. Referred to as the "Mustang Lot" (because new Ford Mustangs are parked there after assembly), the lot has worked well, and current Ford plans include the construction of additional areas of porous pavement areas that will drain to constructed stormwater wetlands.

Figure 7.8 – Mustang Lot

7.8 WATER QUALITY

There has been limited sampling data on the porous pavement systems, although the available data indicate a very high removal rate for total suspended solids, metals, and oil and grease (Table 3). More recently, Brian Dempsey, Ph.D., and his research assistant, David Swisher, have conducted research at the Pennsylvania State University. Dr. Dempsey has been studying a porous pavement system constructed at the Centre County/Pennsylvania State Visitor Center in 1999, comparing the water quality in the infiltration beds to observed runoff from a nearby impervious parking lot. Dr. Dempsey has monitored the infiltration rates of this system and found that the system has maintained a consistent infiltration rate. During a 25-year precipitation event, there was no surface discharge from the stone beds.

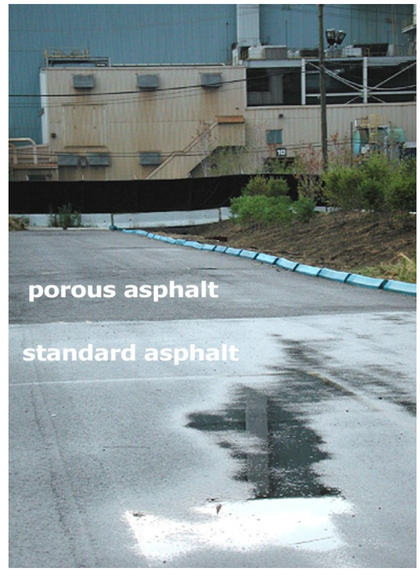

Figure 7.9 – Porous & Standard Lot Sections

Water Quality Parameter	INFILTRATION BMP TYPE				
	Trench	Trench	Porous Paving	Porous Paving	Average Removal Efficiency
TSS	90%	---	95%	89%	91%
TP	60%	68%	71%	65%	66%
TN	60%	---	---	83%	72%
TOC	90%	---	---	82%	86%
Pb	---	---	50%	98%	74%
Zn	---	---	62%	99%	81%
Metals	90%	---	---	---	90%
Bacteria	90%	---	---	---	90%
BOD	75%	---	---	---	75%
Cd	---	---	33%	---	33%
Cu	---	---	42%	---	42%
TKN	---	53%	---	---	53%
Nitrate	---	27%	---	---	27%
Ammonia	---	81%	---	---	81%

Table 7.2 – Water Quality Benefits of Porous Pavement with Infiltration

7.9 CONSTRUCTION

Almost always, when an infiltration Best Management Practice (BMP) fails, it is due to difficulties and mistakes in the design and construction process. This is true for porous pavement and all other infiltration BMPs. Carelessness in compacting the subgrade soils, poor erosion control, and poor-quality materials are all causes of failure. For that reason, we provide detailed specifications on site protection, soil protection and system installation.

On every project, we meet with the contractor before construction and discuss the need to prevent heavy equipment from compacting soils, the need to prevent sediment-laden waters from washing on to the pavement, the need for clean stone, etc. We verbally review the installation process with the project foreman. During construction, we routinely stop by the site or provide construction advice. Successful installation of any infiltration BMP is a hands-on process that requires an active role for the designer. While we have prevented failures with this approach, most of the problems we have seen at other infiltration BMPs are a result of construction problems. Often, the failure does not lie with the contractor or with poor soils, but instead is due to a lack of specific guidance for construction procedures.

Because construction sites are inherently messy places, we have often found it best to install the porous pavement towards the end of the construction period. By doing this, there is less risk of creating problems. On many projects, we will excavate the stone bed area to within six inches of the final grade and use the empty bed area as a temporary sediment basin and stormwater structure. Care must be taken to prevent heavy equipment from compacting the soils, but sediment can accumulate.

In the later stages of the project, the sediment is removed, the bed is excavated to final grade, and the porous pavement system is installed. This also avoids the need for a separate sediment basin during construction.

7.10 MAINTENANCE

We recommend that all porous pavement surfaces be vacuum-swept twice per year with an industrial vacuum sweeper. Unfortunately, like many stormwater maintenance requirements, this advice is often overlooked or forgotten. Fortunately, even without regular maintenance, the systems continue to function (We routinely send observers out in heavy storms to confirm this.).

When runoff is conveyed from adjoining areas or roof surfaces into the bed, we often use a drop inlet box or other structure to reduce the amount of detritus and sediment that is conveyed to the bed. This structure also requires regular removal of sediment and debris.

7.11 DEICING AND FREEZING ISSUES

One of the most common questions relates to concerns about freezing conditions. Freezing has not been an issue, even in very cold climates. We were quite surprised when the owners of early installations first told us that there was less need to snowplow on the porous pavement surfaces. The water drains through the pavement and into the bed below with sufficient void space to prevent any heaving or damage, and the formation of “black ice” is rarely observed. The porous surfaces tend to provide better traction for both pedestrians and vehicles than conventional pavement. Not a single system has suffered freezing problems.

Obviously, the use of sand or gravel for deicing would be detrimental to the porous surface. Salt may be used, however, and the surface may be plowed if needed. Most sites have found that light plowing eliminates the need for salt since the remaining snow quickly drains through the asphalt. This has the added benefit of reducing groundwater and soil contamination from deicing salts.

7.12 WHERE IT DOESN’T WORK

Porous asphalt is not recommended for slopes over 6 percent. We have not used the material for roadways, although it has been applied to some degree in Europe. There are also locations where the threat of spills and groundwater contamination is quite real. In those situations (such as truck stops and heavy industrial areas), we have applied systems to treat for water quality (such as filters and wetlands) before any infiltration occurs. The ability to contain spills must also be considered and built into the system. Finally, we have avoided the use of porous asphalt in areas where the pavement is likely to be coated or paved over due to a lack of awareness, such as individual home driveways.

7.13 Variations on the Theme: Porous Walkways and Playgrounds, Porous Concrete

More recently, we have applied the asphalt to situations such as walkways and playgrounds, including paths at Swarthmore College in Philadelphia (Figure 10)

Figure 7.10 – Porous Asphalt Walking Paths

and an urban playground at the Penn New School in Philadelphia (Figure 11). At Swarthmore College, the paths are not part of an infiltration bed but are merely intended to reduce impervious cover. The Penn New School project works to reduce the volume of stormwater discharging to the Philadelphia combined sewer overflows. Both of these applications are "retrofits" in urban areas that were previously paved.

Figure 7.11 – Porous Playground

Although we have used other materials such as porous concrete for both sidewalks and parking areas, the asphalt is less expensive and easier to install, and it remains our first choice. Even in hot Southern climates, such as the University of North Carolina in Chapel Hill (Figure 12) where two large commuter parking lots have recently been installed, the porous asphalt has performed quite well.

Figure 7.12 – Large Commuter Parking Lot

7.14 SUMMARY

Porous bituminous asphalt for parking lots has proven itself to be one of the most effective and affordable techniques for addressing stormwater management from development. It performs in both hot and cold climates and in a variety of situations. To date, our installations include pavements at schools and universities, corporate offices, industrial sites, shopping centers, parks, libraries, a prison, and even fast food restaurants. Porous asphalt is cost-effective, long-lasting, and an ideal solution to reducing the environmental effects of pavement.

7.15 REFERENCES

This chapter is a reprint of an article written by Thomas H. Cahill, P.E., Michele Adams, P.E., and Courtney Marm of Cahill Associates

CONSTRUCTION SEQUENCE FOR PORUS ASPHALT PARKING LOT WITH SUBSURFACE INFILTRATION BED

The subsurface infiltration bed located beneath the porous pavement must be excavated without heavy equipment compacting the bed bottom. Fine grading is done by hand.

Earthen berms (if used) between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.

Non-woven geotextile is laid immediately after fine grading is completed.

Clean (washed) uniformly graded aggregate is placed in the bed as the storage media.

5. The asphalt is laid down just like standard asphalt.

The finished surface looks like standard asphalt – until it rains. Infiltration beds are completely under the parking lots, minimizing the disturbance envelope.

Chapter 8

High Performance Intersection Design

8.0 HIGH PERFORMANCE INTERSECTION DESIGN

8.1 INTRODUCTION

Asphalt pavements typically provide excellent performance and value. They require minimal construction time and are easy to maintain, resulting in minimum traffic delays. Intersections can be opened to traffic minutes after placing asphalt, minimizing the impact to local businesses and motorists, who dread lengthy lane closures and rerouting.

While asphalt has continually proven to have superior life-cycle cost benefits, intersections require special consideration to ensure the same outstanding performance. Mixes that have a history of good performance in standard posted-speed applications may not perform well in intersections or other slow speed areas. Slow or standing loads subject the pavement to higher stress conditions that can be enough to induce rutting and/or shoving. Designers often neglect the fact that lower frequency load applications are much more severe. There is a reduction in mixture stiffness as the loading time is increased or the frequency of the load application is reduced. This explains why some pavements may perform well in moderate/high speed areas, but not perform as well in slower or standing traffic areas.

However, lower load frequencies are not the only reason intersections deserve special design considerations. The braking, accelerating and turning movement found in intersections causes additional stress in the pavement. Engine fluid drippings and heat exhaust, which cause softening, increase with slower traffic. Another reason intersections are treated differently is that load repetitions can be double that of mainline pavement due to the cross flow of traffic.

The key to achieving the desired performance for intersections is recognizing that these pavements need to be treated differently than typical road pavements. The pavement must be designed and constructed to withstand more severe conditions. There are four fundamental steps to intersection design.

1. Insuring structural adequacy
2. Selecting and controlling materials
3. Following proper construction practices
4. Implementing the plan

The design criteria for intersections in this guide pertain to intersections with traffic volumes greater than 300,000 EALs. Intersections with lower traffic volumes can be designed using conventional methods, unless the intersection has a history of poor performance. If the intersection has performed poorly in the past using traditional design methods, the designer should consider following the procedures presented in this chapter.

8.2 INSURING STRUCTURAL ADEQUACY

Structural Adequacy. Intersections must have adequate thickness to carry the excepted load capacity. Thickness design procedures are discussed in detail in Chapter 3.0 of this guide. However, for new pavements the thickness must now also account for the loss of pavement stiffness due to the slower speeds.

For existing pavements, there must be enough structural capacity to carry the loads after any failed or weak layers have been removed. If rutting has occurred, the cause must be identified and addressed. Paving over failed material will likely result in reoccurring failure.

Rutting is the most detrimental problem occurring with asphalt intersections. There are four types of rutting, however, only one (Mechanical Deformation) relates to structural inadequacy. Types of rutting include:

Consolidation. This occurs due to inadequate compaction during construction. The mix further compacts under the load of traffic, especially in hot weather conditions and under slow/static loads. A dip occurs in the wheel path without humps on either side (Figure 8.1).

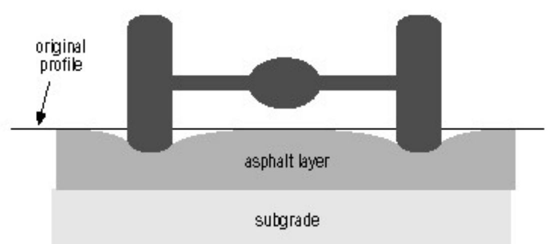

Figure 8.1 - Consolidation

Surface Wear. This type of rutting occurs during to the wear on the pavement due to studded tires and the use of chains on vehicles. The resulting depression is similar to consolidation, but with signs of abrasion.

Plastic Flow. Plastic flow occurs when asphalt layer is structurally inadequate. This inadequacy could be caused by too much asphalt, low air voids, poor aggregate properties or too soft of an asphalt binder. This deformation typically occurs in the surface layer. Intersections are particularly prone to this type of rutting due to slow/standing loads. Figure 8.2 demonstrates the appearance of the plastic flow rutting.

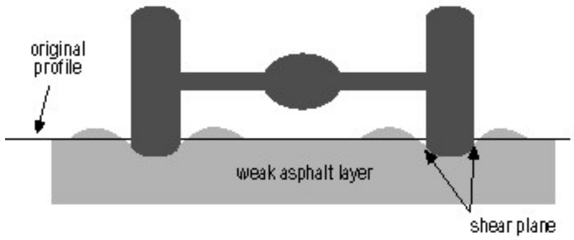

Figure 8.2—Plastic Flow

Mechanical Deformation. Mechanical deformation occurs when the pavement system in structurally insufficient to support the given traffic loads. This type of rutting is usually accompanied by longitudinal and/or alligator cracking (see Appendix B).

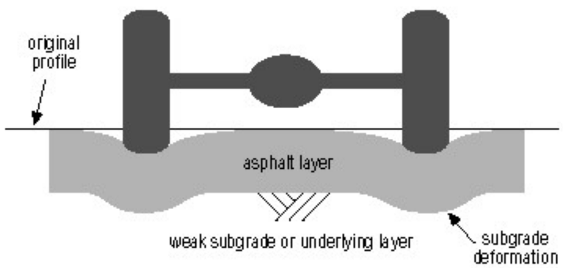

Figure 8.3 – Mechanical Deformation

Along with identifying the type of rutting that has occurred, the physical assessment of the existing intersection needs to provide the location and depth of rutting. It is recommended to walk the pavement project with a straightedge or stringline. Options for further physical assessment include trenching and coring. Coring consists of measuring the depth of each asphalt lift across the lane width, which determines if there is any plastic flow in the layers and from what layer any deformation occurred. Trenching is the more preferred method since a stringline can be run along the top and bottom of each asphalt lift. The aggregate base should also be checked at this time for contamination with clay.

The required thickness should be determined as if it were a new pavement using AASHTO procedures. Estimates of the traffic volume (in EALs) should reflect several directions of traffic since intersections accommodate travel in several directions.

After the assessment of the current conditions of an existing intersection, the appropriate repair alternative needs to be selected. The following are repair procedures for different types of rutting:

No Rutting, Consolidation Rutting or Surface Wear. There are times when milling the surface may be necessary (maintaining proper curb height, drainage, etc.), but typically milling is not required for these kinds of rutting. If milling is required it should be performed first. Any other surface preparation such as crack sealing and spot repairs should be done next. The next step is to place a leveling course prior to placing the overlay.

Plastic Flow Rutting. When plastic flow rutting has occurred it is important to identify the extent of rutting in terms of location and depth. Layers exhibiting plastic flow need to be milled. Exposed subgrade or aggregate base should be recompacted prior to placing pavement to prevent reoccurring ruts.

Rutting Caused by Structural Failure. Structural failure is characterized by a wheel path cracking in combination with rutting. Cracking often is in an alligator pattern and rutting generally is in excess of ¾ inch. Cracking without rutting may be only surface or top down. Coring through the cracks will help determine if the cracking is structural or not. Structurally cracked areas should be removed; paving over these will only delay the same structural problem. If the aggregate is contaminated with the subgrade material, it should also be removed. A geotextile may be considered if it is necessary to remove and replace the aggregate base. See Chapter 4.0 for more details on geotextile use. The existing drainage conditions should also be examined. If the drainage is inadequate, sufficient drainage plans should be included in the rehabilitation.

After the failed layers have been removed, new layers should be placed on top of the recompacted base layer. The thickness should meet the required design minimums.

By assessing the existing conditions and selecting an appropriate repair method, the designer can insure that an intersection will have the structural capacity to perform well throughout its design service life.

8.3 SELECTING AND CONTROLLING MATERIALS

Asphalt Binders. Selecting the appropriate asphalt binder and aggregate combination is essential in intersection design. Knowing that increased rut resistance is needed at intersections, Standard Specification for Superpave Volumetric Design (AASHTO MP-2) requires that the high temperature be increased by two grades for standing traffic (<12 mph) and by one grade for slow traffic (12 to 42 mph). Table 8.1 shows which high temperature binder grade should be used in various Oregon regions.

Binders with a high temperature grade of PG 76 have proven to perform well in intersections throughout the United StatesHowever, these high grade binders may not be available in all areas. Check with ODOT or APAO for availability prior to specifying the binder. Cost and availability should be taken into consideration when choosing an asphalt binder.

	Traffic Load Rate	
Region[1]	*Standing*	*Slow*
Willamette Valley	PG 70	PG 64
Coast	PG 64	PG 64
Southern	PG 76	PG 70
Central/Eastern	PG 70	PG 64

[1] Some cities may have climates that deviate from the Regional climate assessment. You may wish to check the specific climate for the project

Table 8.1 – Binder Selection Recommendations for Oregon

Aggregate. Selecting the appropriate aggregate gradation is equally important as binder selection and should be done with great care. The aggregate is the part of the pavement system that carries load. Using angular aggregate reduces the risk of shearing by developing a high degree of stone-to-stone interlock. There must be consistency in the aggregate gradation, particle shape, texture and absorption. Limiting the use of rounded aggregate and uncrushed sand is crucial. Processing (washing, crushing, etc.) usually improves aggregate quality.

Controlling the mix design is important to achieve the desired intersection pavement performance. Typically mixes meeting Superpave volumetric criteria perform well due to their ability to resist rutting. Mixes with low VMA (voids-in-mineral-aggregate) can be sensitive to small changes in the total fluids content (asphalt binder, moisture and fine filler). Small increases in fluids can cause these mixes to be subject to rutting or shoving. Mixes with high VMA will produce thick asphalt coatings on the particles that can act as a lubricant, allowing the particles to rearrange themselves under traffic. This can lead to rutting, shoving or bleeding. For intersection mix designs it is advised that the maximum VMA be limited to 1 percent above the minimum specification value.

Rut Susceptibility Testing. Strength or proof testing is highly recommended to evaluate rutting, which is a major concern when designing an asphalt mix. Emerging technology has improved our ability to prevent rutting in asphalt pavements. One new device for rut susceptibility testing is the Asphalt Pavement Analyzer (APA), which is a temperature controlled wheel-tracking device. It measures the rutting that occurs in laboratory compacted specimens. Rutting is induced with the use of a pneumatic hose loaded by an oscillating aluminum wheel.

The hose is inflated to 100 psi and placed over the compacted asphalt specimens. A 100-pound load is then applied to the top of the hose by the oscillating wheel. A normal test is 8000 cycles of loading applied to specimens held at 64°C (147°F). Testing can be performed at other temperatures to model actual site temperatures. Proposed specifications would set a limit on the amount of rutting that can occur during this test. For intersections rut susceptibility testing should be performed during the mix design phase. The tests should be run at the high PG temperature grade specified. If a PG 70 mix is specified the test should be ran at 70 °C. The current acceptance criterion is less than 5 mm of rutting at 8000 cycles.

The designer should give careful thought to the proposed mix by asking the following questions:

- Is there experience/history with a similar mix?
- What was the performance of the similar mixes?
- Is the asphalt content appropriate?
- Is the mix too wet or dry?
- Does the mix meet the rut susceptibility criteria?

These questions do not guarantee a well performing asphalt mix, but are intended to cause the designer to consider how the mix is expected to perform.

Quality control of the mix process is essential to have a well performing pavement intersection. Deviation from the mix design could cause early pavement failure.

8.4 FOLLOWING PROPER CONSTRUCTION PRACTICES

The main factors to consider in constructing a successful pavement intersection are achieving acceptable density and durability levels. The mix must be compacted to a density where stone-to-stone contact is present. This limits the risk of shoving or rutting. Aggregate durability can be improved by avoiding segregation (a well-graded mix is desirable), constructing dense joints and producing an impermeable mat. Standard practices for segregation and joint construction must be followed closely to avoid problems. Another construction practice to keep in mind is keeping traffic off the mat until it has gained sufficient strength to resist early rutting. The impermeable mat should be cooled to 150 - 175°F before traffic loads are applied.

Intersections must be constructed following well established “good practices,” while paying attention to details. The following are examples:

- Milled areas should be thoroughly cleaned. All crumbs at the edges of the milled area must be removed, all debris must be removed and a uniform tack coat applied to the surface and vertical sides of the milled pavement.

- To prevent water from entering the pavement structure there must be proper joint construction. Stiffer, stonier mixes require careful joint construction, but provide the best resistance to rutting.
- There should be consistency in the aggregate mix, without segregation of the particles or varying density or texture.
- All compaction standards must be met. This means that extra effort may be required for stiffer mixes.
- Other standard “good practice” construction procedures must be followed, such as, not overheating the mix, avoiding the use of diesel fuel in truckbeds, etc. Even a well designed mix can fail if proper construction practices are not followed.

8.5 IMPLEMENTING THE PLAN

A major decision that must be made when designing intersections is how much of the pavement should be treated differently. A barrier to intersection design is that the typical volume of hot mix asphalt needed is relatively low. Many contractors do not want to do a small volume project that requires special attention and potentially different materials. At the same time, engineers are often reluctant to write a special specification for intersection design. It is important to recognize that intersections may sometimes need to be treated differently depending on the performance of the typical mix being used for the mainline road.

A possible solution to the low volume barrier is to combine paving of multiple intersections into one project. This may require several local agencies working together on the project. For roadways with many closely spaced intersections, you may want to consider using the improved intersection mix for the entire project.

Evaluating the past performance of intersections should be a key part in deciding whether changes should be made to the normal process. The initial cost of constructing improved intersection may be higher than the cost of regular pavements, but the performance life will be greatly increased, reducing the life-cycle cost. The final product will be a long lasting, smooth, cost-effective intersection.

8.6 SUMMARY

Quality control is very important in intersection pavements designs. The principles involved with the design are straight forwarded, however the execution of the design can be difficult. The commitment to produce well performing intersections is not simple. The work is not high production and the cost is greater than for conventional applications. However, the extra effort and money exerted initially will produce a long lasting, cost effective, smooth intersection.

8.7 REFERENCES

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Chapter 9

Life Cost Analysis

9.0 LIFE CYCLE COST ANALYSIS

9.1 INTRODUCTION

Life-cycle cost analysis is a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user, reconstruction, rehabilitation, restoring and resurfacing costs, over the life of the project segment (*Transportation Equity Act for the 21st Century – TEA 21*). Life-cycle cost analysis (LCCA) evaluates the overall long-term economic efficiency between competing alternative investment options, but does not address equity issues. It attempts to identify the best value (lowest long-term costs that satisfies the performance objective being sought) for investment expenditures.

Life-cycle costs refer to all costs during the lifetime of a pavement, including construction costs, maintenance costs, rehabilitation costs, etc. Since all of these costs do not occur at the same time, it is useful to determine the amount of money that could be invested at a fixed time (generally the beginning) and would earn enough money at a specific interest rate to permit payment of all costs when they occur. Therefore, an interest rate or time value of money becomes important in economic evaluation calculations. LCCA is a complete and current economic analysis tool that accurately compares alternatives.

Currently FHWA encourages the use of LCCA in analyzing all major investment decisions where such analyzes are likely to increase the efficiency and effectiveness of investment decisions. It is important for local agencies to realize the importance of LCCA and the impact it can have on the decision making process for the design of roadway projects. Many transportation agencies are investigating economic tools that will help them choose the most cost-effective project alternative and communicate the value of those choices to the public. FHWA believes that LCCA can help transportation agencies with this process.

LCCA is an engineering economic analysis tool that allows users to quantify the differential costs of alternative project investments. LCCA can be used to examine new construction projects and preservation strategies for existing pavement structures. LCCA considers all agency expenditures and user costs throughout the life of an alternative, not only the initial investments. More than a simple cost comparison, LCCA offers sophisticated methods to determine and demonstrate the economic merits of the selected alternative in an analytical, fact-based manner. LCCA helps users answer question like these:

- Which design alternative results in the lowest total cost over the life of the project?
- To what level of detail have the alternatives been investigated?
- What are the user-cost impacts of the alternative preservation strategies?

LCCA's structured methodology provides the information and documentation necessary for successful public interaction. This allows an agency to demonstrate their commitment to infrastructure preservation, making LCCA a very valuable tool.

AASHTO has adopted the following principles, which are applicable to pavement design:

- The level of management at which the evaluation is to be performed should be clearly identified; this can range from the planning/programming level to a sublevel of design where only one element (i.e., surface type) is being considered within a project.
- The analysis provides the basis for decision but does not provide a decision. Criteria for such decisions must be prepared separately before the results can be applied. The economic evaluation itself has no relationship to the method or source of financing a project.
- An economic evaluation should consider many possible alternatives within the time constraints and design resources.
- Alternatives should be compared over the same time period. The time period should be chosen so that all factors involved in the comparison can be defined with reasonable accuracy.
- The economic evaluation of pavements should include agency costs and user costs/benefits whenever possible.

9.2 BASIC CONSIDERATIONS

When using the LCCA process the first step is to define reasonable design or preservation strategy alternatives. For each proposed alternative, identify initial construction or rehabilitation activities, the necessary future rehabilitation and maintenance activities and the timing of those activities. From this information, construct a schedule of activities for each project alternative.

Next, estimate all activity costs. The most efficient LCCA includes not only direct agency expenditures (i.e., construction or maintenance activities) but also user costs. User costs are the costs to the public that result from work zone activities, including lost time and vehicle expenses. A predicted schedule of activities and their associated agency and user costs combine to form a projected expenditure stream for each project alternative.

Once the expenditure streams have been determined for the different competing alternatives, calculate total life cycle costs for each alternative. Since dollars spent at different times have different values to an investor, the projected costs for an alternative cannot simply be added together to calculate total life-cycle costs. Discounting, which is an economic method of accounting for the time value of an investment, is necessary to convert anticipated future costs to present dollar values so that the lifetime costs of different alternatives can be directly compared. Discounting calculations are identical to those of compound interest. Because the level of service provided by each project alternative in the analysis is assumed to be the same, LCCA allows users to evaluate alternatives based on their life-cycle costs. The results of the analysis can be used to revisit the design or preservation strategy behind the project.

Design Options. LCCA should be conducted as early in the project development cycle as possible. For pavement design, the appropriate time for performing the LCCA is during the design stage. The LCCA level of detail should be consistent with the level of investment. LCCA models based on primary pavement management strategies can be used to reduce unnecessarily repetitive analyses.

Only consider differential costs among alternatives. Costs common to all alternatives cancel out and are not included in LCCA calculations. Including all potential LCCA factors in every analysis is counterproductive; however, all LCCA factors and assumptions should be addressed, even if limited to an explanation of the rationale for not including eliminated factors in detail. Sunk costs, which are irrelevant to the decision at hand, should not be included.

While different alternatives may be structurally equivalent over the analysis period considered, they are unlikely to be equivalent from the economic standpoint. Since the costs of constructing and maintaining pavements occur at different times for each alternative, the cost streams must be adjusted to the same base before total costs can be assessed. This is accomplished by using either the Present Worth of Costs (PW) or the Net Present Value (NPV) technique.

LCCA analysis periods should be sufficient to reflect long-term cost differences associated with alternate design strategies. While FHWA's LCCA Policy Statement recommends an analysis period of at least 35 years for pavement projects, including new/total reconstruction projects, rehabilitation, restoration and resurfacing projects, analysis periods of 30 to 40 years are not unreasonable.

Future cost and benefit streams should be estimated in constant dollars and discounted to the present using a real discount rate. Although nominal dollars can be used with nominal discount rates, use of real/constant dollars and real discount rates eliminates the need to estimate and include an inflation premium.

In any given LCCA, real/constant or nominal dollars must not be mixed (i.e., all costs must be in real dollars or all costs must be in nominal dollars) and the discount rate selected must be consistent with the dollar type used (i.e., use real cost and real discount rates or nominal cost and nominal discount rates). The discount rates used in LCCA should reflect historical trends. Although long-term trends for real discount rates hover around 4 percent, 3 to 5 percent is an acceptable range, consistent with values historically reported.

Performance periods have a considerable impact on analysis results. Longer performance periods require fewer rehabilitation projects and associated agency and work zones users costs. While most analyses include traditional agency costs, some do not completely account for the agency's engineering and construction management expenses, particularly on future rehabilitations. This can be a serious oversight on short-lived rehabilitations as agency design processes lengthen in an era of downsizing.

Analysis Period. The analysis period is the length of time (typically in years) used for consideration of the life-cycle costs. It is customary to designate the final year of new construction as "year 0," and subsequent years as "year 1," "year 2," etc. This is a convenient way to structure the cost streams throughout the period considered. The particular period selected is generally based on the policy of the agency concerned. However, the NPV method allows the discounted costs of alternative strategies to be compared with each other for any period and can be applied to short-term as well as long-term projects.

The analysis period is not necessarily the service life of the pavement. The distinction is often troublesome for engineers, causing confusion in the accurate application of life cycle cost analyses. Most pavements are constructed for long-term benefits to society and many are still in service 30+ years after initial construction. Agencies frequently use 20, 30 or 40 years in their life-cycle costing analyses. In fact, any period is acceptable provided that the application of the method recognizes the following guidelines:

1. Selection of the analysis period should not be biased towards any particular design or maintenance strategy.
2. The analysis period should include a major rehabilitation for all alternates.

Routine, reactive type annual maintenance costs have only a marginal effect on NPV. They are hard to obtain, generally very small in comparison to initial construction and rehabilitation costs, and differentials between competing pavement strategies are usually very small, particularly when discounted over 30 to 40 year analysis periods.

Salvage value, which is the value of an investment remaining at the end of the analysis period, should be based on the remaining life of an alternative at the end of the analysis period as a prorated share of the last rehabilitation cost. The salvage value depends on several factors including, but not limited to the following: the volume of material, the position of material, contamination, age, durability and the anticipated use at the end of the design period. It is typically denoted as a percentage of the original cost.

User Costs. User costs that should be considered in LCCA include travel time, vehicle operation, accidents, discomfort, time delay and extra vehicle operating costs during resurfacing or major maintenance. Vehicle delay and crash costs are unlikely to vary among alternative pavement designs between periods of construction, maintenance and rehabilitation operations. Although vehicle-operating costs are likely to vary during periods of normal operations for different pavement design strategies, there is little research on quantifying such vehicle operating cost differentials under the pavement condition level prevailing in the United States.

User costs are heavily influenced by current and future roadway operating characteristics. They are directly related to the following:

- current and future traffic demand
- facility capacity
- the timing, duration and frequency of work zone induced capacity restrictions
- increased mileage caused by detours

Directional hourly traffic demand forecasts for the analysis year in question are critical for determining work zone user costs.

As long as work zone capacity exceeds vehicle demand, user costs are normally manageable, representing more of an inconvenience than a serious cost to the traveling public. When vehicle demand exceeds work zone capacity, the facility operates under forced-flow conditions and user costs can be immense. Queuing costs can account for more than 95 percent of work zone user costs with the majority of the cost being the delay time of crawling through long, slow-moving queues. Due to the fact that different vehicle classes have different operating characteristics and associated operating costs, user costs should be analyzed for at least three broad vehicle classes:

- passenger vehicles
- single-unit truck
- combination trucks

User delay cost rates are probably the most controversial of all user cost inputs. While there are several different sources for the dollar value of time delay, it is important to note that commercial vehicles support higher values of travel time delay rates and that passenger vehicles, particularly pickup trucks, represent both commercial and noncommercial use.

Work zone crash cost differentials between alternatives are very difficult to determine due to the lack of hard statistically significant data on work zone crash rates and the difficulty in determining vehicle work zone exposure. However, default dollar value ranges associated with fatal and nonfatal injury highway crashes are included in LCCA.

Agency Costs. Agency costs should include all major initial and reoccurring costs for each alternative. An accurate LCCA will include the following agency costs:

- initial construction costs
- future construction or rehabilitation costs (i.e., overlays, seal coats, reconstruction)
- maintenance costs, recurring throughout the design periods
- salvage value at the end of the design period (may be a negative cost)
- engineering and administration costs
- traffic control costs

Level of Detail. The influence of individual life-cycle cost factors on analysis results may vary from major to minor to insignificant. The analyst should ensure that the level of detail incorporated in the LCCA is consistent with the level of investment under consideration. A point of diminishing returns occurs as more and more cost factors are incorporated in an LCCA. For example, slight differences in future costs have a marginal effect on discounted present value. Including such factors unnecessarily complicates the analysis without providing substantial improvement in analysis results. Including all factors in every analysis is not always productive. The difficulty in determining some costs makes omitting them the more sensible choice, particularly when the effect on the LCCA results is marginal at best.

In conducting an LCCA, designers should evaluate all factors for inclusion and explain rationale for eliminating factors. Such explanations make analysis results more supportable when they are scrutinized by critics who are not pleased with the analysis outcome.

A good reference relating to life-cycle cost analysis is the FHWA publication #FHWA-SA-98-079. This publication can be obtained from FHWA.

9.3 LCCA SOFTWARE PROGRAMS

Many software programs have been developed to assist those performing a life-cycle cost analysis. The Asphalt Pavement Alliance has developed a LCCA program which follows the guidelines in FHWA-SA-98-079. It can be downloaded from the Asphalt Alliance website www.asphaltalliance.com or http://www.asphaltaliance.com/library.asp?MENU=12 When using any software program, care should be exercised in developing input costs data, especially those costs associated with user cost and maintenance cost.

9.4 SUMMARY

Either the PW or the NPV technique may be used to determine the life-cycle costs for comparisons between alternate pavement design or rehabilitation strategies. In either case, it is essential that comparisons be made only for equal analysis periods.

9.5 REFERENCES

Colorado Asphalt Pavement Association, *Guideline for the Design and Use of Asphalt Pavements for Colorado Roadways*.

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CHAPTER 10

Pavement Maintenance And Rehabilitation

10.0 PAVEMENT MAINTENANCE AND REHABILITATION

This chapter presents a general discussion on maintenance and rehabilitation of pavements for both asphalt and portland cement concrete pavements. Included is a discussion of why pavements deteriorate, the need for pavement maintenance and rehabilitation and a general discussion of various maintenance and rehabilitation techniques.

It should be emphasized that properly designed and constructed pavements should provide many years of maintenance free service. For example, there are pavements in Oregon over 20 years in age without any maintenance treatments and providing good service.

Not included is a discussion of overlay design procedure for asphalt or portland cement concrete pavements. The reader should refer to the references at the end of this chapter for appropriate overlay design procedures or confer with a pavement consultant.

10.1 DETERIORATION OF PAVEMENTS

Pavements have a finite life as shown in Figure 10.1. They wear out for several reasons including:

Design considerations. Many pavement failures are associated with the use of the wrong design or mix or not considering drainage.

Extreme climates. Changes in temperature, moisture, freezing and thawing all cause pavements to wear out.

Traffic loads. Trucks and buses are particu-larly damaging, the heavier they are the more damage they cause. Also increased tire pres-sures and slow speeds accelerate the damage in the pavement surface. In some instances, automobiles (with studded tires) can cause severe pavement surface problems.

Construction quality. Variability in the quality (or thickness) of the materials or construction practices can lead to early failure.

Pavement condition index (PCI) is used by pavement managers to track pavement distress over time. The higher the number, the lower the amount of distress present. Pavements are maintained and/or rehabilitated when the PCI drops to a level of 40-60. PCI is different from the present serviceability index (PSI) used in the design of the pavement section. PSI is dominated by ride quality and not by pavement distress. Normally, ride quality deteriorates within 1-2 years after the first evidence of distress is noted.

Table 10.1 summarizes the most important causes of pavement failures. Common types of distress are given in Appendix B.

Category	Factor
Design	· Inadequate thickness · Use of inappropriate mix · Drainage problems
Traffic	· Heavy loads · High tire pressures · Studded tires
Extreme Climate	· Freeze-thaw cycles · Moisture · Aging
Construction Quality	· Variable materials · Variable thickness · Poor compaction

Table 10.1 Important Factors Affecting Pavement Performance

10.2 PLANNING FOR MAINTNANCE AND REHABILITATION

Pavements are costly to build and to maintain. These costs are borne by the owner (or agency) funding the facility. However, it also costs money for users to operate vehicles on deteriorating or poorly maintained roads. Generally, the poorer the road (in terms of condition), the higher the costs for the user. User costs, which include vehicle operating and maintenance costs and costs associated with delays, can be very substantial.

Owner (or Agency) Costs. Agency costs (construc-tion, maintenance, and rehabilitation) depend to a great deal on the following:

- Pavement type/treatment
- Age of pavement
- Consistency of preventive maintenance
- Traffic conditions
- Location of facility
- Availability of quality materials and contractors to do the work.

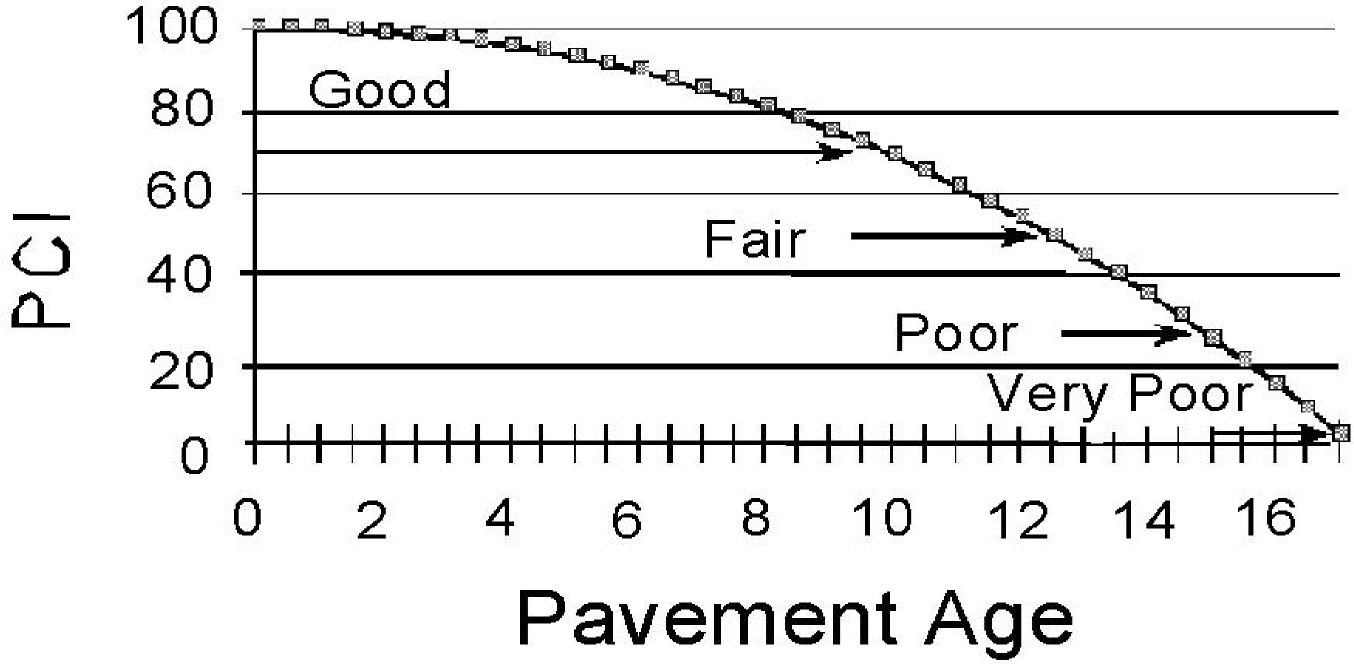


Figure 10.1 Pavement Condition Index (PCI) as a Function of Pavement Age (Years)

Depending on the existing condition (or pavement condition index [PCI]) of the roadway in question, one might consider one of several maintenance techniques (discussed in Section 10.3) such as chip seals which are less expensive but do not last as long or thin hot mix overlays which are more expensive but last longer. Maintenance of pavements is similar in concept to maintenance of one's home or car. For example, consider the following:

Roof Analogy. If you don't repair your roof, it will leak and cause more damage in the house.

Vehicle. Do you remember the Fram oil filter commercial of "pay me now or pay me later"?

The longer one waits to maintain a pavement, the more it will cost to repair. Figure 10.2 illustrates this concept while typical costs for pavement maintenance/rehabilitation are given in Table 10.2.

Treatment Type	Cost/yd^2		
Chip Seal	0.70	to	1.00
Slurry Seal	0.85	to	1.35
Microsurfacing	1.25	to	1.75
Thin HMA Overlay (< 25 mm)	1.80	to	2.40
HMA Overlay (100 mm)	7.20	to	9.60

Table 10.2 type of Maintenance/Rehabilitation Costs per Yd^2

Timing of Maintenance. Pavements are normally designed to accommodate the design traffic over a specific period (10 or 20 years). Most roadways are designed for a 20-year life. Some commercial pavements are designed for 10 years. If the design traffic occurs in less than the design life, then the pavement will fail sooner than expected.

Regardless of the design life, pavements require maintenance and the timing of the maintenance can be critical. What happens if you maintain the pavement too soon? It is similar to painting your house more frequently than needed or spending money foolishly. The annual cost of premature maintenance is shown in Figure 10.3. As illustrated, early maintenance results in higher annual costs. When the costs of delayed maintenance vs. that of early maintenance are superimposed (as shown in Figure 10.4), one can determine optimum timing to fix pavements. Based on this approach, the optimum timing (based on total costs) for the various treatments are generally as follows:

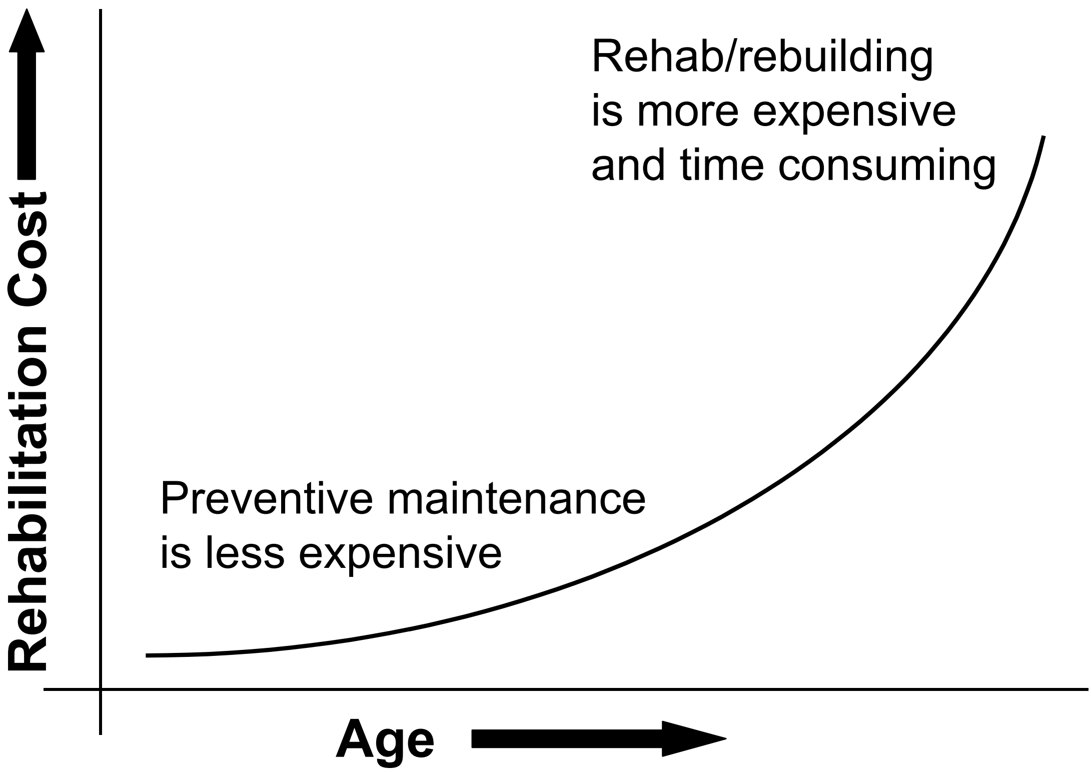
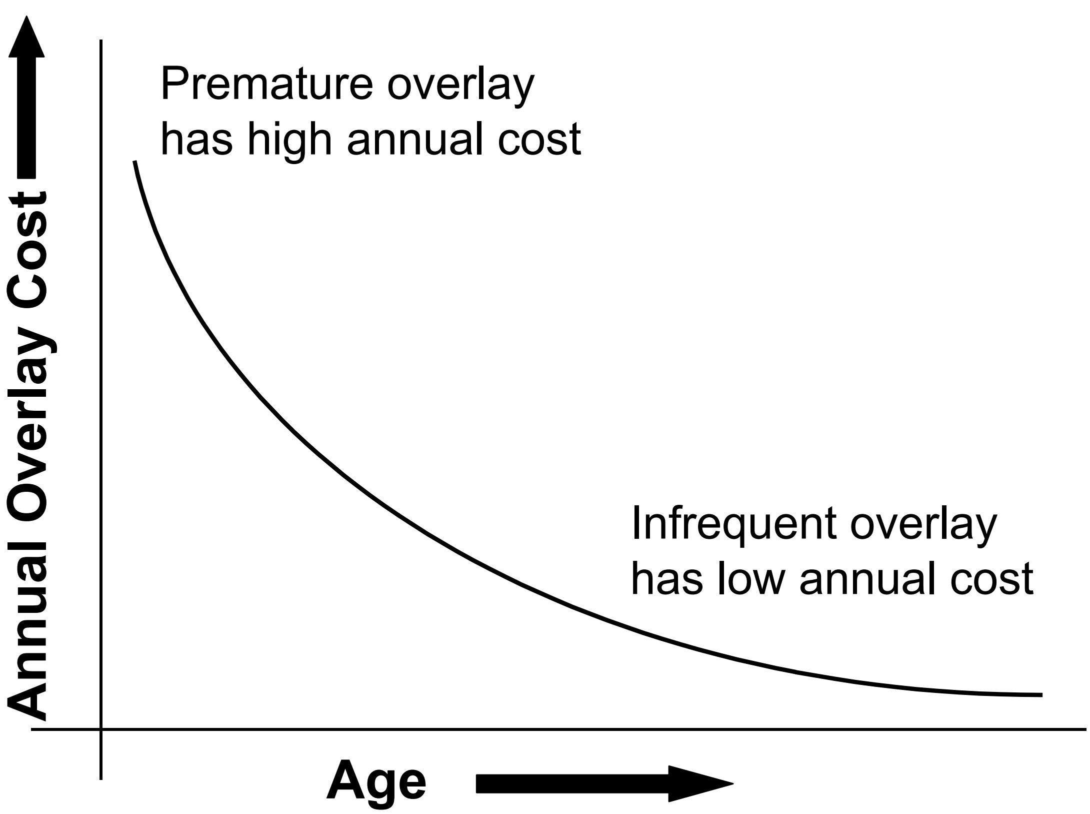


Figure 10.2 Cost of Maintenance as a Function of Age (Years)



Treatment	Pavement Age
Fog Seals	1-2
Emulsion Seal Coats	1-3
Chip Seals	4-7
Slurry Seals	4-7
Thin Overlays (< 25 mm)	8-12
Thick Overlay (100 mm)	10-18

The actual timing for the various treatments varies depending on traffic level and environment. The agency (or owner) of the facility should be encouraged to develop the optimal timing for maintenance treatments to minimize life-cycle costs.

10.3 REPAIRING OUR PAVEMENTS

Several maintenance/rehabilitation methods are available for managing and protecting the pavements. They include:

Preventive maintenance. Used to preserve the pavement in good condition and can include the following treatments:

- crack sealants
- fog seals
- chip seals
- slurry seals and microsurfacing
- thin hot-mix overlays

To achieve best results for all treatments, proper surface preparation techniques and mixing and application methods must be followed.

Corrective maintenance or rehabilitation. Used when the pavement provides lower service in terms of:

- load carrying capability (excessive deflec-tion),
- waterproofing (cracks),
- surface deformation (rutting),
- surface friction (too slick), or
- ride quality (bumps).

Environmental degradation (frost, thermal cycles, ultraviolet light) can also cause pavement deterioration requiring maintenance.

Techniques commonly used for corrective maintenance or rehabilitation could include not only those used for preventive maintenance, but also hot mix overlays, profiling, mill and fill, and recycling. Each of these is discussed in more detail later in this chapter.

The timing for the maintenance/rehabilitation is also critical. It affects the cost of doing work. Since pavement wear-out rates are generally predictable and their life is determined by climate and the number of trucks, it is possible to determine the best time to perform maintenance on a roadway.

What is the effect of maintenance on the performance curve? It can both improve the pavement condition index (PCI) and extend the life of the pavement. Figure 10.5 illustrates this concept for the case where maintenance is performed before the PCI drops significantly.

Common maintenance and rehabilitation techniques are discussed in the following sections of this chapter.

10.4 MAINTENANCE TREATMENTS

Several maintenance treatments are available to the owner (agency) for preventive or corrective maintenance. They include the following.

Crack sealants. The materials, which usually consist of a modified asphalt, are applied to cracked pavements to prevent water entering the cracks. Most of these materials have an effective life of only 1 to 2 years. Further, if crack sealants are applied too thickly on the surface adjacent to the crack, they have a tendency to bleed through subsequent overlays. It is important to clean the cracks prior to applying the sealant.

Fog (or flush) seals. This is a light application of an asphalt emulsion (usually a CSS-1) without aggregate cover to restore the durabil-ity of the asphalt mix. It can be very effective, but if applied in excess it can produce a slip-pery pavement.

Asphalt emulsion seal coats. An asphalt emulsion seal coat consists of a mixture of asphalt emulsion and inert fillers. The mixture is approximately 80-85% emulsion and 20-15% filler, depending on the manufacturer. Often 30 mm mesh sand is added to the seal coat material immediately prior to application. One or two coat applications are common. Most emulsion seal coats are machine applied either by spraying or with a squeegee.

Chip seals. A chip seal is an application of an asphalt followed with an aggregate cover. This type of maintenance technique can consist of single or multiple layers ranging in thickness from 9.5 to 25 mm. A typical chip seal used in Oregon consists of an application of a rapid setting emulsion followed by an application of 9 x 2 mm (3/8 x 10) aggregate.

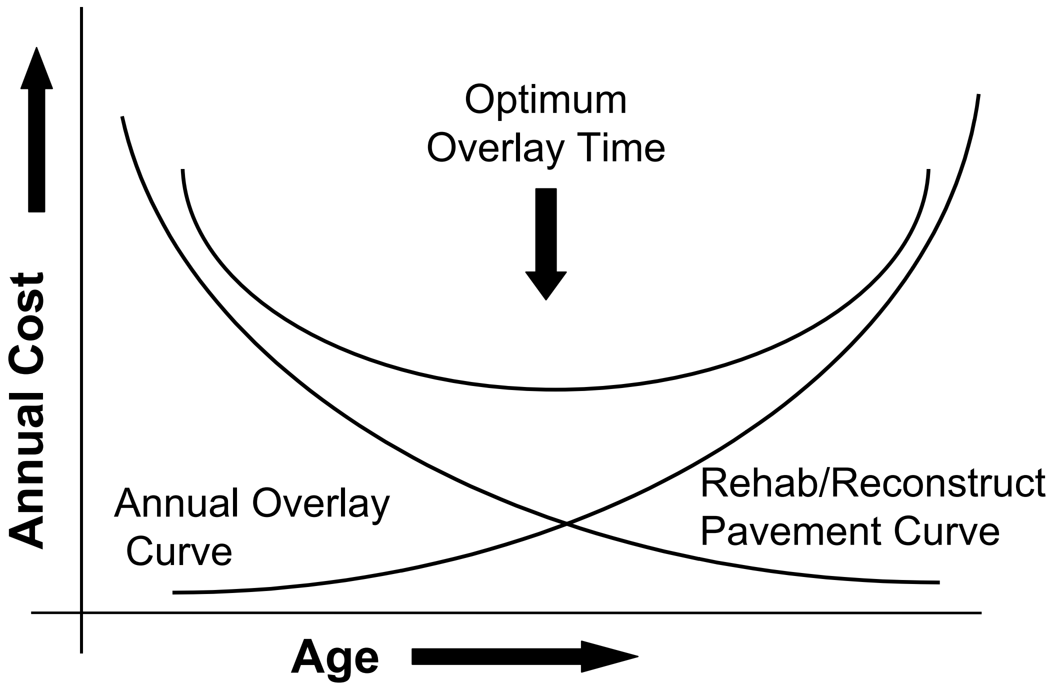
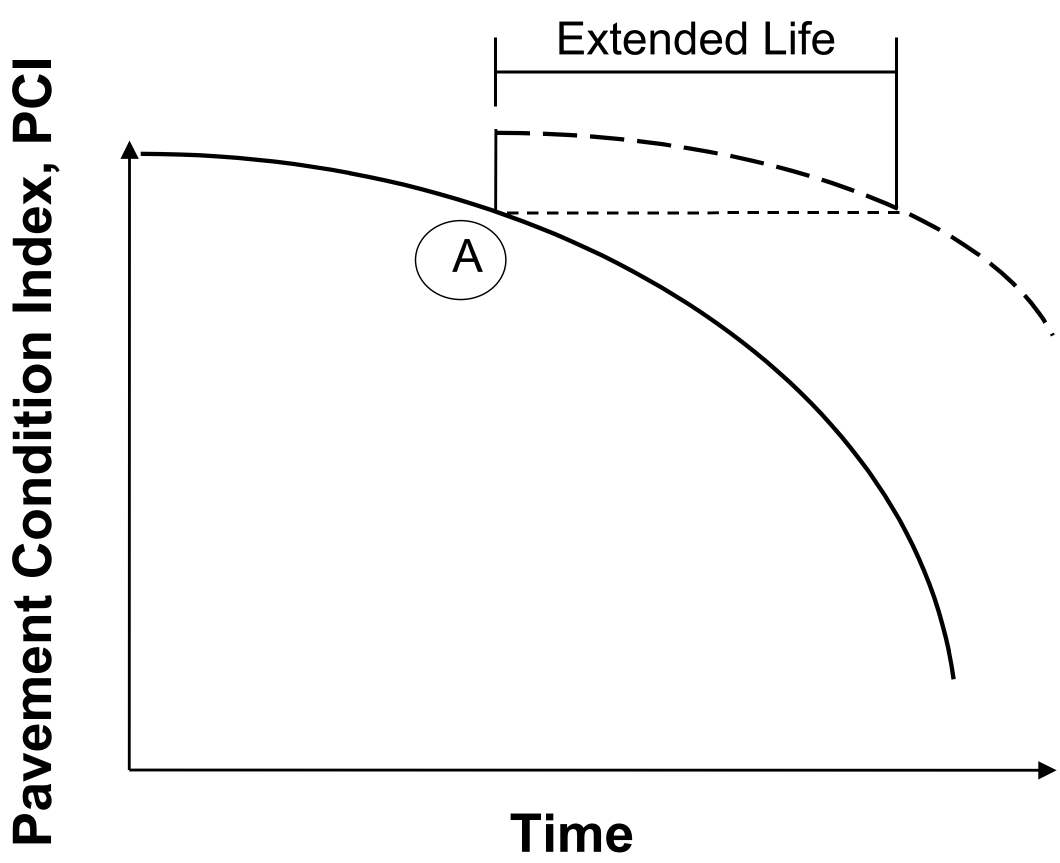


Figure 10.4 Optimum Time to Fix Pavements (Years)



Slurry seals. This treatment is a mixture of well-graded sand size aggregate, mineral filler, and asphalt emulsion. A single course is usually applied in thickness of 3 to 9 mm (1/8 to 3/8 inch). Slurry seals are normally used in areas where the primary pavement distress is excessive oxidation and hardening of the existing asphalt pavement. They are used for sealing minor surface cracks and voids, retarding surface raveling, and, in some cases, for improving surface friction characteristics.

Microsurfacings. This is a polymer-modified slurry seal system developed originally in Europe. Its most common uses are rut filling, minor leveling, and restoration of skid resis-tance surfaces. The polymer-modified slurry cures and develops strength faster; therefore, it can be placed in greater thicknesses. For example, it has been used to fill ruts in excess of 25 mm (1 inch), but is normally used on projects with rut depths up to 19.0 mm (3/4 inch). Microsurfacing requires special paving equip-ment with a more powerful and faster mixer than used for slurry seals. An experienced contractor is also recommended if this product is used.

Thin hot mix overlays. Both open-graded and dense-graded mixes have been used in thicknesses of 25.0 to 37.5 mm. These materials make use of aggregates with a top size of 9.5 to 12.5 mm. The expected life of thin hot mix overlays is normally 8-12 years, depending on the condition of the pavement it is placed on, the traffic, and climate. This maintenance treatment is the best one at improving the ride quality and the only treatment that adds to the structural strength of the pavement.

Details of these maintenance treatments can be found in the publications of the Asphalt Institute (MS-16, MS-17, and MS-19).

It should be pointed out that each of the above treatments has a different impact on pavement condi-tion index (PCI) and present serviceability index (PSI). Table 10.3 summarizes the typical impacts. As noted, all treatments improve the PCI, but only a few treatments improve the ride quality or PSI. The use of life cycle cost analysis will enable one to determine which treatments are most cost effective for a given situation.

10.5 REHABILITATION

Treatments for AC

Overlays. Conventional dense- or open-graded mixes are normally used on highways to rehabilitate asphalt concrete pavements. The recommended overlay thickness should be determined by a consultant to ensure it will accommodate the anticipated traffic. Normally, this will require some type of non-destructive deflection testing to determine the structural capacity of the existing pavement.

Mill and fill. This is another common rehabilitation technique for repairing distressed asphalt pavements. It typically consists of milling the existing pavement to depths of 50 mm to remove the distressed surface layer and filling the cavity with a dense-graded mix. Open-graded mixes have also been used, but drainage channels are required to remove the water, which will accumulate in the trenched areas. If only a mill and fill is used, the procedure does not necessarily strengthen the pavement. Strengthening is achieved when the mill and fill operation also receives an overlay.

Recycling. As natural resources become scarcer and more costly to obtain, their rehabilitation and re-use, or recycling, becomes more important. Asphalt cement and aggregates used in roadway construction constitute a sizable public investment. They are two very important natural resources whose value as construction materials are recoverable. This ability to recycle has enormous implications not only for the conservation of valuable resources but also for energy savings and total economic benefits.

Recycling asphalt concrete pavements can be accomplished through: removal and transport to another location for crushing and reprocessing with transport to the new site for laydown and rolling; or through cold milling the surface; and/or conventional removal, with crushing, reprocessing, laydown and rolling accomplished on the site.

	Effect of Treatment on	
Maintenance Treatment	PCI	PSI
Chip Seal	Increases	Little or no effect
Slurry Seal	Increases	Little or no effect
Microsurfacing	Increases	Slight increase
Thin HMA Overlay (1 inch)	Increases	Significant increase

Table 10.3 Typical Effect of Various Maintenance Treatments on PCI and PSI

Reprocessing the salvaged materials, plus the addition of new asphalt binder and aggregate, can be accomplished through three different processes. In a hot mix process, a special drum for mixing is used to comply with environmental pollution requirements and the mixture produced is a fully recycled product containing 15 to 50 percent RAP.

A cold, in-place recycling process normally involves processing a 50 to 100 mm (2 to 4 inch) depth followed by an asphalt concrete overlay.

Full depth cold-in-place recycling consists of pulverizing the existing asphalt concrete with the existing aggregate base. The pulverized material is regraded, compacted and covered with an asphalt concrete surface or a bituminous surface treatment. The advantages of this technique include strengthening of the existing material as well as the provision of a new wearing surface.

Another process, termed surface recycling involves heater scarification of the top 25 mm (1 inch) of pavement followed by an asphalt concrete overlay.

Hot mix recycling advantages. These include the following:

- Structural improvements can be obtained with little or no change in thickness.
- Additional right-of-way is not needed.
- Surface and base distortion problems may be corrected.
- Base preparation and shoulder work are reduced.

Cold mix recycling advantages. These include the following:

- Corrects many types of pavement distress that involve both surface and base courses.
- Reduces the need for new materials and overall cost.
- Hauling costs may be decreased if in-place method is used.
- Drainage problems are avoided.
- Adding asphalt waterproofs the base and renders it less susceptible to frost action and moisture changes

Surface recycling advantages. These include the following:

- Provides a very low-cost maintenance strategy.
- Restores flexibility of aged and brittle asphalt.
- Cracks are interrupted and filled.
- Surface distortion, removed and leveled, drainage and crowns are re-established.
- Improves skid resistance.
- Eliminates the need for surface repairs.

Treatments for PCC

Asphalt overlays placed directly on jointed or jointed-reinforced portland cement concrete will normally exhibit reflection cracking. The reflection cracking takes longer for thicker overlays. Because of this, it is recommended that the owner consider the use of breaking and seating, rubblizing or paving fabrics.

Asphalt overlays placed on continuously reinforced concrete pavements will not normally require the special treatment described below unless the existing concrete pavement is badly distressed.

Breaking and seating. A portland cement concrete (PCC) pavement that has good drainage and is still relatively sound can be salvaged through breaking and seating and a hot mix asphalt concrete overlay. This option for rehabilitation is designed to reduce the opportunity for reflective cracking by decreasing the slab size of the PCC. Proper breaking and seating will virtually eliminate reflective cracking. If reflective cracks should appear they usually will be small, tight cracks that can be maintained easily.

With this method of rehabilitation, the PCC is cracked at 24- to 30-inch intervals with heavy drop hammer equipment to create a more uniform pattern of cracking. Next, the cracked PCC pavement is seated with a rubber-tired roller of at least 35 tons. This seating action by the roller pushes down any pieces of PCC that might be over a void in the subbase. After the breaking and seating steps are completed, a 3- to 5-inch asphalt overlay is placed directly on the prepared old pavement. This method of recycling has been used for more than 30 years in many states. However, it is not recommended for facilities with utilities close to the surface.

Rubblizing. The rubblizing of PCC pavements before asphalt concrete overlay means the complete destruction of the concrete slab and of all concrete slab action. With this technique, the concrete-to-steel bond is broken on jointed-reinforced concrete pavements and on continuously reinforced concrete pavements. The rubblizing process effectively reduces the existing slab to an in-place crushed aggregate base. The benefits of this method are as follows:

- Prevents reflective cracking
- Provides a sound base for the overlay
- Extends service of the pavement
- Provides a maintainable surface

ODOT has begun to use this technique to rehabilitate highways. Again, it would not be recommended on facilities where utilities are close to the surface.

Overlays with paving fabrics. Paving fabrics, or geomembranes, have been used to reduce reflective cracking from the underlying pavement joints or cracks. A membrane is established through the application of liquid asphalt cement, fabric, and an asphalt concrete overlay. Fabric has been shown to be effective in developing a waterproof layer to minimize surface water intrusion.

An example of a possible use would be as a spot application on asphalt pavement sections that show signs of alligator cracking related to a weakened subgrade condition. Fabric would be placed just before the asphalt concrete overlay. Strip application of fabrics will be more effective if the crack or joint is a nonworking joint, such as a longitudinal joint in a PCC pavement.

Experimental studies of fabric applications have not been conclusive. Early reflective cracking may be delayed through the use of fabric in many cases, especially over a nonmoving joint. Also, where water in the pavement structure is a potential problem, fabric can aid in the development of a waterproof membrane. Guidelines on the use of fabrics to prevent reflection cracking can be found in NCHRP Synthesis 171. One needs to carefully weigh the costs vs. the benefits before specifying these materials.

10.6 REFERENCES

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Chapter 11

Construction Specifications

11.0 CONSTRUCTION SPECIFICATIONS

Construction specifications are a means to an end. Their objectives are to provide users with an adequate and economical pavement on which vehicles can move easily and safely from point to point. A practical specification is one that is designed to insure adequate performance at minimum cost. A realistic specification is one that recognizes that there are variations in materials and construction, which are inevitable and characteristic of the best construction possible today.

The objective of this chapter is to: 1) identify the general factors which need to be considered in developing construction specifications; 2) introduce the concepts of quality control (QC) and quality assurance (QA); 3) identify the differences between specifications currently in use in Oregon; 4) introduce the Oregon Standard Specifications for Construction proposed for public works projects and guide specifications for non-public works projects in both conventional and CSI formats; and 5) provide guidelines (a priori) for dealing with potential disputes between the owner and the seller.

11.1 FACTORS TO CONSIDER

General Concepts. This section of the manual is designed to assist in the preparation of guide specifications for construction of asphalt concrete pavements. Specifications are an essential element in communicating to the contractor information necessary to assure the expected performance of the designed pavement system. Construction plans communicate location, slope, drainage, material type and thickness information. Specifications convey the quality of the materials and workmanship necessary for the completed construction to provide the design service life.

The importance of quality of construction cannot be understated. Quality is the "how good" of construction. Quality comes from knowledgeable and skilled workers using consistently applied good prac-tices with equipment designed to achieve the specified results. Specifications, which require difficult to achieve standards or tolerances, or unusual equipment, or are unclear or ambiguous, will fail in producing quality work. Considerations in creating or editing specifications include the following concepts:

Language. The language of specifications must be understandable by those who will use the specifications to regulate the production of the final product. Terms must be familiar to these workers or clearly explained within the specifications. In addition to words, items such as charts, tables, figures or formulas may be employed to communicate requirements. The specification writer should employ the most concise and clear communication method.

Consistency. The specification organization and phrasing should be consistent within sections and within the entire document. Lack of consistency can lead to misinterpretation of the intent of the specifications. This is especially true for descriptions of work included in each section.

Quality. Quality standards must be clearly conveyed. In most instances, the attributes of the final product should be described in measurable terms. Such specifications are referred to as end result or performance specifications. The other approach is to describe the method in which the work is to be performed. Only one of the approaches can be used at one time. Using both can lead to conflicting specification requirements.

Responsibility. Responsibility for achieving specification compliance must be clearly identified for each item. To avoid confusion, the contractor's measuring and testing for quality is referred to as quality control. Other parties (owner, engineer, independent labora-tory, etc.) not employed by the contractor are referred to as quality assurance. Correlation and resolution procedures for independently performed testing should be included.

References. Reference standards should be current and immediately available to all parties. Care must be exercised that the correct standard and version is used. Refer-ence standards should be carefully checked to avoid conflicting requirements.

Achievability. The specification requirements must be achievable using commonly available materials, equipment or methods. If any requirements are not common, attention to these items should be emphasized during the work proposal stage. Prebid meetings are strongly recommended for new procedures, processes or requirements.

Specifics. The specifications should be edited to include only work included in the specific project to avoid conflicts and confusion.

Coordinated. The specifications must be coordinated with the project plans to include all relevant requirements and avoid potential conflicts between the plans and specifications.

Priority. Most construction contracts place specifications ahead of the plans in importance for interpreting contract requirements. This priority can cause errors and conflicts if the specifications do not agree with the plans. To avoid conflicts, information should be indicated in only one place, either the plans for specifications

Clarity. In case of disputes, courts often rule against the party who authored the contract. This is especially true of construction contracts where contractors must generally accept the contract without negotiation or contractor input. Therefore, the burden of clarity is on the shoulders of the designer and specifier.

Measurements. Measurements are an important part of the specifications. The measurement method and accuracy should be specified. Quantity roundoff methods should also be indicated.

Tolerances. Tolerances should be included wherever applicable. The tighter the tolerances, the higher the construction cost. Tolerances should be directly related to both the product performance and cost. They should not incorporate unreasonable risk. For example, asphalt concrete is expensive and its thickness cannot be easily changed once placed and compacted. Specifying a minimum thickness provides risk to contractors or bidders. A minimum specification directly places economics against performance in both the bidding and performance stages. How much extra thickness does the contractor have to place to make sure that the minimum is met since correction is very expensive? If the contractor bids the specified minimum thickness, the final product may not meet the minimum requirement at all locations. If the contractor includes extra thickness in the bid, the work is not competitive. A better approach is to specify the average thickness and the minimum allowable thickness based on achievable practices. This is the approach incorporated into the sample specifications given in Appendix D.

Materials Quality. Considerable effort has been applied to increase the quality of asphalt concrete produced in Oregon. The result of this effort is a statewide standard for specifying asphalt concrete quality. (See Appendix C.) The benefit to this statewide standard is that the purchaser of asphalt concrete in Oregon can expect the same material quality based on mix and binder type from any producer. A 12.5 mm mix using a 50 blow Marshall compaction requirement with given PG binder is the same in Bend, Portland and Pendleton. This change makes specifying mix quality relatively simple. Follow the procedures in this manual to specify the mix type, laboratory compaction method and binder type. Edit the sample specifications to reflect these choices.

Workmanship Quality. Workmanship quality includes the areas of layer thickness and consistency, compaction, and surface uniformity. All of these items can impact the final product.

Layer thickness is usually specified as a thickness on the plans. The specifications identify the plan thickness as the average layer thickness. Variations in thickness of treated soil or aggregate layers are usually indicated as variation from the grading plane. Variations in layer thickness directly affect the reliability of the pavement's performance. Care is necessary to avoid higher quality material being replaced by lower quality material. An example of this would be a subgrade soil installed at the maximum variation above the grading plane and the top of the aggregate layer above it at the maximum lower variation below the grading plane. If the asphalt concrete is placed with the specified average layer thickness, the net result is a deficiency in aggregate base. To avoid this problem, a maximum layer thickness variation should be specified in addition to variations from the grading plane to avoid cumulative deficiencies.

Deficiencies in grading of the native soil subgrade, treated layers and imported bases are generally easily corrected if the deficiency is identified prior to adding additional layers. Correction of high elevations requires additional excavation. Correction of low areas can either be performed by regrading or adding additional quantity of next layer or higher quality material.

Correction of deficiencies in asphalt concrete is very difficult and expensive after the material is placed and compacted. For this reason, the grading plane on which the asphalt concrete material is to be placed must be very uniform. Final drainage, layer thickness and grading should be carefully checked prior to paving. If paving over rough or nonuniform surfaces, a leveling course of asphalt concrete may be necessary to assure a uniform final pavement surface.

Compaction of the various materials increases their structural strength and durability. The higher quality of the material, the more the importance of compaction. Compaction of asphalt concrete is essential and critical to its performance. Compaction of aggregate bases and native soils is also important. Compaction can generally be easily corrected on native soils, treated soils and aggregate bases if additional layers have not been placed. Correction of deficient asphalt concrete compaction is virtually impossible after cooling of the mix.

Specifications should clearly indicate the required compaction for each material type and the responsibility for testing the compaction. If the owner or their agent is not going to test compaction, testing by the contractor should be specified. For the asphalt concrete layer, the work should not proceed if compaction requirements are not being met prior to cooling of the material below compaction temperatures.

Compaction is generally specified as an end result type specification indicating a minimum level of compaction. For areas hard to test, a method specifica-tion might be applicable. An example is compaction of edges and corners inaccessible to rollers. Hand tamp-ing and vibraplating should be performed prior to or at the same time as the break down rolling. Additional hand compaction will be necessary during intermediate and finish rolling.

Surface uniformity is the pavement quality most noticed by pavement users. This property includes overall texture, variations in texture, unsightly marking and surface variations from a uniform plane.

Overall texture is a property of the mix type. Often fine surface texture is desirable but not compatible with other durability requirements. The specifier must choose the best mix given all of the design constraints.

Variation in the surface texture is a product of the machinery used to place and compact the mix and the hand working of the surface. In general, handwork should be kept to a minimum. Handworking the mix increases its coarseness. Coarse aggregates raked from the surface often must be removed to avoid creating a coarser appearance, especially rock pockets of segregated material. Handworking asphalt concrete requires significant skill to regulate the surface uniformity and thickness so that the compacted surface reflects the quality of the machine laid mat in both texture and uniformity. Texture variation is checked by visual comparison with the nonhandworked machine laid mat. Surface uniformity can be checked with a straight edge. Surface slope can be verified using hand levels, or in some extremely flat pavements, water testing. The contractor should continuously check surface uniformity during installation.

Correction of deficient handwork is best performed while the material is hot, preferable no later than after the breakdown rolling. If the pavement is hot, additional mix is placed over the coarse area and raked into the surface voids. If the underlying mix is segregated, the segregated mix should be removed prior to placement of additional new mix. All left over aggregate should be removed.

If the pavement has cooled, reheating the pavement thoroughly prior to reworking is essential. Continued reheating may be necessary. Application of a tack coat after the initial reheating and immediately prior to placement of new material may be necessary. Correction of coarse areas after cooling of the pavement will generally be obvious initially, even with the best workmanship. With poor workmanship, the areas will be visible for a long time in nontravel areas such as parking stall corners. This type of work should only be done with close supervision.

11.2 QUALITY CONTROL/QUALITY ASSURANCE CONCEPTS

Quality Control (QC). Quality is defined as a characteristic with respect to excellence or grade of excellence. The quality of asphalt concrete can be described as the characteristics (asphalt content, air voids, density, smoothness, etc.) of that product that are required to achieve a specific level of excellence. In the case of asphalt concrete materials or construction, quality is measured in terms of some level of performance; normally expressed in terms of durability, ride quality and/or safety.

Control means exercising direction, guidance, or restraining power over some item or thing and maintaining some limits about this direction or restraint. Asphalt concrete **quality control** or **process control**, then implies that if certain ingredients (aggregates and asphalt) are mixed and placed in a prescribed manner, it is reasonable to expect the process will perform as expected. Quality control, therefore, includes process control, plant calibration, inspection, sampling and testing and necessary adjustments in the process related to the production and placement of asphalt concrete pavements. Quality control is generally the sole responsibility of the producer (or contractor). The requirements are similar for public works and private projects.

Quality Assurance (QA). A general definition for **quality assurance** is those activities which concern making sure the quality of a product is what it should be. This definition has two parts. “Making sure what the quality of a product is” is the first part and deals with the decisions necessary to determine conformity to the specifications. The second part - “what it should be” - deals with the basic engineering properties of the material or construction process.

QA includes all actions necessary to provide confidence that a product or service will satisfy given requirements for quality. QA is an all-encompassing concept that includes QC, **acceptance and independent assurance** (IA).

Acceptance. Acceptance is defined as “all the factors that comprise the owner’s determination of the quality of the product as specified in the contract requirements.” These factors include verification sampling, testing and inspection and may include results of quality control sampling and testing. **Independent Assurance** (IA) are those activities that are an unbiased and independent evaluation of all the sampling and testing procedures used in the acceptance program. Test procedures used in the acceptance program, which are performed in the owner’s central laboratory, would not be covered by an independent assurance program.

11.3 SPECIFICATION TYPES

Presently agencies operate under two broad classifications of HMA specifications - Materials and Methods and QC/QA. The materials and methods specifications have been traditionally used for private work while the QC/QA specifications have been used in Oregon for state and federally funded projects. The Oregon Standard Specifications for Construction (Appendix C) is a QC/QA type speci-fication with pay incentives and disincentives. Following is a general discussion of these two broad specification types.

Materials and Methods Specifications. This was the most widely used type of specification in pavement construction until the mid-1980s. In fact, even today some agencies utilize these specifications entirely. With this type of specification, the agency directs the contractor to use specific materials, proportions, and equipment. Additionally, the placement process is explicitly defined. Each step in the process is either controlled or directed.

Relative to asphalt concrete production, the specifications require that the component materials - asphalt cement, aggregates, additives - must be pretested and approved. These materials must be combined in specified proportion and mixed in a specified way. Quite often the agency performs the mix design and designates the job-mix formula (JMF). The mixture must meet further specific requirements, for example, air voids, stability, flow, etc.

Materials and methods specifications evolved over the years based on experience and that no quick tests had been developed (i.e., asphalt content, gradation, etc.). In most instances, the quality control and acceptance decision is based on single or individual test results.

The disadvantages of materials and methods specifications include:

- Contractors may not be allowed to use the most economical or “innovative” procedures to produce the product sought.
- The specifications are inspector labor intensive.
- If the quality is measured and found to be less than desirable, the contractor has no legal responsibility to improve it.
- The agency assumes the bulk of the specification risk.
- The quality attained is difficult to relate to the performance of the finished product.

A major weakness of this type of specification is that there is no assurance that it will produce the desired quality of construction. Most important, by explicitly specifying the material and procedures, the agency has obligated itself to a great degree to accept the end product. A specification under these circumstances is also very difficult to uniformly enforce. The terms “reasonable close conformity” and “substantial compliance” cannot be clearly defined. In the absence of a clearly established quality level and a uniform means of measuring compliance, decisions become arbitrary and acceptance procedures become inconsistent in their application. Material and methods specifications usually have limits based solely on subjective judgment or experience and are often difficult to meet due to a lack of definition of the capabilities of the production process and the desired product.

Quality Control/Quality Assurance (QC/QA) Specifications. A number of agencies have moved toward QC/QA specifications in which the contractor is responsible for quality control and is free to choose the construction methods. These specifications incorporate statistics into both sampling and analysis of materials for acceptance. With the adoption of QC/QA specifica-tions, the burden of choosing the proper construction methods and the responsibility for quality control shift from the agency to the contractor. With QC/QA specifications, the desired “end result” is stated and the contractor or producer is allowed the fullest possible latitude in obtaining it. However, certain restrictions are generally included so as to insure at least a minimum acceptable level of quality and to prevent the construction or production of a large quantity of work before defects are discovered. This is the type of specification included in Appendix C.

The distinction between **process control** and **acceptance testing** is important. **Acceptance testing** is based on the principle of estimating the parameters of a characteristic of the lot by limited random sampling. A **lot** is a quantity of material (day’s production run, 5000 linear feet, 1500 tons, etc.) produced essentially under the same conditions. **Random sampling** is a procedure whereby every portion of the lot has an <u>equal chance</u> of being selected as the sample. Normally these parameters consist of the acceptable quality level and a measure of variability or dispersion. It is the owner’s responsibility to accept the lot at full payment, at reduced or increased payment or reject the lot entirely.

Process control is the means of providing adequate checks during production (or construction) to minimize the contractor’s or producer’s risk of having the lot rejected. A process is said to be in control when all economically removable variations have been eliminated. In fact, a primary purpose of process control is to eliminate assignable causes of variance so that the overall variability of the finished lot will approximate the variation that was used to design the sampling plan for acceptance of the lot.

It may be said that process control testing endeavors to maintain a given level of production with respect to both the acceptable level and the degree of uniformity, whereas acceptance testing is a check on the finished product to see to what degree these goals have been attained.

The greatest advantage to QC/QA is the actual placing of responsibility for materials and construction quality on the contractor or producer. Other advantages include reduced testing by the owner and elimination of duplicate testing between the owner and contractor.

Advantages to contractors and producers stem from greater latitude in the choice of materials and equipment, and design of the most economic mixtures meeting the specified requirements. Perhaps the greatest benefit is due to the lot-by-lot acceptance procedures that are incorporated in most QC/QA specifications. When lots are immediately accepted, conditionally accepted with a reduction in payment or rejected, contractors or producers understand their position. An enforced reduction in price is almost certain to attract the attention of management at higher levels. This gives owners the opportunity to take corrective action before large quantities of non-specification material or construction are produced and avoids tie-up of capital when payment is held up due to failing tests. The primary advantage to both the agency and the contractor is that the risks to both parties can be quantified and balanced.

11.4 TYPICAL GUIDE SPECIFICATIONS

Guide specifications for public works and non-public works projects are briefly discussed below.

Public works projects. The Oregon Standard Specifications for Construction, Section 00745 given in Appendix C provides a standard reference specification for construction of street and highway pavements (Public Works projects). These specifications require the following:

- Contractors have ODOT certified technicians and laboratories
- Contractors perform QC on a regular basis

Non-public works projects. Appendix D provides sample specifications for construction of pavements for parking lots and private roadways. Appendix D has two formats. The first format is a general engineering format suitable for inclusion in engineering projects. The second format conforms to the specification format of the Construction Specifications Institute (CSI). The CSI format is the most commonly used on building projects prepared by architects.

Purchasers of small quantities of mix for driveways / parking lots / recreational facilities can do so without the need for special testing by requiring the contractor to certify compliance using ODOT certified technicians and laboratories. Regardless of the type of project, the author of the specifications must consider the factors given in Table 11.1. Quality Control / Quality Assurance responsibilities are given in Table 11.2.

11.5 DISPUTE RESOLUTION GUIDELINES

The best way to avoid disputes between the owner and the contractor is through partnering. Cooperation and communication are keys to successful projects. However, in the event disputes arise, the following guidelines are recommended. Detailed steps in the dispute resolution process can be obtained from APAO.

General. Disputes regarding pavement construction generally involve concerns about materials quality, layer thickness, compaction and surface quality. Whereas the specifications may contain allowable standards and tolerances, most specifications fail to provide evaluation methods for assessing relative value for construction that falls below the specified tolerance limits. As most deficiencies in pavement structures are not readily corrected, assessing relative value becomes very important.

Dispute resolution guidelines provide a recognized standard assessment procedure for relative value for pavement structures. The guidelines have been developed with the input, comment and review by professionals representing manufactures, contractors, municipalities, consultants, owners and researchers. The procedures are specifically tailored to be compatible with the guide specifications given in Appendix D.

Disputes cost money to resolve. Investigation and evaluation of constructed pavements usually means destructive field sampling and testing and laboratory evaluation of materials quality. The procedures present proration of these costs depending on the outcome of the investigation and evaluation. When the costs of the procedures are established ahead of time, negotiation of a financial resolution without assessment of fault might be the most economical approach.

In all cases, disputes should be handled expeditiously to avoid undue financial burdening of contractors and suppliers. Cash flow is the live blood of any business. Undue withholding of major sums of progress payments for relatively minor problems is unjustified. However, if there are serious concerns over the functionality of the completed work with major loss of value or performance, withholding payments may be judicious.

	Yes	No
1. Is the language in the specification simple and understandable?	□	□
2. Are the specifications organized in a consistent fashion, from section to section?	□	□
3. Have the quality standards been conveyed clearly?	□	□
4. Have the parties responsible for quality control and quality assurance been clearly identified? If so, are the technicians and laboratories certified by ODOT?	□	□
5. If partnering is not included, have guidelines for resolving disputes been included?	□	□
6. Have all the appropriate (and current) reference standards been included?	□	□
7. Have sampling and testing plans been included?	□	□
8. Are the specification requirements appropriate for the job? Are they achievable?	□	□
9. Do the specifications include only work for the job at hand?	□	□
10. Are the specifications in agreement with the requirements in the project plans?	□	□
11. Are tolerances for all items included in the specification clearly identified?	□	□
12. Are the methods of measurement of each item (thickness, asphalt content, gradation, compaction, etc.) identified?	□	□
13. Is the method of payment (including incentives and disincentives) clearly stated?	□	□

Table 11.1 Check List for Developing Guide Specifications

Process	Items to be Considered	Responsibility
Quality Control	• Plant calibration • Process control • Plant adjustments • Sampling/testing plans	Contractor using certified technicians and laboratories
Quality Assurance	• Sampling/testing plans • Pay incentives/disincentives	Owner/contractor using certified technicians and laboratories or Certificate of Compliance provided by contractor

Table 11.2 Quality Control/Quality Assurance Responsibilities

In all cases, moving from identification of a problem to investigation and to dispute resolution should be carried out without delay. Such timely resolution requires the cooperation of all parties.

Disputes regarding pavement work most often arise at the completion of the project after final inspection and development of a list of corrections or "punch list." APAO recommends that the owner (or representative) present to contractor a written punch list of work within two weeks of work completion or final paving. The contractor should respond with disputed items within one week of punch list receipt. The owner should reconfirm disputed items within one week of the contractor's notice that items are under dispute. If no agreement can be reached regarding the items and an impasse occurs, it is time to enter into the dispute resolution process.

Principles. Dispute resolution procedures have been developed within the concept of contractual equity. Pavements are built by contractors to meet a specified standard of materials and workmanship. For the specified construction work, the contractor is to be paid an agreed amount.

The owner deserves to receive the quality and quantity of work agreed upon and the contractor deserves to be paid for his work. This seems simple enough, but in reality, there are many variables that complicate the issues. The procedures identify the issues, determine the potential affects of each issue, and assign relative value for various levels of performance.

Most of the work performed for public agencies is governed by various specifications types. The Oregon Standard Specifications for Construction provides a uniform approach for public agency work. APAO has also established specification guidelines for privately constructed pavements (Appendix D). The guidelines utilize the materials quality specifications from the Public Agency Guidelines. The private specifications address the specific workmanship issues involved in constructing private pavements. These guidelines are intended to provide an industry standard for private pavements in Oregon. These guidelines become the basis for judging the quality of constructed private pavements.

Specifications provide the quality standard for acceptance of pavements construction. Unfortunately, acceptance of private pavements is often performed by inexperienced persons. Often pavements with minor surface flaws but excellent structures are rejected, while pavements with excellent surfaces but inferior structures are accepted. When the pavements do not meet the specification minimums, procedures must be designed to evaluate the relative value of the various elements of pavement quality.

Plan of Action. Basically, the steps for dispute resolution can be summarized as follows:

- fact finding (both parties)
- identify facts both parties agree on
- identify facts that are disputed
- share understanding of each other's disputed facts using good practices
- each party define, prioritize and share needs
- negotiate disputed issues to meet each party's needs

Hopefully, through the use of this guide and the specifications included in the appendices, disputes on product will be greatly reduced.

11.6 REFERENCES

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APPENDIX A

GLOSSERY OF TERMS

GLOSSERY OF TERMS

A

AASHTO. The American Association of State Highway and Transportation Officials. An organization of highway engineers from the 50 states that develops guides and standards.

Aggregate. Any hard, inert, mineral material used for mixing in graduated fragments. It includes sand, gravel, crushed stone or slag.

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

Asphalt. A dark brown to black cementitious material that can be solid, semi-solid, or liquid in consistency, in which the predominant constituents are bitumens that occur in nature as such or are obtained as residue in refining petroleum. Asphalt is a constituent in varying proportions of most crude petroleums.

Asphalt Base Course. A foundation course consisting of mineral aggregate, bound together with asphaltic material.

Asphalt Binder Course. An intermediate course between a base course and an asphalt surface course. The binder course is usually a coarse-graded aggregate Asphalt Concrete containing little or no mineral matter passing through a 75 µm (No. 200) sieve.

Asphalt Cement (AC). Asphalt that is refined to meet specifications for paving, industrial and special purposes.

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

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 a uniform course or courses to provide needed thickness.

Asphalt Pavements. Pavements consisting of a surface course of mineral aggregate coated and cemented together with asphalt cement on supporting courses such as asphalt bases; crushed stone, or gravel.

ASTM. The American Society for Testing and Materials. A national organization of users and producers of materials that establishes standards.

Asphalt Soil Stabilization (Soil treatment). Treatment of naturally occurring nonplastic or moderately plastic soils with liquid asphalt at normal tempera-tures. After mixing, aeration and compaction provide water resistant base and subbase courses with improved load-bearing qualities.

Asphalt Surface Treatments. Applications of asphaltic materials to any type of road or pavement surface, with or without a cover of mineral aggregate that produces an increase in thickness of less than 25 mm (1 inch).

B

Base Course. The layer or layers of specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course. This can include asphalt base course.

Bituminous Concrete. A designed combination of graded crushed stone, filler and bituminous cement mixed in a central plant, laid and compacted while hot. This is the same as asphalt concrete.

C

Cement-Treated Base. Cement-treated base consists of specified soil or aggregates and portland cement concrete mixed in a pug mill and deposited on the subgrade to the specified thickness.

Coarse Aggregate. Aggregate particles retained on a No. 8 sieve.

Coarse Graded Aggregate. An aggregate having a continuous grading in size of particles from coarse through fine with a predominance of coarse sizes.

Compaction. The densification of crushed stone base, subgrade soil or bituminous material by means of vibration or rolling.

Contract. The written agreement executed between the contractor and other parties, setting forth the obligations of the parties thereunder; including, but not limited to the performance of the work, the furnishing of labor and materials and a basis of payment.

Contractor. The individual, partnership, corporation or joint venture contracting for performance of prescribed work.

Crushed Stone. The product resulting from the artificial crushing of rocks, boulders or large cobblestones with the particles resulting from the crushing operation having all faces fractured.

Crusher Run. Aggregates that have received little or no screening after initial crushing operations. Crusher run aggregates are generally more economical than screened aggregates.

Cul-de-Sac. An area at the terminus of a dead-end street or road constructed for the purpose of allowing a vehicle to turn around.

Culvert. Any structure that is not classified as a bridge and that provides an opening under any roadway

D

Deep Lift Asphalt Pavement. A pavement in which the asphalt base course is placed in one or more lifts of 100 mm (4 inches) or more compacted thickness.

Dense Graded Aggregate. A mineral aggregate uniformly graded from the maximum size down to and including sufficient mineral dust to reduce the void space in the compacted aggregate to exceedingly small dimensions approximating the size of voids in the dust itself.

Design Period. Also known as performance period, this refers to the period of time that an initial pavement structure will last before it needs rehabilitation. It also refers to the performance time of a rehabilitation measure.

Design Thickness. The total pavement structure thickness above the subgrade.

Drainage. Structures and facilities for collecting and carrying away water.

E

Economic Analysis. Involves the application of the principles of engineering economy to pavement projects at two possible levels (management and project).

Emulsified Asphalt. An emulsion of asphalt cement and water that contains a small amount of an emulsifying agent, a heterogeneous system containing two normally immiscible phases (asphalt and water), in which the water forms the continuous phase of the emulsion and minute globules of asphalt form the discontinuous phase. Emulsified asphalts may be either anionic, electro-negatively-charged asphalt globules or cationic, electro-positively-charged asphalt globules, depending upon the emulsifying agent.

Equivalent Single Axle Loads (ESALs). Summation of equivalent 80 kN (18,000 lbs) single axle loads used to combine mixed traffic to design traffic for the design period.

F

FHWA. Federal Highway Administration.

Fine Aggregate. Aggregate particles passing a No. 8 sieve.

Fine Graded Aggregate. An aggregate having a continuous grading in sizes of particles from coarse through fine with predominance of fine sizes.

Flexible Pavement. A pavement structure that maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction and cohesion for stability. Asphalt or bituminous concrete pavements are flexible pavements; concrete is not.

Fog Seal. A light application of liquid asphalt without mineral aggregate cover. Slow-setting asphalt emulsion diluted with water is the preferred type.

Free Water (Groundwater). Water that is free to move through a soil mass under the influence of gravity.

French Drain. A trench loosely backfilled with stones, the largest being placed on the bottom with the size decreasing toward the top.

Full-Depth Asphalt Pavement. An asphalt pavement 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 (see deep lift asphalt pavement).

G

Gravel. A coarse granular material (usually larger than 1/4 inch in diameter) resulting from the natural erosion and disintegration of rock. Crushed gravel is the result of artificial crushing with most fragments having at least one face resulting from fracture.

I

Improved Subgrade. Any course of courses of select or improved material between the foundation soil and the subbase is usually referred to as the improved subgrade. The improved subgrade can be made up of two or more courses of different quality materials.

L

Leveling Course. An asphalt/aggregate mixture of variable thickness used to eliminate irregularities in the contour of an existing surface before superimposed treatment or construction.

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Low Volume Road. A roadway generally subjected to low levels of traffic; in this guide, structural design is based on a range of 80 kN (18,000 lbs) ESALs from 50,000 to 1,000,000 for flexible and rigid pavements and from 10,000 to 100,000 for aggregate surfaced roads

M

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.

Mineral Filler. A finely divided mineral product at least 65 percent of which will pass a 75 µm (No. 200) sieve. Pulverized limestone is the most common manufactured filler, although other stone dust, hydrated lime, portland cement and certain natural deposits of finely divided mineral matter are also used.

O

Open-Graded Aggregate. An aggregate containing little or no mineral filler of in which the void spaces in the compacted aggregate are relatively large.

P

Pavement Distress. Deformation, cracking, durability problems in flexible rigid pavements (See Appendix B for a description of the different distress types.)

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 Structure (Combination or Composite). All courses of selected material placed on the foundation or subgrade soil, other than any layers or courses constructed in grading operations. When the asphalt pavement is on an old portland cement concrete base or other rigid-type base, the pavement structure is referred to as a combination of composite-type pavement structure.

Performance Period. The period of time that an initially constructed or rehabilitated pavement structure will last (perform) before reaching its terminal serviceability; this is also referred to as the design period.

Permeability. A measure of the rate or volume of flow of water through a soil.

Petroleum Asphalt. Asphalt refined from crude petroleum.

Plans. The standard drawings current on the date bids are received; and the official approved plans, profiles, typical cross sections, electronic computer output listings, working drawings and supplemental drawings, or exact reproductions thereof, current on the date bids are received; and all subsequent approved revisions thereto, which show the location character, dimensions, and details of the work to be done.

Plant Mix. A mixture produced in an asphalt mixing plant that consists of mineral aggregate uniformly coated with asphalt cement or liquid asphalt.

Portland Cement Concrete (PCC). A composite material that consists essentially of portland cement and water as a binding medium in which is mixed coarse and fine particles of crushed stone.

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

Present Serviceability Index (PSI). A number derived by formula for estimating the serviceability rating from measurements of certain physical features of the pavement.

Prime Coat. An application of low-viscosity liquid asphalt to an absorbent surface. It is used to prepare an untreated base for an asphalt surface.

Pumping. The ejection of foundation material, either wet or dry, through joints or cracks, or along edges of rigid slabs resulting from vertical movements of the slab under traffic.

Punch List. A list of items that require correction before payment is made.

R

Reclaimed Asphalt Pavement (RAP). Removed and/or reprocessed pavement materials containing asphalt and aggregates.

Reconstruction. Refers to the process of removing and replacing materials from an existing pavement to create a new pavement structure.

Recycling. Refers to any means of reusing materials from existing pavements in a subsequent pavement rehabilitation or reconstruction operation.

Rehabilitation. Refers to a number of different repair, resurfacing and reconstruction activities, which are intended to address poor conditions in an existing pavement facility.

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

Restoration. Refers to rehabilitation activities, which either restore an existing pavement to a serviceable condition without an overlay or prepare the existing pavement to receive an overlay.

Resurfacing. Existing surfaces may be improved by resurfacing (or overlaying) with a plant mix asphalt mat of varying thicknesses. It may be considered in two categories: 1) overlays to provide smooth, skid- and water-resistant surfaces or to make improvements in grade and/or cross section; and 2) overlays to strengthen existing pavements to handle heavier loads or increased traffic. Sometimes called overlays.

Rigid Pavement. A pavement structure that distributes loads to the subgrade, having as one course a portland cement concrete slab of relatively high bending resistance.

Roadbed. The graded portion of a roadway 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.

S

Seal Coat. A thin asphalt surface treatment used to waterproof and improve the texture of an asphalt wearing surface. Depending on the purpose, seal coats may or may not be covered with aggregate. The main types of seal coats are aggregate seals, fog seals, emulsion slurry seals and sand seals.

Select Material. Suitable material obtained from roadway cuts, borrow areas, or commercial sources and designated or reserved for use as foundation for the subbase, for subbase material, shoulder surfacing, or other specific purposes.

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

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

Slurry Seal. A mixture of slow-setting emulsified asphalt, fine aggregate, and mineral filler with water added to produce slurry consistency.

Soil Cement Base. Consists of a mixture of the natural subgrade material and portland cement in the proper amounts. After thorough mixing, the proper amount of water is added, and the material is compacted to the required thickness.

Soil Support. A term expressing the ability of the roadbed material, or subgrade soil, to support the traffic loads transmitted through a flexible pavement structure.

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

Street. A general term denoting a public way for purpose of vehicular travel, including the entire area within the right-of-way.

Subbase. The course in the asphalt pavement structure between the base and subgrade. It is of superior quality than the subgrade.

Subcontractor. Any individual, partnership or corporation for whom the contractor sublets part of the contract.

Subdrain. A structure placed beneath the ground surface to collect and carry away underground water.

Subgrade. The uppermost material placed in embankments or unmoved from cuts in the normal grading of the roadbed. It is the foundation for the asphalt pavement structure. The subgrade soil sometimes is called basement soil or foundation soil.

Subgrade Stabilization. Modification of roadbed soils by admixing with stabilizing or chemical agents that will increase load-bearing capacity, firmness and resistance to weathering or displacement.

Subsurface Drainage. Removal of free water from various structural components of the pavement or the surrounding soil.

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 is sometimes called the “wearing course.”

T

Tandem Axle Load. The total load transmitted to the road by two consecutive axles extending across the full width of the vehicle. The spacing of the tandem axles used at the AAHTO Road Test was 122 cm (48 inches).

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Traffic Equivalence Factor (e). 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. In this guide, all axle loads are equated in terms of the equivalent number of repetitions of an 80 kN (18-kip) axle.

Triple (Tridem) Axle Load. The total load transmitted to the road by three consecutive axles extending across the full width of the vehicle. There were not tridem axles at the AAHTO Road Test; however, the spacing that may be inferred for consecutive triple axles based on the tandem axle spacing is 122 cm (48 inches).

U

Underdrain. A perforated or porous-walled pipe placed with suitable pervious backfill beneath the ground surface to collect and carry away underground water.

V

Viscosity. This is a measure of the resistance to flow. The term is used as “high viscosity” or “low viscosity.” A high viscosity material refers to a heavy or still material that will not flow easily. A low viscosity material is the opposite. Viscosity is measured in absolute units called poises.

W

Wearing Course. The top course of asphalt pavements, also called the surface course.

APPENDIX B

PAVEMENT FAILURE IDENTIFICATION

PAVEMENT FAILURE IDNETIFICATION

The key to proper maintenance of asphalt pavements is to understand the causes of failures and the action(s) needed for correction before any repair work is done. To make the most of maintenance budgets, proven methods must be used to correct failures and to prevent their recurrence.

The following section provides basic information on the most common types of pavement failures, including their probable cause and the measures recommended for their correction. Personnel involved in asphalt maintenance operations must be well advised, trained and properly equipped. With diligent application, the following section can assist in helping them achieve an efficient, effective and consistent asphalt pavement maintenance system.

Types of Pavement Failures. The following photographs illustrate the types of pavement failures most commonly encountered in asphalt pavements. Also included is a description of the failure type, probable cause of the failure, and recommended correction.

Bleeding or flushing (Fig. B.1). This distress is caused by excess asphalt in the surface layer. Contributing factors include insufficient coarse stone, excessive rolling during placement, stripping of the asphalt from the aggregate, or low air voids.

Minor bleeding can often be corrected by applying coarse sand or stone screenings to blot up excess asphalt. Major bleeding can be corrected by cutting off excess asphalt with a motor grader or removing it with a "heater planer." If the resulting surface is excessively rough, resurfacing may be necessary.

Corrugations and shoving (Fig. B.2). Corrugations and shoving are caused by instability in the asphalt layers caused by a mixture that is too rich in asphalt, has too high of a proportion of fine aggregate, has coarse or fine aggregate that is too rounded or too smooth-textured, or has asphalt cement that is too soft for the traffic conditions. Corrugations and shoving may also be caused by excessive moisture, contamination caused by oil spillage, or lack of curing time between placing seal treatments. This type of distress frequently occurs at grade intersections as a result of braking forces imposed by stopping vehicles.

To repair corrugations in an aggregate base overlain with a thin surface treatment, scarify the pavement, add aggregate as needed, mix well, recompact, prime and then resurface. Where the surface has 50 mm (2 inches) or more of asphalt plant mix, corrugations can be removed with a "heater planer" or by cold planing. After removal of corrugations, cover with a new surface treatment or new asphalt overlay.

To repair shoved areas, remove surface and base as necessary and replace with a more stable material to prevent a recurrence. For temporary out-of-season inclement weather repairs, smooth shoved areas with patching if the surface unevenness is hazardous to traffic.

Cracking, alligator (Figs. B.3 and B.4). Interconnected cracks forming a series of small polygons resembling an alligator's skin are called alligator cracks. There are numerous kinds of alligator cracks, some of which are illustrated and discussed below.

In-situ investigations must be performed to determine the most probable of several causes of alligator cracking. If poor drainage is implicated, corrections should be made as quickly as possible. Should the pavement be properly drained, then the base is probably inadequate, and the pavement will require reconstruction or a heavy resurfacing. Major resurfacing will also be required if cracking results from the fatigue effect of repetitive heavy truck loads. If the cause of distress cannot be corrected soon (rebuilding of the pavement may be several years in the future), temporary repairs may be required.

Skin patching should be applied when weather permits. This is often a temporary measure and should not be considered a permanent correction of a major problem. Alligator cracking generally requires removal of the cracked pavement and an asphalt patch of at least 100 mm (4 inches) in depth.

Where distortion (or rutting) is 25 mm (1 inch) or less and the existing surface is intact, a skin patch should be applied. Where distortion is more than 25 mm (1 inch) and the existing surface is intact, a tack coat should be applied followed by an asphalt concrete overlay.

Where the existing surface is badly cracked and loose (regardless of amount of distortion), remove old surface, tack area and repair using asphalt concrete. Sound judgment should be used to determine when the existing surface is considered firm and should remain in place or when it is considered loose and should be removed before placing the asphalt concrete overlay.

There are several causes of this type of distress. Often poor drainage resulting in a wet base and/or subgrade is responsible. If the pavement is properly drained, then water is getting to the base and/or subgrade from cracks or holes in the surface or from moisture coming up through the subgrade. This distress should be repaired as follows:

- Cut out and pavement and wet material.
- If the base or surface is wet from underneath, install necessary underdrains to prevent future saturation.

Figure B.1 Bleeding/Flushing Surface

Figure B.2 Shoving in Surface Layer

Figure B.3 Alligator Cracking – Low

Figure B.4 Alligator Cracking - Moderate

- Prime area.
- Replace with a minimum of 4 inches of asphalt concrete.
- Compact asphalt concrete.

For temporary out-of-season inclement weather repair, keep the area filled with either cold patch material or treated aggregate base.

Cracking, edge (Figs. B.5 and B.6). The following items discussing edge cracks concern those pavement surfaces underlain by base material and not areas where the surface has been gradually widened over the years until its edge is inadequately supported by a base layer.

Cracking without surface distortion (Fig. B.5) is usually caused by lack of shoulder (lateral) support. When the surface is distorted, possible causes are more diverse. In some cases, the base layer may be of insufficient quality or thickness to support the traffic loads. Poor drainage is also a frequent cause. Is water getting in from the top, sides or bottom? Is base failure causing distortion and allowing water to wet the base and/or subgrade? Is a clogged ditch line causing water to seep through porous shoulder material and saturate the base and subgrade? Corrective measures should be under-taken as soon as possible. The first step is to correct the problem of lack of lateral support if neces-sary. For cracks less than 6 mm (1/4 inch) in width, no maintenance is required. A skin patch is sufficient for larger cracks.

Where distortion is 25 mm (1 inch) or less (Fig. B.5) and the existing surface is intact, a skin patch should be applied. Where distortion is more than 25 mm (1 inch) (Fig. B.6) and existing surface is intact, tack area and build up with asphalt concrete.

Where the existing surface is badly cracked and loose, regardless of distortion, the old surface must be re-moved. Prior to replacing the surface, consideration should be given to the necessity of first replacing the base material if it has been pushed up and out into the shoulder. This action will have reduced the amount of base material that remains in place and thus will have reduced the strength of the pavement. If this condition exists, it should be corrected by either replacing the base material or by building up the depressed area with asphalt concrete.

Sound judgment should be used to determine whether the existing surface is considered firm and should re-main in place or if it is considered loose and should be removed and replaced. When asphalt concrete is used to replace the base material, it should be of equal or greater strength than the material it replaces. To repair such distress, take the following steps:

- Remove unsuitable material.
- Install any necessary underdrains.
- Replace base with a well-graded aggregate.
- Compact aggregate.
- Prime area.
- Replace surface using asphalt concrete.

When inclement weather prohibits proper repair, try to keep the distressed area filled with cold patch materi-al.

Cracking, longitudinal (Figs. B.7 and B.8). These cracks occur where the shoulder or paved wedge sepa-rates from the mainline pavement or along weak seams of adjoining pavement spreads in the surface layers.

This distress is caused by wetting or drying action be-neath the shoulder surface caused by conditions that trap water and allow it to stand along and seep through the joint between the shoulder or gutter and the mainline surface.

If the cracking is less than 6 mm (1/4 inch) in width, no maintenance is required. Otherwise, a crack should be filled with an emulsified asphalt or a joint seal ma-terial. Distress is caused by a weak seam between adjoining spreads in the courses of the pavement.

Cracking, random (Figs. B.9 and B.10). The causes of random cracking are numerous and, in its early stages, difficult to determine. Consequences range from severe, such as deep foundation settle-ment, to slight, such as a construction error or mishap.

For cracking less than 6 mm (1/4 inch) in width, take no action. If associated distress of another type ex-ists, the cracking will progress and remedial action will ultimately be required.

When random cracks reach 6 mm (1/4 inch) or more in width, remedial action is often required. However, the appropriate action may be difficult to determine. On some pavements, cracking will not progress signif-icantly from year to year. Previous experience and/or the traffic volume and type of pavement or age of pavement may indicate that it is not necessary to take immediate action. Sound judgment should be used when deciding if action should be taken in this case.

In most cases, the crack should either be covered with a skin patch or be filled with an emulsified asphalt and covered with sand. Both methods are accept-able, and good judgment should be used to determine which method is best according to the particular dis-tress, materials available and previous experience.

Cracking, reflection (Figs. B.11 and B.12). Re-flection cracking is caused by vertical and horizontal movements in the pavement beneath overlays that result from expansion and contraction with tempera-ture or moisture changes. Reflection cracking is very apparent where plant mix has been placed over port-land cement concrete pavement or where old alligator cracks have propagated up through an overlay or patch.

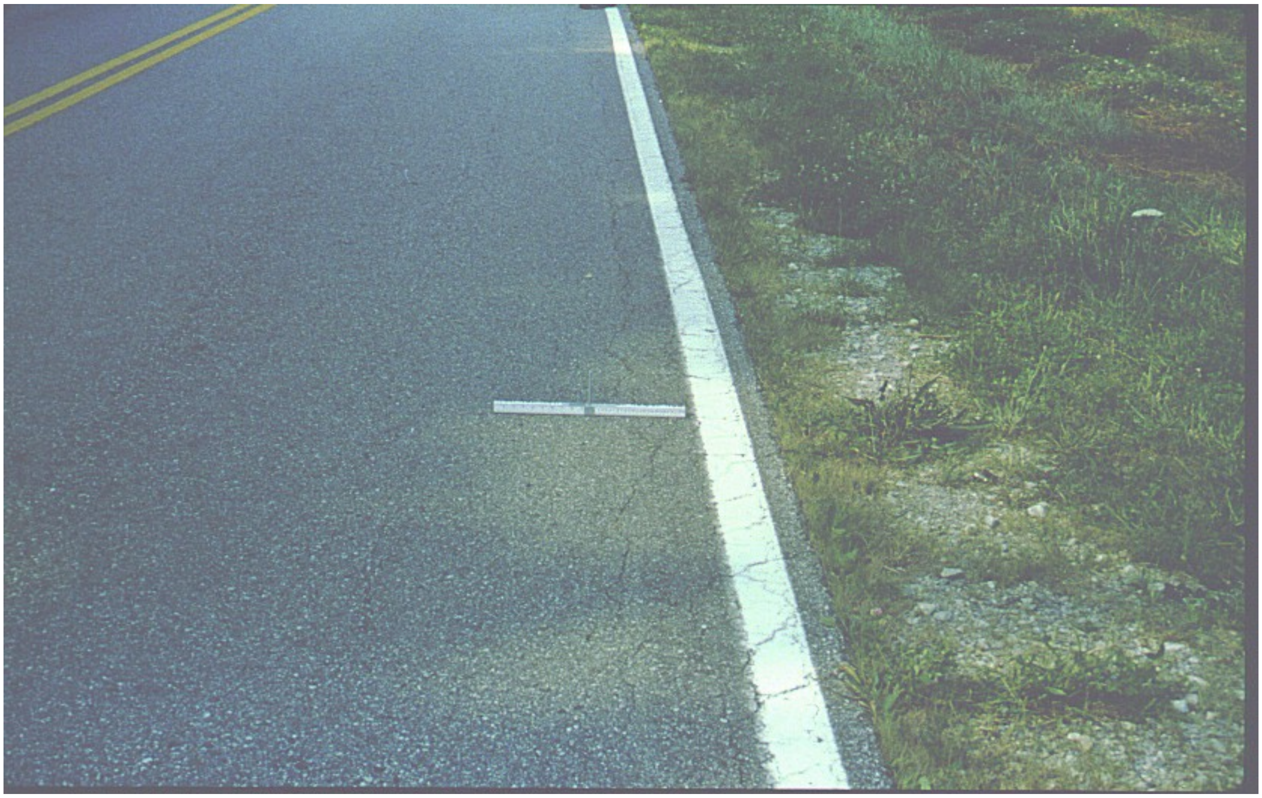

Figure B.5 Edge Cracking without Surface Distortion

Figure B.6 Edge Cracking with Distortion

Figure B.7 Longitudinal Crack - Low

Figure B. 8 Longitudinal Joint—Moderate

Figure B.9 Random Cracking – Narrow Cracks

B.10 Random Cracking - Moderate Cracks

Figure B.11 Reflection Cracking – Narrow Cracks

Figure B. 12 Reflection Cracking—Wide Cracks

If reflection cracks are less than 6 mm (1/4 inch) in width, no maintenance is required. Larger cracks should be routed, cleaned, and filled with a joint seal material or an emulsified asphalt and covered with sand.

Such treatment is seldom permanent when applied to overlays over old portland cement concrete pavement. Continual expansion and contraction of the concrete causes conventionally repaired cracks to reappear quickly. A single course surface treatment over the existing pavement immediately preceding the overlay is a good crack relief measure that minimizes reflective cracking.

Cracking, shrinkage (Fig. B.13). Shrinkage cracking appears on the pavement surface as interconnected cracks forming a series of polygons, usually having sharp angles at the corners. Unlike alligator cracking, which is associated primarily with traffic loading, shrinkage cracking is caused by volume change within the asphalt concrete, the aggregate base and/or the subgrade layers.

If the shrinkage cracking is severe and has seriously weakened the pavement structure, a structural overlay will be necessary to restore it. Most likely, however, the cracking will not be progressive, and a surface treatment Cpreceded by filling the larger cracks with a cutback or emulsified asphalt will suffice for surface restoration.

Cracking, slippage (Fig. B.14). Slippage cracks are crescent-shaped cracks that usually point in the direction of traffic movement. They result from insufficient bond between the surface and underlaying courses, caused by dust, oil, rubber, dirt, water or no tack coat between the two courses.

To repair slippage cracks, neatly remove the unbonded section of the surface, thoroughly clean the underlying surface and apply a suitable tack, and replace the surface with a high quality asphalt concrete. During inclement weather, keep the exposed area filled with cold mix material if it is likely to be a traffic hazard.

Cracking, transverse (Fig. B.15). A transverse crack follows a course approximately at right angles to the pavement center line, usually extending across the full pavement width. Transverse cracks are often the result of reflection cracking; however, they are also the result from stresses induced by low-temperature contrac-tion of the pavement, especially as the asphalt ages and becomes more brittle. Repair procedures for trans-verse cracking are similar to those for reflection cracking.

Potholes (Fig. B.16). Potholes occur most frequently during the winter months when it is difficult to make the most desirable repairs. Consequently, it is often necessary to repair potholes in ways that are less than permanent. General patching should not be done during inclement weather except to correct hazardous conditions. Sound judgment must be exercised when making repairs during poor weather conditions.

Potholes are caused by water penetrating the surface and causing the base and/or subgrade to become wet and unstable. They also may be caused by a surface that is too thin or that lacks sufficient asphalt cement, lacks sufficient base, or has too many or too few fines. Did you and/or your personnel fail to perform maintenance that would have prevented pothole formation? If water is the culprit, it is caused by a cracked surface, high shoulders or greater pavement depressions ponding water on the pavement, porous or open surface, or clogged side ditches or edge drains? Correct the cause of the problem as soon as possible.

To repair potholes in asphalt concrete surface, take the following actions:

- Clean out hole.
- Remove any wet base.
- Square up pothole so that it has neat lines both perpendicular and parallel to the center line and has vertical sides.
- Prime the pothole.
- Fill the pothole with asphalt concrete.

Raveling (Figs. B.17 and B.18). Raveling is caused by a dry brittle surface; dirty, dusty, or soft aggregate; patching beyond base material; lack of compaction of surface during construction; too little asphalt cement in mix; or excessive heating during mixing.

When a small percentage of the pavement is raveling, it can be repaired with a skin patch (this includes edge raveling). When a large percentage of the pavement shows raveling, the pavement should be surface treated or resurfaced.

Channels or rutting (Figs. B.19 and B.20). Channels are caused by heavy loads and high tire pressures, studded tire wear, subgrade settlement caused by saturation, poor construction methods, or asphalt mixtures of inadequate strength. Rutting can also occur due to wear from studded tires operating on bare pavements.

Where the depression is 25 mm (1 inch) or less and the surface is cracked but still largely intact, the area can be skin patched. Where the depression is more than 25 mm (1 inch) and the surface is cracked but still largely intact, an asphalt concrete overlay is recommended.

Where the surface is badly cracked and loose (regardless of amount of depression), remove the old surface. If the area shows signs of mud being pumped to the surface, remove all wet material, replace base material, compact, prime and build up with asphalt concrete.

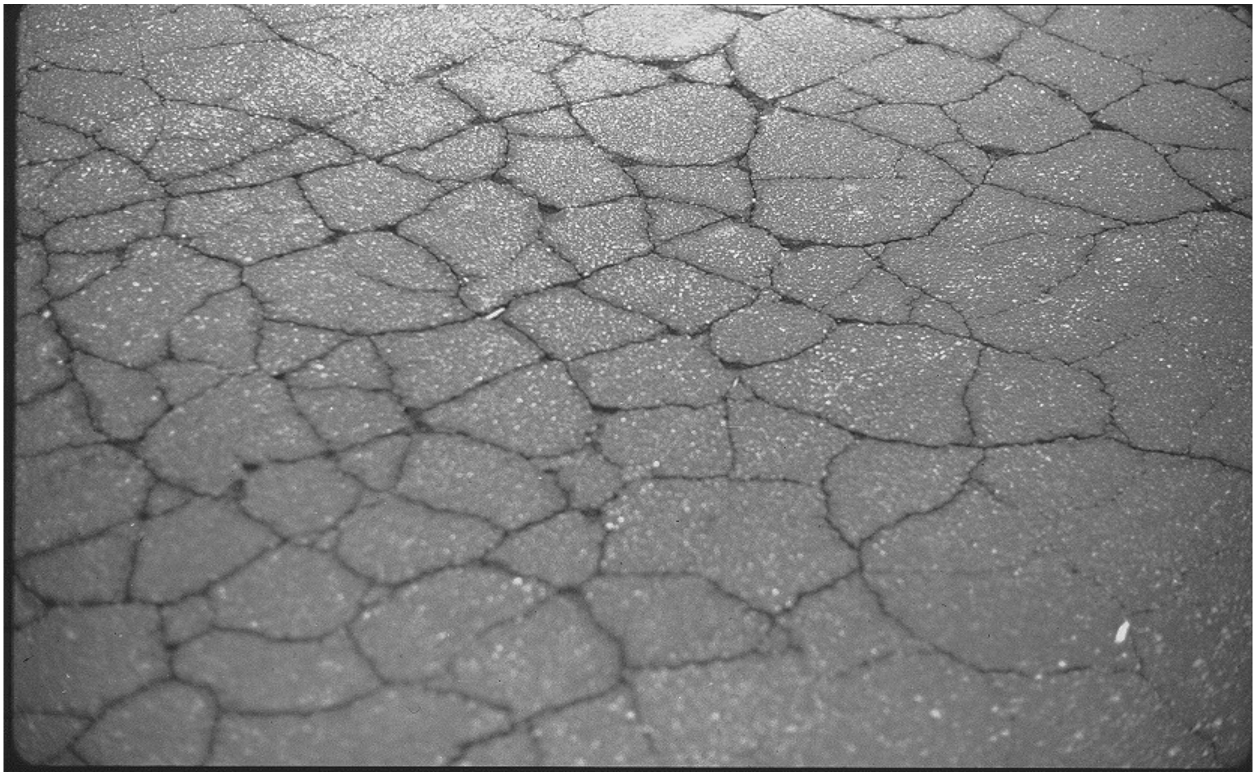

Figure B.13 Shrinkage Cracking

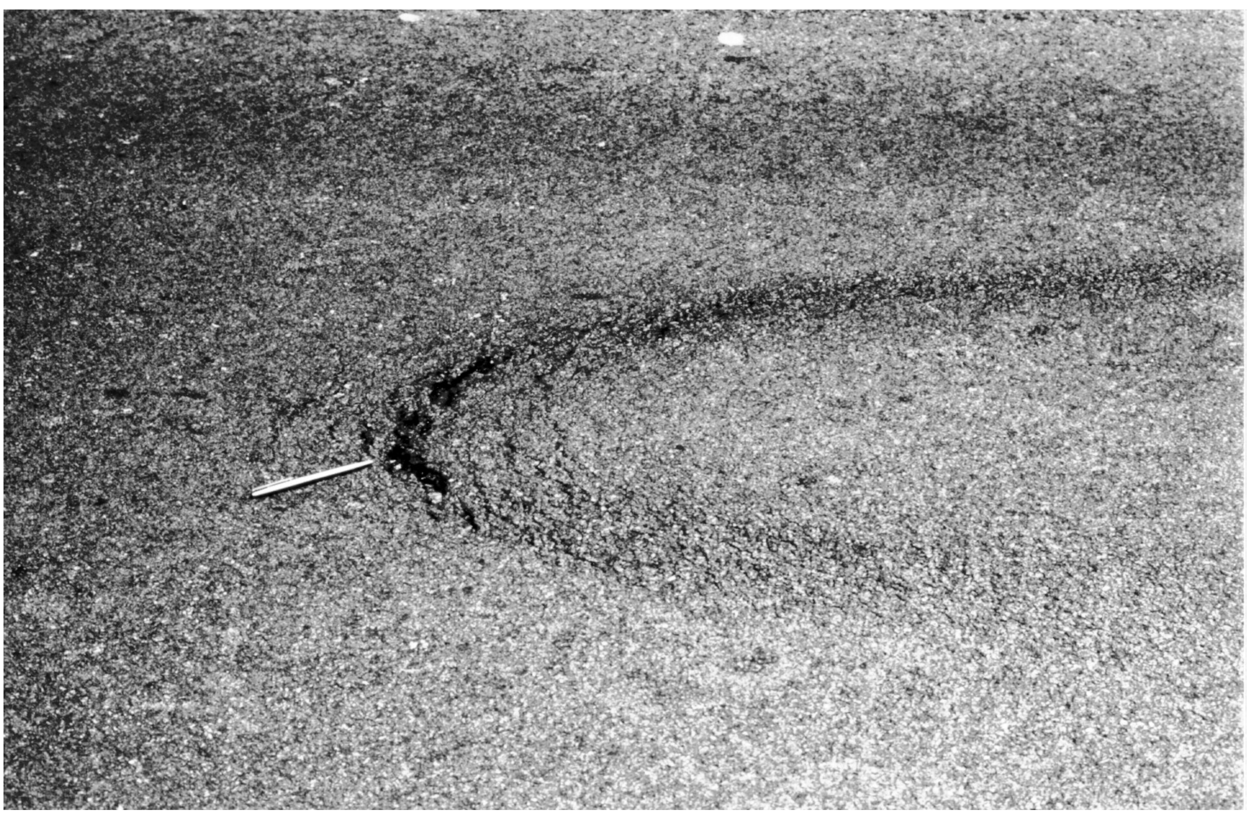

Figure B.14 Slippage Cracking

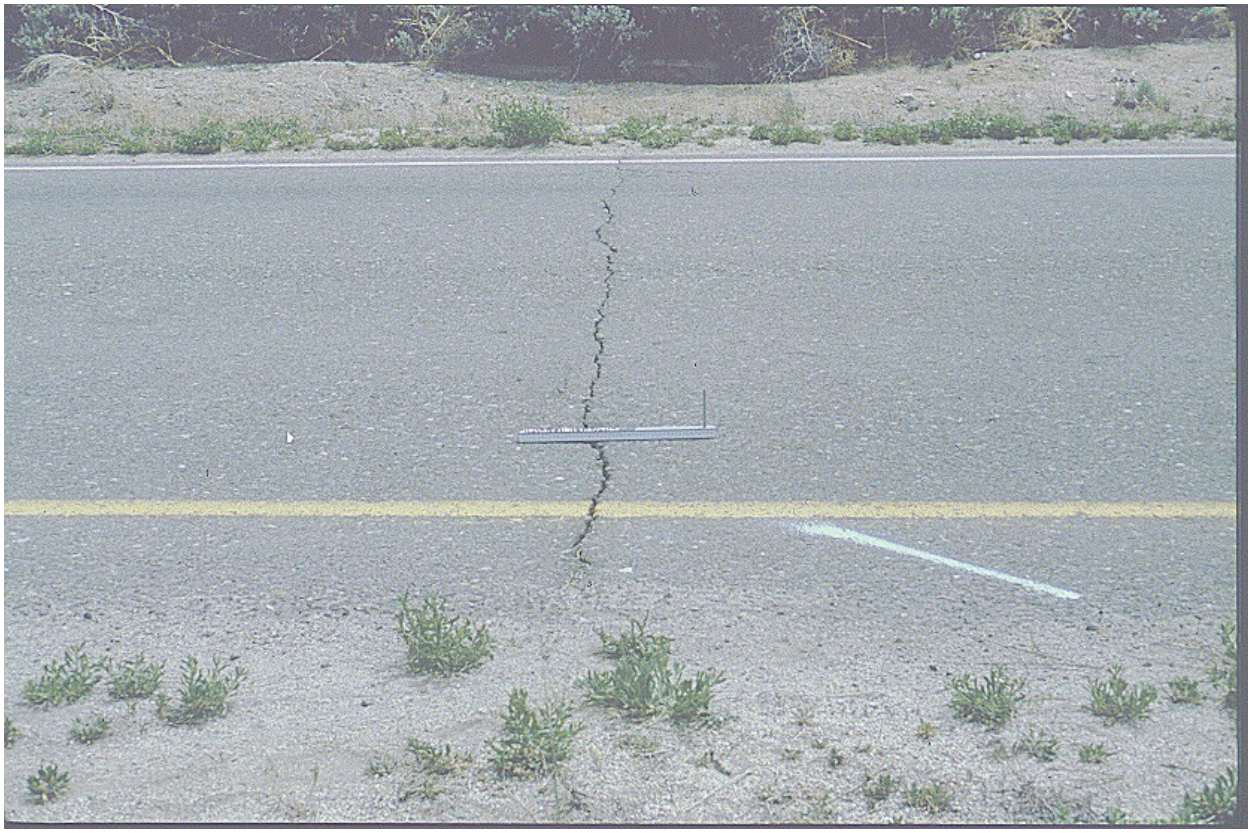

Figure B.15 Transverse Cracking

Figure B.16 Potholes

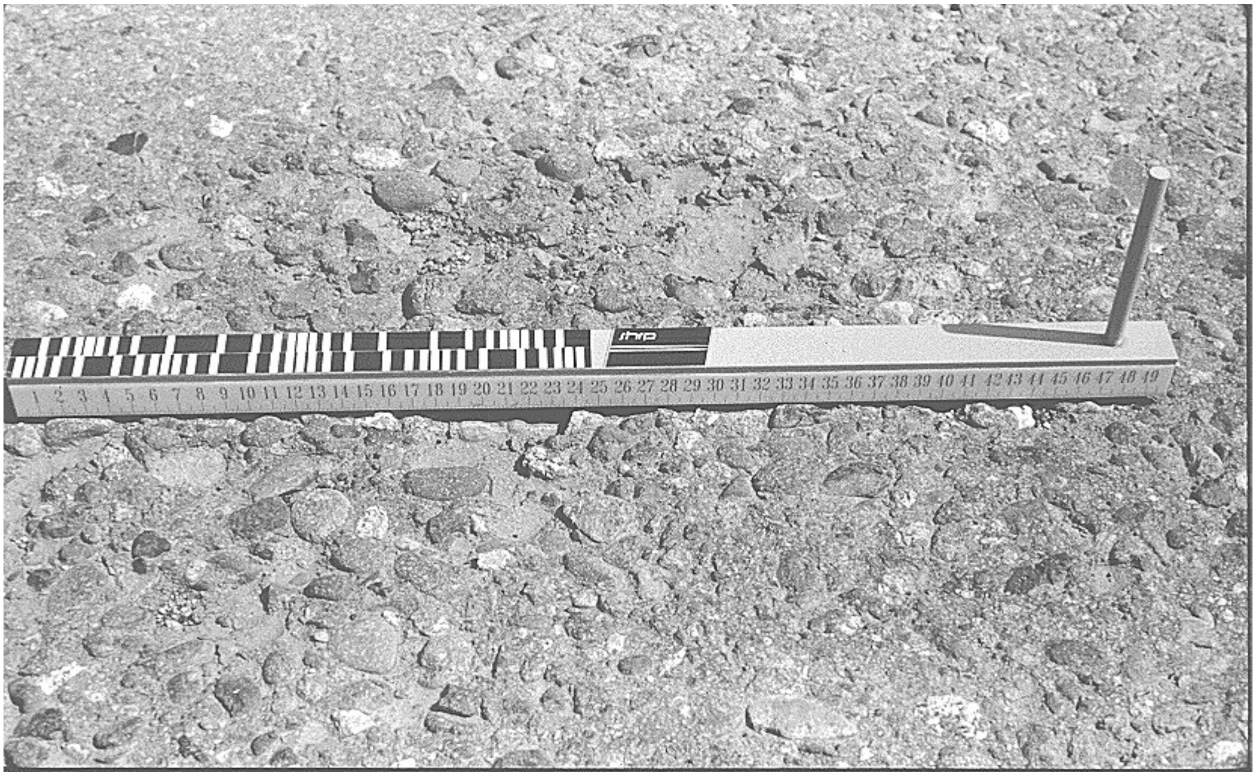

Figure B.17 Raveling

Figure B.18 Disintegrated Surface

Figure B.19 Rutting – Load Associated

Figure B.20 Rutting – Studded Tire Wear

APPENDIX C

OREGON STANDARD SPECIFICATIONS FOR CONSTRUCTION

(c) Fractured Faces - Provide crushed aggregate with not less than the minimum number of fractured faces as determined by AASHTO TP 61 as follows:

	Percent of Fracture (by Weight)	
Type of Mix	**Material Retained on 1 1/2", 1", 3/4", 1/2" and No. 4 Sieve (two fractured faces)**	**Material Retained on No. 8 sieve (one fractured face)**
All Dense Graded MHMAC	75	75

(d) Harmful Substances - Do not exceed the following maximum values:

	Test Method		Aggregates	
Test	**ODOT**	**AASHTO**	**Coarse**	**Fine**
Lightweight pieces		T 113	1.0%	
Wood Particles	TM 225		0.10%	
Elongated Pieces (at a ratio of 5:1)	TM 229		10.0%	
Plasticity Index		T 90		0 or NP
Sand Equivalent		T176		45 min

(e) Coarse Aggregate - Produce coarse aggregate from crushed rock or other inert material of similar characteristics.

(f) Fine Aggregate - Produce fine aggregate from crushed rock or other inert material of similar characteristics.

Blend sand is allowed for Levels 1, 2, and 3 mixes. Do not blend more than 10% by weight of natural or uncrushed blend sand into the total fine aggregate unless approved. Provide a means of verifying and documenting the amount of blend sand added to the aggregate.

(g) RAP Aggregate - Use RAP aggregates in the MHMAC, according to 00744.03, that are no larger than the specified maximum allowable aggregate size before entering the cold feed. Blend the RAP material with new aggregate to provide a mixture conforming to the JMF within the tolerances specified.

00744.11 Asphalt Cement and Additives - Furnish the following:

(a) Asphalt Cement - Use PG 64-22 or PG 70-22 asphalt unless otherwise specified in the Contract documents. Provide asphalt cement conforming to the requirement of ODOT's publication "Standard Specifications for Asphalt Materials". Copies of the publication are available from ODOT's Pavement Services Engineer. The applicable specifications are those contained in the current publication on the date the Project is advertised.

Testing of the asphalt cement used on this Project will be at the discretion and expense of the Agency.

Asphalt in RAP material, when blended with new asphalt shall provide properties similar to the above specified asphalt. When RAP material is used at a rate of less than 15%, no adjustment to the new asphalt will be required. When utilizing RAP at a rate at or above 15%, the combined RAP and new

Section 00744 - Minor Hot Mixed Asphalt Concrete (MHMAC) Pavement

Description

00744.00 Scope - This work consists of constructing minor hot mixed asphalt concrete (MHMAC) pavement to the lines, grades, thicknesses, and cross sections shown or established.

00744.01 Abbreviations:

TSR - Tensile Strength Ratio **VFA** - Voids Filled with Asphalt **VMA** - Voids in Mineral Aggregate

00744.02 Definitions:

Minor Hot Mixed Asphalt Concrete (MHMAC) - A hot plant mixed, uniformly coated mixture of asphalt cement, graded aggregate and additives as required.

Level 1 MHMAC - MHMAC for use in applications with very low traffic and only limited exposure to trucks.

Level 2 MHMAC - MHMAC for use in applications with low traffic volumes and low volume truck traffic.

Level 3 MHMAC - MHMAC for use in applications exposed to moderate truck traffic.

00744.03 Reclaimed Asphalt Pavement (RAP) Material - Reclaimed HMAC pavement (RAP) material used in the production of new MHMAC is optional. No more than 30% RAP material will be allowed in the new MHMAC pavement.

Materials

00744.10 Aggregate - Furnish coarse, fine, and RAP aggregates for MHMAC meeting the following requirements:

Testing of aggregates for soundness, durability, and harmful substances will be at the discretion and expense of the Agency.

(a) Soundness - Provide coarse and fine aggregate with a weighted loss not exceeding 12% when subjected to five cycles of the soundness test using sodium sulfate solution according to AASHTO T 104.

(b) Durability - Provide aggregate not exceeding the following maximum values:

	Test Method		**Aggregates**
Test	**ODOT**	**AASHTO**	**Coarse**
Abrasion		T 96	30.0%
Degradation Passing No. 20 sieve	TM 208		30.0%
Sediment Height	TM 208		3.0"

asphalt shall provide blended properties equivalent to the specified grade. Determine the blended properties according to ASTM D 4887. Determine asphalt cement properties for the RAP material from asphalt cement recovered from the RAP according to AASHTO T 170.

(b) Asphalt Cement Additives - When required by the JMF, add antistripping additives meeting the requirements below and satisfying the Tensile Strength Ratio (TSR) specified in 00744.13.

Additives to prevent stripping or separation of asphalt coatings from aggregates, and admixtures used to aid in the mixing or use of asphalt mixes or for experimental purposes, shall be standard recognized products of known value for the intended purpose and approved for use on the basis of laboratory tests. They shall have no deleterious effect on the asphalt material and be completely miscible. Do not use silicones as an additive.

00744.12 Mix Type and Broadband Limits - Mix type and broadband limits shall meet the following:

(a) Mix Type - Furnish the type(s) of MHMAC shown or as directed. The broadband limits for each of the mix types are specified in (b) below. When the plans allow an option of two types for a course of pavement, use only one type throughout the course.

(b) **Broadband Limits** - Provide a JMF for the specified mix type within the control points listed below:

Sieve Size	**3/4" Dense**		**1/2" Dense**		**3/8" Dense**	
	Control Points (% passing by Weight)		**Control Points (% passing by Weight)**		**Control Points (% passing by Weight)**	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
1"	100					
3/4"	90	100	100			
1/2"		90	90	100	100	
3/8"				90	90	100
No. 4						90
No. 8	23	49	28	58	32	67
No. 200	2.0	8.0	2.0	10.0	2.0	10.0

00744.13 Job Mix Formula (JMF) Requirements - Provide a JMF for the Project meeting the following criteria and that was either developed or verified within three years of the date the Contract was advertised:

	Level 1	**Level 2**	**Level 3**
Design Method	Superpave	Superpave	Superpave
Compaction Level	65 Gyrations	65 Gyrations	80 Gyrations
Air Voids, %	3.5	4.0	4.0
VMA, % minimum	1/2 inch - 14.0 3/8 inch - 15.0	3/4 inch - 13.0 1/2 inch - 14.0 3/8 inch - 15.0	3/4 inch - 13.0 1/2 inch - 14.0 3/8 inch - 15.0
VMA, % maximum	min + 2.0%	min + 2.0%	min + 2.0%
P No. 200 / Eff. AC ratio	0.8 to 1.6	0.8 to 1.6	0.8 to 1.6
TSR, % minimum	80	80	80
VFA, %	70 - 80 3/8 inch: 70 - 80	65 - 78 3/8 inch: 70 - 80	65 - 75 3/8 inch: 70 - 80

The JMF shall have been developed according to the ODOT Contractor Mix Design Guidelines for Asphalt Concrete or verified according to the ODOT Mix Design Verification process. Submit the proposed JMF and supporting data to the Engineer for review at least 10 calendar days before anticipated use. If acceptable, written acceptance will be provided. Perform a new TSR if the source of the asphalt cement changes.

00744.14 Tolerances and Limits - Produce and place MHMAC within the following JMF tolerances and limits:

Gradation Constituent	MHMAC Type 3/4"	1/2"	3/8"
1"	JMF ± 5% *		
3/4"	90 - 100%	JMF ± 5% *	
1/2"	JMF ± 5%	90 - 100%	JMF ± 5% *
3/8"			90 - 100%
No. 4	JMF ± 5%	JMF ± 5%	JMF ± 5%
No. 8	JMF ± 4%	JMF ± 4%	JMF ± 4%
No. 30	JMF ± 4%	JMF ± 4%	JMF ± 4%
No. 200	JMF ± 2.0%	JMF ± 2.0%	JMF ± 2.0%

* Maximum not to exceed 100%

Constituent of Mixture	MHMAC All Types
Asphalt Cement - ODOT TM 321 (Cold Feed/Meter)	JMF ± 0.20% Asphalt Cement -
AASHTO T 308 (Ignition) and ODOT TM 323	JMF ± 0.50% RAP Content - ODOT
TM 321	JMF ± 2.0%
Moisture content at time of discharge from the mixing plant - WAQTC TM 6	0.80% max.

When a JMF tolerance applies to a constituent, full tolerance will be given even if it exceeds the Control Points established in 00744.12(b).

00744.16 MHMAC Acceptance - The mixture will be accepted by visual inspection by the Engineer. If the mixture is considered suspect, the Engineer may verify that the mixture is within tolerances and limits of 00744.14. When requested, obtain samples according to appropriate procedures in the MFTP under the observation of the Engineer at a frequency established by the Engineer. The Engineer will test for gradation, asphalt content, moisture, and RAP content (if applicable) according to procedures specified in 00744.14 and the MFTP. Take corrective action when testing shows that MHMAC is not within the tolerances and limits of 00744.14.

Equipment

00744.24 Compactors - Provide self propelled rollers capable of reversing without backlash as follows:

(a) Steel-Wheeled Rollers - Steel-wheeled rollers shall have:

- A gross static weight of at least 8 ton.

If steel-wheeled rollers are used for finish rolling, they shall have:

- A gross static weight of at least 6 ton.

(b) Vibratory Rollers - Vibratory rollers shall be:

- Equipped with amplitude and frequency controls.
- Specifically designed to compact MHMAC.
- Capable of at least 2,000 vibrations per minute.
- Have a gross static weight of at least 8 ton.

Do not operate in vibratory mode for lifts thinner than two times the maximum aggregate size for the type of MHMAC being compacted.

Labor

00744.30 Quality Control Personnel - Provide certified technicians in the following fields:

- CAgT
- CAT-1
- CDT

Construction

00744.40 Season and Temperature Limitations - Place MHMAC when the temperature of the surface that is to be paved is not less than the temperature indicated:

Nominal Compacted Thickness of Individual Lifts and Courses as shown on the typical section of the plans	**All Levels**	**Level 1 and Level 2**	**Level 3**	
		All Courses	**Travel Lane Wearing Course**	**All Other Courses**
	Surface Temperature*	**From To Inclusive**	**From To Inclusive**	**From To Inclusive**
Dense Graded Mixes				
Less than 2 inches	60 F	All Year**	3/15 9/30	All Year**
2 inches - 2 1/2 inches	50 F	All Year**	3/15 9/30	All Year**
Greater than 2 1/2 inches	40 F	All Year**	3/15 9/30	All Year**
Temporary	40 F	All Year**	All Year**	All Year**

* If placing MHMAC between March 15 and September 30, temperature requirement may be lowered 5 F.

** Do not use field burners or other devices to heat the pavement surface to the specified minimum temperature.

00744.43 MHMAC Mixing Temperatures - Produce MHMAC within the temperature ranges recommended by the asphalt cement supplier for the grade of asphalt being used on the Project.

00744.44 Tack Coat - Construct a tack coat prior to placing each lift of MHMAC according to Section 00730. A tack coat is not required prior to placing MHMAC on aggregate base.

00744.49 Compaction - Immediately after the MHMAC has been spread, struck off, and surface irregularities and other defects remedied, roll it uniformly with rollers meeting the requirements of 00744.24 until compacted as specified.

Perform breakdown and intermediate rolling until the entire surface has been compacted by at least six coverages of the roller (s). Complete breakdown and intermediate compaction before MHMAC temperature drops below 180 F, unless otherwise directed. Perform additional coverages for finish rolling until all roller marks are eliminated.

Maintenance

00744.60 Correction of Defects - Correct all defects in materials and work, as directed, at no additional cost to the Agency, as follows:

(a) Fouled Surfaces - Immediately repair, clean and retack fouled surfaces that would prevent full bond between successive lifts of mixture.

(b) Boils, Slicks, and Oversized Material - Immediately replace boils, slicks, and oversized materials with fresh mixture.

(c) Segregation - Take immediate corrective measures when segregation or non-uniform surface texture is occurring in the finished mat. If segregation continues to occur, stop production until a plan for providing uniform surface texture is approved.

(d) Roller Damage to the Surface - Immediately correct surface damage from rollers with additional fresh mixture or by other means approved.

(e) Longitudinal Joints - Take immediate corrective measures when open longitudinal joints are being constructed or when the elevation of the two sides of a longitudinal joint does not match. If problems with the longitudinal joint continue to occur, stop production until a plan for providing tight, equal elevation longitudinal joints is approved.

(f) Other Defects - Remove and replace any MHMAC that:

- Is loose, broken, or mixed with dirt.
- Shows visually too much or too little asphalt.
- Is defective in any way.

00744.61 Longitudinal Joints - At longitudinal joints, bond, compact and finish the new MHMAC equal to the MHMAC against which it is placed.

(a) Location - Place the MHMAC in panel widths which hold the number of longitudinal joints to a minimum. Offset the longitudinal joints in one panel by at least 6 inches from the longitudinal joints in the panel immediately below.

(1) Base Course - Place base course longitudinal joints within 12 inches of the edge of a lane, or within 12 inches of the center of a lane, except in irregular areas, unless otherwise shown.

(2) Wearing Course - Longitudinal joints shall not occur within the width of a traffic lane. They shall be located at either skip lines or fog lines unless approved. On median lanes and on shoulder areas the joints shall occur only at lane lines or at points of change in the transverse slopes, as shown or directed.

(b) Drop-offs:

- Provide warning signs and markings according to Section 00225 where abrupt or sloped edge drop-offs 1 inch or more in height occur.
- Protect edges from being broken down.

If unable to complete the pavement without drop-offs according to 00744.61(c) do the following:

- Construct and maintain a wedge of MHMAC at a slope of 1V:10H or flatter along the exposed longitudinal joint.
- Remove and dispose of the wedge before continuing paving operations.
- Construct, maintain, remove, and dispose of the temporary wedge at no additional cost to the Agency. MHMAC for the temporary wedge will be paid for at the pay item price.

(c) Placing MHMAC Under Traffic - When placing MHMAC pavement under traffic, schedule work for the nominal thickness being laid as follows:

(1) More Than 2 Inches - Schedule work so at the end of each working shift the full width of the area being paved, including shoulders, is completed to the same elevation with no longitudinal drop-offs.

(2) Less Than or equal to 2 Inches - Schedule work so that at the end of each working shift one panel of new travel lane pavement does not extend beyond the adjoining panel of new travel lane pavement more than the distance normally covered by each shift. At the end of each workweek complete the full width of the area to be paved, including shoulders, to the same elevation with no longitudinal drop-offs.

00744.62 Transverse Joints:

(a) Travel Lanes - Construct transverse joints on the travel lane portion of all specified pavement courses, except leveling courses, as follows:

(1) Temporary End Panel - Maintain pavement depth, line and grade at least 4 feet beyond the selected transverse joint location, and from that point, wedge down on the appropriate slope until the top of the course being laid meets the underlying surface (assuming a pavement course thickness of 2 inches) as follows:

- For wedges that will be under traffic for less than 24 hours, construct a 8 foot long wedge (1V:50H taper rate).
- For wedges that will be under traffic for 24 hours or longer, construct an 25 foot long wedge (1V:160H taper rate).
- Construct, maintain, remove, and dispose of the temporary wedge at no additional cost to the Agency. MHMAC for the temporary wedge will be paid for at the pay item price.

When the pavement course thickness is different than the above 2 inch example, use the appropriate taper rate to compute the length of the wedge. The wedge length plus the 4 feet or longer panel form the "temporary end panel".

(2) Vertical Face - After the mixture has reached the required density:

- Provide a smooth, vertical face the full depth of the course being laid at the location selected for the joint by sawing, cutting or other approved method.
- Remove the MHMAC material from the joint to the end of the panel. If removed before resuming paving beyond the joint, reconstruct the temporary end panel immediately by placing a bond-breaker of paper, dust, or other suitable material against the vertical face and on the surface to be occupied by the temporary end panel. Construct a full-depth panel at least 4 feet long, beginning at the sawed or cut joint, and taper it on a 1V:50H slope to zero thickness.

(3) Excess MHMAC - After completing a temporary end panel as specified, dispose of unused, remaining MHMAC as directed. Payment will be made for the entire load of MHMAC, but will be limited to only one load per joint per panel.

(4) Resume Paving - When permanent paving resumes, remove the temporary end panel and any bond-breakers. Clean the surface of all debris and apply a tack coat to the vertical edge and the surface to be paved.

(5) Joint Requirements - Compact both sides of the joint to the specified density. When tested with a straightedge placed across the joint, the joint surface shall conform to the specified surface tolerances.

(b) Abutting Bridge Ends - Compact the MHMAC abutting bridge ends and other rigid type structures in the transverse and/or diagonal direction, as well as longitudinally, as directed.

(c) Bridge Deck Overlays - Saw cut the wearing course of pavement directly over the joints in bridge decks, bridge end joints and end panel end joints as soon as practical but within 48 hours of paving each stage of the wearing course, unless otherwise directed. The saw cut shall be 3/8 inch wide, 1/8 inch, and 1/2 inch less than the thickness of the panel of pavement, to a maximum depth of 1 1/2 inches.

Flush the saw cut thoroughly with a high-pressure water stream immediately after the cut has been made. Before the cut dries out, blow it free of water and debris with compressed air. Fill the joint with a poured filler from the QPL.

Finishing and Cleaning Up

00744.70 Pavement Smoothness - Furnish a 12 foot straightedge. Test with a 12 foot straightedge parallel to and perpendicular to the centerline, as directed. The pavement surface shall not vary by more than 1/4 inch. Mark areas not meeting the surface tolerance.

00744.75 Correction of Pavement Roughness - Immediately correct equipment or paving operation procedures when tests show the pavement smoothness does not comply with 00744.70. In addition, do the following:

(a) Methods - Correct surface roughness to the required tolerances, using one of the following methods as approved by the Engineer:

- Remove and replace the wearing surface lift.
- Profile to a maximum depth of 0.3 inch with abrasive grinders equipped with a cutting head comprised of multiple diamond blades, and apply an emulsion fog seal as directed.

(b) Time Limit - Complete correction of all surface roughness within 14 calendar days following notification, unless otherwise directed.

Measurement

00744.80 Measurement - The quantities of MHMAC will be measured on the weight basis.

No deductions and no separate measurement will be made for asphalt cement, mineral filler, lime, anti-strip, or any other additive used in the mixture.

No separate measurement will be made for asphalt tack coat. An estimated amount of asphalt in tack coat will be listed in the Special Provisions.

Payment

00744.90 Payment - The accepted quantities of MHMAC incorporated into the project, whether or not recycled materials are used, will be paid for at the Contract unit price, per ton, for the item "Level ___, _____, MHMAC Mixture, ______".

The following will be inserted in the blanks:

- The level(s) of MHMAC (1, 2, 3) will be inserted in the first blank
- The type(s) of MHMAC (3/4 inch Dense, 1/2 inch Dense, 3/8 inch Dense), will be inserted in the second blank
- The words "in Leveling", "in Temporary", or "in Leveling and Temporary" will be inserted in the third blank when applicable

Payment will be payment in full for furnishing and placing all materials, and for furnishing all equipment, labor, and incidentals necessary to complete the work as specified.

No separate or additional payment will be made for the asphalt tack coat.

No separate or additional payment will be made for sawing, cleaning, and filling joints on bridge deck overlays.

The following changes are made to the Project Special Provisions:

1. Subjection **00745.00** Scope—Add the following paragraph to the end of this section :

The Contractor, a their option ,may use Warm Mix Asphalt Concrete (WMAC) as a substitute for HMAC on the wearing course and all base lifts. WMAC will be subject to all requirements for HMAC in Section 00745, except as modified below.

2. Subsection **00745.02** Definitions—This subsection is added after subsection 00745.00

00745.02 Definitions - Add the following paragraph to this section.

Warm Mix Asphalt Concrete (WMAC) - An asphalt concrete mix following all requirements of HMAC, except that through use of approved additives or processes it is mixed, place and compacted at lower temperatures.

Add the following bullet to the definition of Lot size

- A new lot will be established for WMAC technology

3. Subsection **00745.11 (d) WMAC Asphalt Cement Additives**—This subsection is added after subsection 00745.11 (b):

Add the following to the end of this section

(d) WMAC Asphalt Cement Additives –If WMAC is proposed for use in this contract, only warm Mix Asphalt Concrete (WMAC) additives or processes listed on the approved list below shall be used unless otherwise approved by the Engineer.

WMAC Technology	Processing Type	Supplier
LEA-CO	Foaming Process	Advanced Concepts Engineering Co
Eco Foam II	Foaming Process	AESCO /Madsen
Redi-Set WMX	Chemical Additive	Akzo Nobel Sufactants, Inc.
CECABASE RT	Chemical Additive	Arkema Group
Aspha-Min (Synthentic Zeolite)	Foaming Process	Aspha-Min
Double Barrel Green System	Foaming Process	Astec Industries
Green Machine	Foaming Process	Gencor Industries
HGRANT Warm Mix	Foaming Process	Herman Grant Company
Qualitherm	Chemical Additive	Iterchimica
Aquablack Warm Mix Asphalt	Foaming Process	Maxam Equipment Inc.

Low Emission Asphalt	Chemical Additive	McConnaughay Technologies
Evotherm	Chemical Additive	MeadWestVaco Asphalt Innovations
Meeker Warm Mix	Foaming Process	Meeker Equipment Corp.Inc.
Advera (Synthetic Zeolite)	Foaming Process	PQ Corporation
Sasobit	Organic Additive	Sasol Wax Americas, Inc.
Shell Thiopave	Chemical Additive	Shell
Accu-Shear Dual Warm Mix Additive System	Foaming Process	Stainsteel
Tri-Mi WARm Mix Injection	Foaming Process	Tarmac Inc,
Warm Mix Aspahlt System	Foaming Process	Terx Roadbuilding

If WMAC is proposed for use in this contract, the Contractor shall submit the proposed WMAC technology to be used and a plan for its implementation at the pre-Construction conference.

Comply with the manufacturer's recommendations for incorporating additives and WMAC technologies into the mix. Comply with manufacturer's recommendations regarding receiving, storage and delivery of the additives.

4. Subsection 00745.13 Job Mix Formula (JMF) Requirements—This subsection is added after subsection 00745.11 (d) WMAC Asphalt Cement Additives:

00745.13 Job Mix Formula (JMF) Requirements—Add the following after the paragraph ending with "…. JMF requirements of 00745.13 (b) are met."

A separate JMF will be issued for WMAC. If WMAC is used on this contract provide the following information in addition to the requirement listed:

1. WMAC Technology and/or WMAC additives information.
2. WMAC technology manufacturer's established recommendations of usage.
3. WMAC technology manufacture's established target rate for water and/or additives, the acceptable variation for production, and documentation showing the impact of excessive production variation.
4. WMAC technology material safety data sheets (=MSDS) if applicable.
5. Temperature range for mixing
6. Temperature range for compacting.
7. Asphalt binder performance grade test data of the asphalt binder and chemical additive at the manufacturer's recommendation dosage rate.
   (Note: this does not apply to foaming technology)

8. WMAC mixture performance test results per 00745.13 (c). (Note: this testing will be done on production mix for foaming technology on specimens compacted at WMA compaction temperatures)

9. Recycled asphalt shingles cannot be used in WMA mixes with a minimum compaction temperature less than 260 degrees Fahrenheit.

5. Subsection **00745.16 HMAC Production QC/QA**—This subsection is added after subsection 00745.14 Tollerance and Limits:

   00745.16 HMAC Production QC/QA: Replace the subsection title **HMAC & WMAC Production QC/QA**

6. Subsection **00745.16(b-1-a) General**—Replace the first paragraph with the following:

   a. **General**—Prior to beginning production and placement of any EMAC:

      1. Perform MDV tests on HMAC as required at start-up according to 00745.16(b-1-c).

      2. Two consecutive running averages of four MDV test results form testing of HMAC shall be within the limits of 00745.16(b-1-a).

   Perform MDV testing on projects with Level 2, Level 3, or Level 4 dense graded HMAC or WMAC. Perform MDV tests on every sublot and as required at start up according to 00745.16(b-1-c) and the MFTP. Perform gradation and asphalt content testing with each MDV test. Calculate the following values for each MDV test.

7. Subsection **00745.16(b-1-c) MDV Requirements at Start-up**– The paragraph that begins with the words "Perform MDV testing at the start-up…" is replaced with the following:

   Perform MDV testing at the start-up of the HMAC JMF production according to the following process"

8. Subsection **00745.16(b-4) MDV for WMAC**—This subsection is added after subsection **00745.16(b-3) MDV for Open Graded HMAC:**

   00745.16(b-4) MDV for WMAC—Perform MDV testing on WMAC per the requirements of 00745.16(b-1-a). Continued production and placement of WMAC will be allowed at the discretion of the Engineer.

9. Subsection **00745.21 HMAC Mixing Plant**—This subsection is added after subsection **0074516(b-4) MDV for WMAC:**

   00745.21 HMAC Mixing Plant—Add the following to the end of this section:

   (g) WMAC Mixing Production - Modify the asphalt mixing plant as required by the manufacturer to introduce the WMAC technology. Plant modifications may include additional plant instrumentation, the installation of asphalt binder foaming systems and/or WMAC additive delivery systems, tuning the plant burner and adjusting the flights in order to operate at lower production temperatures and/or reduced tonnage. Document the integration of plant controls and interlocks

10. Subsection **00745.43(b) Heating Temperatures**—This subsection is added after subsection **00745.40 Season and Temperature Limitations:**

00745.43(b) Heating Temperatures—Add the following table

WMAC Temperature, ° F

Grading	Minimum Behind Paver
Dense	215

11. Subsection **00745.49(a-1) Temperature**—This subsection is added after subsection **00745.48 Depositing**:

00745.49(a-1) Temperature—Add the following after the first sentence in the first paragraph.

For WMAC, complete breakdown and intermediate compaction before the WMAC temperature drops below 160° F

12. Subsection **00745.49(b-2-b) Core Correlation of Nuclear Gauge Re**adings—This subsection is added after sub-section **00745.49(b-1) General:**

00745.49(b-2-b) Core Correlation of Nuclear Gauge Readings—Replace with the following:

b. Core Correlation of Nuclear Gauge Readings—Perform core correlations of nuclear gauge readings on HMAC wearing course and the WMAC wearing course.

Apply correlation factors to all nuclear gauge readings for all dense graded mixtures placed on the Project. Cut the required cores and patch the core holes with dense graded HMAC or WMAC. Determine the core correlation factor according to WAQTC TM 8 and ODOT TM 327.

New Correlations are required if the aggregate source or the asphalt cement source changes. Perform additional core correlation of Nuclear gauge readings for each lift when requested by the Engineer or Contractor. The party requesting the core correlation pays the costs of coring and lab testing of the cores. The party performing nuclear gauge testing pays the costs of the nuclear gauge testing.

APPENDIX D

GUIDE SPECIFICATIONS FOR NON-PUBLIC WORKS PROJECTS

PREFACE

This appendix provides two examples of guide specifications for asphalt concrete used on non-public works projects. One of the specifications is in a conventional engineering format while the other is in CSI format. Both are available in electronic format from APAO for easy use. Note that the specifications in engineering format include only the asphalt paving layers. Specifications written in CSI format include all pavement layers.

ENGINEERING FORMAT

ASPHALT CONCRETE GUIDE SPECIFICATIONS

1 General

Asphalt concrete shall comply with all of the requirements specified herein.

2 Materials

2.1 General

Only materials conforming to the Specifications shall be incorporated in the work. The materials shall be manufactured, handled and used in a workmanlike manner.

All materials shall comply with the Oregon Standard Specifications for Construction 00745-Hot Mixed Asphalt Concrete (HMAC) and contained in Subsections 00745.10 to 00745.12. The latest version is in Appendix C of this guide.

2.2 Binder

The asphalt binder shall be PG 64-22, PG 64-28, PG 70-22 or PG 70-28 (choose one) as per Section 2.1 of this guide.

2.3 Aggregates

The aggregates used in surface mixes shall be 9.5, 12.5 or 19.0 mm (choose one) as per the specific mix recommendations in Chapters 5.0 and 6.0 of this guide, which meets the gradation given in Section 00745.12.

2.4 Mix Design

The mix design shall conform to the general requirements given in Section 00745 referenced above. Specific guidelines are given in Chapter 2.0 of the APAO guide. A certified laboratory technician should perform the mix design.

2.5 Mixing and Proportioning

Asphalt concrete shall be hot plant mixed and shall be furnished from the plant at a temperature not to exceed 325°F. The mixing temperature shall be selected based on the temperature-viscosity of the binder and be included in the mix design.

2.6 Tack Coat

The tack coat shall conform to Section 00730 - Asphalt Tack Coat of the current Oregon Standard Specifications for Construction.

2.7 Submittals

The Contractor shall furnish the Owner's representative, at least ten (10) working days prior to the start of work, a list of sources of materials together with a Certificate of Compliance indicating that materials to be incorporated in the work fulfill the requirements of these specifications and a mix design for the asphalt concrete. Provide a Certificate of Compliance signed by the material supplier or his representative. It is the intent of these specifications that materials to be incorporated in the work must meet the requirement of these

It is the intent of these specifications that materials to be incorporated in the work must meet the requirement of these specifications after incorporation in the paved area shown on the plans. The Contractor shall be responsible for all costs associated with the required mix design.

Provide delivery tickets for identifying the asphalt mixture type and include plant identification on each delivery ticket. Material delivered to the project without such information on the delivery ticket shall be subject to rejection. No payment or compensation shall be granted for material so rejected.

2.8 Sampling and Testing

The Owner's representative will have the right to obtain samples of all materials to be used in the work and to test such samples for the purpose of verifying the contractor's QC results. Normally the sampling point will be the same as for process control (QC) or the point of manufacture. The Owner shall also have the right to inspect sources of materials to be used in the work to determine workmanlike procedures used by the materials supplier. All sampling and testing will be performed by certified laboratory technicians including those tests performed by or for the owner (QA). Refer to the Oregon Standard Specifications for Construction (Appendix C) for acceptance based on QC results.

3 Construction

3.1 General

Asphalt concrete shall be delivered in a thoroughly blended condition and shall be spread by an asphalt paving machine in such a manner as to avoid segregation during the placing operations. Areas inaccessible to spreading and compaction equipment may be paved by such methods as may be approved by the Owner's representative. All mixtures shall be spread at a temperature not less than 275°F , and not greater than 325°F . Initial rolling shall be performed immediately after placement. Specific compaction temperatures shall be determined using the temperature-viscosity curve of the binder provided in the mix design.

Asphalt concrete should not be placed when the atmospheric temperature is below 50°F and/or raining. However, the temperature may be waived if the guidelines for cold weather construction given in the Oregon Standard Specifications for Construction, Section 00745.40, are used.

3.2 Equipment

3.2.1 Paving Machine

Asphalt pavers shall be mechanical spreading and finishing equipment, provided with a screed or strikeoff assembly capable of distributing the material to not less than eight (8) feet. See Section 00745.23 of the Oregon Standard Specifications for Construction for specific requirements.

3.2.2 Compaction Equipment

The Contractor shall furnish equipment capable of producing the required compaction. Recommendations for the type and size of rollers to be used are given in the Oregon Standard Specifications for Construction, Section 00745.24.

3.2.3 Hand Equipment

Sufficient vibraplates and hand tamper(s) shall be provided to assure their immediate availability when placing asphalt concrete around planters, inside corners or irregular areas. Torches for heating cold joints or making repairs shall be available during every paving operation. Lack of such hand equipment shall be cause to prevent paving from starting or continuing. Hand compaction in such areas shall commence immediately after placement of the mix.

3.3 Tack Coat

Tack coat shall be applied to all vertical surfaces of existing pavement, curbs, gutters, and construction joints, against which additional material is to be placed, to a new or old pavement to be overlaid, and to other surfaces as designated by the Owner's representative. Shields for protecting curb faces shall be provided and used during tacking of curb faces.

If the asphalt cement or emulsion is applied undiluted, it shall be applied at a rate of 0.05 to 0.15 g/yd^2 of emulsion diluted 1:1 with water or as directed by the Owner's representative. Adequate time must be provided for the emulsion to break prior to paving.

4 Workmanship

4.1 Compaction

For normal pavements> 2 inches, asphalt concrete shall be compacted to an average relative density of 91.0 percent of the maximum theoretical unit weight (Rice Gravity) for the first lift or single lifts and 92.0 percent for all other applications. See Oregon Standard Specifications for Construction (Section 00745.49). The theoretical maximum unit weight will be determined from production samples of the asphalt concrete on the project. Tests will be run at random locations to verify compaction. Compaction of the mix will be determined by use of a nuclear density gauge and/or cores.

For thin pavements < 2 inches, compaction to a specified density is not required. Refer to Oregon Standard Specifications for Construction Section 00745.49 for details on compacting thin materials.

The Contractor shall provide sufficient personnel and manual compacting equipment to perform all handwork compaction in unison with the initial compaction rolling. If the handwork compaction begins to lag for whatever reason, the Contractor shall cease paving operations until the handwork compaction is caught up with the rest of the paving operation.

Finish rolling shall be started after the pavement has cooled sufficiently to permit removal of the roller marks and shall be continued in whatever direction is necessary to produce a pavement free of indentations, marks or ridges. Roller marks in the finish lift shall be removed by reheating the pavement with hand torches and rerolling. Roller marks in base lifts are not a problem.

4.2 Thickness

The compacted total thickness of any course, other than leveling courses, shall have an average thickness at least equaling the designated thickness. The minimum thickness at any location shall not be less than the specified thickness minus 1/4 inch.

For pavements over 4 inches, the pavement shall have an average total thickness that equals or exceeds the total specified section thickness. The minimum thickness at any location shall not be less than the specified thickness minus 1/2 inch.

4.3 Finished Surface

The completed surfacing shall be thoroughly compacted, smooth and free from ruts, humps, depressions, irregularities, rock pockets, excessive coarse aggregate and roller marks.

Any ridges, indentations or other objectionable marks left in the surface of the asphalt concrete shall be eliminated by rolling or other means. The use of any equipment that leaves ridges, indentations or other objectionable marks in the asphalt concrete shall be discontinued.

Areas of hand work at joints and miscellaneous structures shall match the smooth surface texture of all other areas of the new pavement. Any areas that have a rough or coarse surface texture shall be reworked with heat and asphalt concrete fines shall be placed immediately after identified. Coarse aggregate removed during raking shall not be returned to the finished mat surface. Cold coarse aggregate shall not be reused, but discarded.

Finished areas of asphalt concrete adjacent to concrete drainage facilities shall be placed in such a manner that the finished surface is no greater than 1/4 inch higher than the facility and no lower than flush with the facility.

When tested with a 10 foot straightedge, the completed surface shall have a maximum variation of ± 1/4 inch for streets and highways. For parking facilities, this requirement may be waived for grade breaks and discontinuities.

CSI FORMAT

SECTION 02742

ASPHALTIC CONCRETE PAVING

PART 1 GENERAL

1.1 SUMMARY

A. Includes But Not Limited To

1. Prepare pavement sub-grade as described in Contract Documents to receive pavement structure (base and paving).
2. Furnish and install pavement base in driveways and parking areas as described in Contract Documents.
3. Furnish and install asphaltic concrete for driveways and parking areas as described in Contract Documents.

B. Related Sections

1. Section 02051 - General Sitework Requirements - CSI specifications

1.2 REFERENCES

A. Oregon Standard Specifications for Construction Section 00745-Hot Mixed Asphalt Concrete (HMAC)

1.3 SUBMITTALS

A. Product Data - Manufacturer's published product data on soil sterilant.

B. HMAC Mix Design.

C. Certificate of Compliance for Aggregate Base

D. Soil Sterilant manufacturer's application instructions.

1.4 QUALITY ASSURANCE

A. Qualifications - Soil sterilants shall be applied by an applicator certified by the State in which project is located.

B. Mix Design shall be produced by Certified Mixture Design Technician in a Certified Laboratory.

1.5 PROJECT/SITE CONDITIONS

A. Environmental Requirements

1. Do not perform work during unfavorable conditions as specified below -
   a. Ambient temperature or temperature of base below 50°F .
   b. Presence of free surface water.
   c. Over-saturated base and sub-grade materials.
2. Variations in temperature requirements are provided in Section 00745.40 of the Oregon Standard Specifications for Construction.

PART 2 PRODUCTS

2.1 MATERIAL

A. Soil Sterilant

1. Selective type pre-emergence control chemical containing 60 percent Trifluralin minimum.

2. Labeled for under pavement use.
3. Acceptable Manufacturers -
   a. Trific 60DF by Terra Industries Inc, Sioux City, IA (712) 277-1340
   b. Equal as approved by Architect before bidding. See Section 01600 (CSI Specifications).

B. Base
1. New Aggregate Base shall conform to Section 02630 for 19.0 mm-0 size aggregate per Oregon Standard Specifications for Construction.
2. New Asphalt Concrete Base shall conform to the 12.5 or the 19.0 mm mixes defined in the Oregon Standard Specifications for Construction in Appendix C of this guide.

C. Prime Coat - Use a MC-70 or RC-250 meeting the requirements of the Oregon Standard Specifications for Construction Section 00705.

D. Tack Coat - Emulsified asphalt meeting requirements of the Oregon Standard Specifications for Construction Section 00730 - Asphalt Tack Coat.

E. Pavement
1. Asphalt Cement -
   a. Meet requirements of ODOT Standard Specifications for Asphalt Materials (see Appendix E).

(Specifier should choose the appropriate asphalt cement based on the considerations outlined in the APAO Asphalt Paving Design Guide, Section 2.1)

2. Aggregates - Conform to Reference A requirements:
   a. Asphalt concrete base courses 2-1/4 inches or thicker shall be 12.5 or 19.0 mm Nominal Size Mixes.
   b. Asphalt concrete surface courses and other courses between 1-1/2 to 2-1/4 inches shall be 12.5 mm Nominal Size Mixes.
   c. Asphalt concrete for thin surface or leveling courses (1-1/2 inches) or skin patching shall be 9.5 mm Nominal Mixes.

(Specifier should choose the appropriate nominal mix size based on the considerations outlined in the APAO Asphalt Paving Design Guide, Section 2.2)

2.2 MIXES

A. Central plant hot mix.

B. Provide Mix Design that conforms to Reference A standards for the appropriate Mix Level 1-4.

(Specifier should choose the appropriate Mix Level based on the considerations outlined in the APAO Asphalt Paving Design Guide, Section 2.5)

A. Survey and stake parking surfaces to show grading required by Contract Documents.

B. Sub-Grade
1. Fine grade parking surface area to grades required by Contract Documents.
2. Scarify, moisture condition to optimum and compact sub-grade to 95% relative compaction of AASHTO T-99 for recreational facilities. AASHTO T-180 should be used for all other applications.

PART 3 EXECUTION

3.1 PREPARATION

A. Survey and stake parking surfaces to show grading required by Contract Documents.

B. Sub-Grade

1. Fine grade parking surface area to grades required by Contract Documents.
2. Scarify, moisture condition to optimum and compact sub-grade to 95% relative compaction of AASHTO T-99 for recreational facilities. AASHTO T-180 should be used for all other applications.

C. Soil Sterilant

1. Apply to prepared subgrade using recommended application rate.
2. Application shall be no more than one day before installation of base.
3. Take necessary precautions to protect adjoining property and areas designated for planting on building site.

3.2 INSTALLATION

A. Site Tolerances

1. Sub-Grade - 0.00 inch high. Measure using string line from curb to curb, gutter, flat drainage structure or grade break.
2. Base -
   a. Base shall have an average thickness equal to or exceeding the design thickness. The minimum thickness shall be 1/2 inch less than the design thickness. Thickness measurements are after compaction.
   b. Measure using stringline from curb to curb, gutter, flat drainage structure or grade break. Variation from grading plane as indicated by string line shall be ± 1/4 inch.
3. Paving -
   a. Apply asphaltic concrete paving in single lift up to 3 inches. Pavement greater than 3 inches should be paved in two or more lifts. The surface lift thickness shall not be less than 1-1/2 inches thick. The average finished total thickness of all lifts of the asphalt concrete surfacing shall be equal to or exceed the design thickness. The minimum total thickness shall be the design thickness minus 1/4 inch for total AC thickness 4 inches or less. The minimum total thickness shall be the design thickness minus 1/2 inch for total pavement thicknesses exceeding 4 inches.
   b. Paving adjacent to cast-in-place concrete site elements shall be between 1/4 inch higher than concrete and flush with concrete.
   c. Surface texture of hand work areas shall match texture of machine-laid areas.

B. Base

1. Grade base to provide uniform surface within tolerances.
2. Compact aggregate base to 95% relative compaction of AASHTO T-180 for all applications.
3. Remove any segregated material.
4. Remove or repair improperly prepared areas as directed by owner’s representative.

C. Asphaltic Concrete Paving

1. Tack coat vertical concrete surfaces that will be in contact with paving.
2. Uniformly mix materials so aggregate is thoroughly coated with asphalt.
3. Place at temperatures between 250° and 325°F with a self-propelled laydown machine.

4. Compaction -

   a. Compact asphaltic concrete paving to 92.0 percent average of Maximum Theoretical Unit Weight (Rice Gravity) of AASHTO T-209. Either cores or nuclear gauges can be used to measure the unit weight of the pavement.

   b. Roll with powered equipment capable of obtaining specified density. See Section 00745.24 of the Oregon Standard Specifications for Construction for specifications on compaction equipment.

   c. Begin breakdown rolling immediately after asphalt is placed when asphalt temperature is at maximum. Complete breakdown rolling before mix temperature drops below 240°F. Complete handwork compaction concurrently with breakdown rolling.

   d. Normally, compaction should be completed as soon as possible after breakdown rolling and before mix temperature drops below 180°F.

e. Execute compaction so visibility of joints is minimized. Complete finish rolling to improve asphalt surface as soon as possible after intermediate rolling and while asphalt paving is still warm.

5. Surface shall be uniform with no ‘birdbaths’ and the finished surfaces clean and smooth. The variation of the surface from along a 10 foot straight edge shall be ± 1/4 inch.

6. Corrections to the surface shall be made by heating the surface of the asphalt concrete with torches or other suitable heating devices, reworking the surface and recompacting the pavement to meet the specifications.

APPENDIX E

STANDARD SPECIFICATIONS FOR ASPAHLT MATERIALS

Oregon Department of Transportation
Standard Specifications For Asphalt Materials
2006

Effective for contracts and purchase orders advertised after January 1, 2006

Revisions – Modified information required on documents to accompany shipments

Deleted optional pH requirement and settlement test for Cationic Emulsified Asphalt Deleted wording under Storage Stability for Polymer-Modified Chip Seal Emulsions Referred to AASHTO R-14 for Hot-Mix Recycling Agents specification

Scope

Materials Covered - These specifications cover asphalt cements, emulsified asphalt, and recycling agents used on highway construction contracts or maintenance purchase orders.

Temperatures

Loading Temperatures - The temperature of the asphalt cement when loaded into tank cars or trucks for shipment shall not exceed the Flash Point specified for the grade.

Documentation

Shipping Document – A Bill of Lading shall accompany each shipment and shall include the following information:

(a) Consignee

(b) Department contract number or purchase order number

(c) Date of Shipment

(d) Type and grade of material

(e) Car initial or number of truck transport

(f) Delivery point or destination

(g) Quantity loaded

(h) Loading temperature

(i) Flash Point and Specific Gravity for PG Grades

(j) Net quantity in Mg (Tons)

(k) Brand, type and amount (% or p.p.m.) of additive such as anti-stripping additive blended with asphalt.

(l) Name and location of the asphalt supplier

(m) Signature of shipper or authorized representative

<u>Additional Information -</u> For CMS-2, CMS-2S and HFMS-2 provide the percent of oil distillate added to the emulsion

<u>Certification of Compliance</u> – A statement certifying that the product in the shipment complies with applicable Oregon DOT specifications shall be on or accompany the bill of lading. The certification shall be signed by an authorized representative of the asphalt supplier.

Acceptance

<u>Acceptance</u> - Asphalt materials will be conditionally accepted for immediate use upon receipt at the point of delivery of a satisfactory certification of compliance and the Materials Safety Data Sheet (MSDS). Final acceptance will be determined by testing at the Department's Central Materials Laboratory of samples obtained at the point of delivery or use on the project site according to the Department's standard procedures for sampling and testing. The Engineer will determine the extent of such additional sampling and testing.

PERFORMANCE GRADED (PG) BINDER

General Requirements: The asphalt cement furnished under this specification shall be petroleum asphalt prepared by the refining of crude petroleum and, when necessary, by the addition of modifiers designed to provide the asphalt characteristics specified. It shall be homogeneous and free from water, and it shall not have been distilled at a temperature high enough to injure by burning or high enough to produce flecks of carbonaceous matter. It shall meet the requirements of Table 1 of AASHTO M320-05, Standard Specification for Performance Graded Asphalt Binder, at the time of use when tested according to the methods specified.

CATIONIC EMUSLIFIED ASPHALT

General Requirement: The Cationic emulsified asphalt furnished under the specification shall be an emulsion of asphalt cement, water and emulsifying agent. The emulsified asphalt shall be homogeneous. It shall show no separation of asphalt after thorough mixing with 30 days after delivery. Ir shall meet the following requirements when tested within 30 days of sampling according to AASHTO Method T 59

GRADE	RAPID SETTING				MEDIUM SETTING						SLOW SETTING			
	CRS-1 [2]		CRS-2 [2]		CMS - 2S		CMS - 2		CMS - 2 h		CSS—1		CSS –1h	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
TEST ON EMULSION:														
Saybolt Viscosity @ 25° C (77° F), SFS											20	100	20	100
Saybolt Viscosity @ 50° C (122° F), SFS	20	100	150*	400	100*	450	100*	450	100	450				
Storage Stability, % (1day)		1		1		1		1		1		1		1
Demulsibility % [1]	40		40											
Coating Ability & water resistance:														
Coating, dry aggregate					Good		Good		Good					
Coating, after spraying					Fair		Fair		Fair					
Coating, wet aggregate					Fair		Fair		Fair					
Coating, after spraying					Fair		Fair		Fair					
Particle charge test	Positive		Positive		Positive		Positive		Positive		Positive		Positive	
Sieve test, % [4]		0.10		0.10		0.10		0.10		0.10		0.10		0.10
Cement mixing test, %												2.0		2.0
Distillation to 260°C (500°F):														
Oil distillate, 5 (by volume of emulsion)		3		3		12[3]		8[3]		8[3]		3[3]		3[3]
Residue, % (by weight)	60		65		60		65		65		57		57	
TESTS ON RESIDUE FROM DISTILLATION:														
Penetration @ 25°C (77°F), 100g, 5s, dmm	100[2]	250[2]	100[2]	250[2]	100	250	100	250	40	90	100	250	40	90
Ductility @ 25°C (77°F), cm	40		40		40		40		40		40		40	
Solubility in Trichloroethylene, %	97.5		97.5		97.5		97.5		97.5		97.5		97.5	

*Modification of AASHTO M 208

[1]The demulsibility test shall be performed within 30 days from shipment.

[2]When CRS-1hh or CRS –2h is specified, the penetration range is changed form 100-250 dmm to 40-90 dmm.

[3]Required under Oregon Administrative Rules, Chapter 340, Division 232-0120—Department of Environmental Quality.

[4]This test requirement on representative samples is waived, if successful application of the material has been achieved in the field. (per AASHTO M-140)

ANIONIC EMULSIFIED ASPHALT

General Requirement: The anionic emulsified asphalt furnished under this specification shall be an emulsion of asphalt cement, water and emulsifying agent. The emulsified asphalt shall be homogeneous. It shall show no separation of asphalt after thorough mixing within 30 days after delivery. It shall meet the following requirements when tested within 30 days of sampling according to AASHTO Method T 59 as modified.

GRADE	HFRS-2		HFMS-2		HFMS-2S	
	Min	Max	Min	Max	Min	Max
TESTS ON EMULSION:						
Saybolt Viscosity @ 25°C , SFS			100		50	
Saybolt Viscosity @ 50°C , SFS	50*	400				
Sieve Test, %		0.10		0.10		0.10
Storage Stability, % (1 day)		1		1		1
Demulsibility, %	30*					
Distillation to 260°C :						
Oil Distillate, % (by volume of emulsion)		7*		7*	1	7
Residue, % (by weight)	63		65		65	
TESTS ON RESIDUE FROM DISTILLATION:						
Penetration @ 25°C , 100g, 5s, dmm	90*	200	100	300*	200	
Ductility @ 25°C , cm	40		40			
Float Test @ 60°C , seconds	1200		1200		1200	

* Modification of AASHTO M 140

POLYMER-MODIFIED ANIONIC EMULSIFIED ASPHALT

General Requirements: This specification has been designed to yield a set of distinguishing characteristics for a polymer-modified emulsion. The binder is not a conventional asphalt cement. The asphalt must be polymerized before emulsification. It shall show no separation of asphalt after thorough mixing within 14 days after delivery. It shall meet the following requirements when tested within 14 days of sampling according to AASHTO Method T 59 as modified.

GRADE	HFMS-2SP	
	Min	Max
TESTS ON EMULSION:		
Saybolt Viscosity @ 50°C , SFS	50	
Sieve Test, %		0.10
Storage Stability: The material after setting undisturbed for 24 hours shall show no white, milky separation, but shall be smooth and homogeneous throughout		
Distillation to 204°C : (1)		
Oil Distillate, % (by volume of emulsion)		7.0
Residue, % (by weight)	65(4)	
TESTS ON RESIDUE FROM DISTILLATION:		
Penetration @ 25°C , 100g, 5s, dmm	300	
Float Test @ 60°C , sec	1200	
Solubility in Trichloroethylene, %	97.5	
Test on Residue from Rolling Thin Film Oven(2): Elastic recovery, % (3)	25	

1)AASHTO T 59 with modifications to include a 204° ± 6°C maximum temperature to be held for 15 minutes.

(2)AASHTO T 240, Rolling Thin Film Oven Test.

(3)ODOT TM 429, Elastic Recovery - method of testing on file at ODOT Materials Laboratory in Salem, Oregon.

(4)The combined percentage of the residue portion and the oil portion from the residue by distillation test shall be 70.0% minimum.

POLYMER-MODIFIED EMULSIFIED ASPHALT FOR CHIP SEALS

General Requirements: This specification has been designed to yield a set of distinguishing characteristics for a polymer-modified emulsion. It is for use in chip seal projects where early chip retention and resistance to chip loss is an important objective. The binder is not a conventional asphalt cement. The asphalt must be polymerized before shipment. It shall show no separation of asphalt after thorough mixing within 14 days after delivery. It shall meet the following requirements when tested within

14 days of sampling according to AASHTO Method T 59 as modified.

GRADE	HFRS-P1		CRS-2P		HFRS-P2		RS-LTP	
	Min	Max	Min	Max	Min	Max	Min	Max
TESTS ON EMULSION:								
Saybolt Viscosity @ 50°C (122°F), SFS	100		100	400	100		100	
Sieve Test, %		0.10		0.10		0.10		0.10
Storage Stability, % (1 day)		1.0		1.0		1.0		1.0
Demulsibility, %	30		40		40		60	
Distillation: Oil distillate, % (by volume of emulsion) Residue, % (by weight)	65(1)	3.0	65(2)	3.0	65(1)	2.0	65(1)	3.0
Breaking Index @ 25°C (77°F) (3)								80
TESTS ON RESIDUE FROM:	**DISTILLATION**						**DISTILLATION**	
Penetration @ 25°C (77°F), 100g, 5s, dmm	90	200	90	200	90	200	150	300
Float Test @ 60°C (140°F) , seconds	1200				1200			
Solubility in Trichloroethylene, % (4)	97.5		97.5		97.5			
Elastic Recovery, % (5) **or**	30		45		58		45	
Torsional Recovery	18(7)		18(6)		18(7)		18(6)	

(1)AASHTO T 59 with modifications to include a 204 ± 5ºC (400 ± 10ºF) maximum temperature to be held for 15 minutes.

(2)AASHTO T 59 with modifications to include 300 grams emulsion and a 177 ± 5ºC (350 ± 10ºF) maximum temperature to be held for 15 minutes.

(3)ODOT TM 431, Breaking Index - method of testing on file at ODOT Materials Laboratory in Salem, Oregon.

(4)AASHTO T 44, Solubility of Bituminous Materials. May be waived if polymer modification interferes with test accuracy. (5)

ODOT TM 429, Elastic Recovery – method of testing on file at ODOT Materials Laboratory in Salem, Oregon.

(6)ODOT TM 428 Method A, Torsional Recovery - method of testing on file at ODOT Materials Laboratory in Salem, Oregon.

(7) ODOT TM 428 Method B, Torsional Recovery - method of testing on file at ODOT Materials Laboratory in Salem, Oregon.

COLD-IN-PLACE RECYCLING AGENTS (1)

General Requirement: The emulsified asphalt furnished under this specification shall be an emulsion of asphalt cement, water and emulsifying agent. The emulsified asphalt shall be homogeneous. It shall show no separation of asphalt after thorough mixing within 30 days after delivery. It shall meet the following requirements when tested within 30 days of sampling according to AASHTO Method T 59 as modified.

GRADE	CMS-2RA		HFMS-2RA	
	Min	Max	Min	Max
TESTS ON EMULSION:				
Saybolt Viscosity @ 50°C , SFS	50	450	50	
Sieve Test, %		0.1		0.1
Storage Stability, % (1 day)		1		1
Distillation to 260°C : Oil distillate, % (by volume of emulsion) Residue, % (by weight)	5 60	15	 65	7
Particle Charge	Positive		Negative	
TESTS ON RESIDUE:				
Penetration @ 25°C , 100g, 5s, dmm	100	250	200	350
Float test @ 60°C , sec			1200	
Solubility in Trichloroethylene, %	97.5		97.5	

(1)Source: Guide Specifications for Partial Depth Cold-In-Place Recycling Agents, Pacific Coast User-Producer Conference, May 1989

HOT-MIX RECYCLING AGENTS

General Requirement: The asphalt cement furnished under this specification shall be petroleum asphalt prepared by the refining of crude petroleum. Recycling Agents RA 1, RA 5, RA 25, RA 75, RA 250 and RA 500 shall meet the requirements of AASHTO R-14 except that Section 5.2 and the note below Table 1 do not apply.

"HOT OIL" CHIP SEAL ASPHALT

The following materials specification is for AC15-5TR, an asphalt product manufactured specifically for use in hot asphalt chip seals. AC15-5TR must contain 5% scrap tire rubber. It has been used by several Oregon counties and for some ODOT maintenance chip seals. Currently, no ODOT specification exists for the construction of hot asphalt chip seals.

AC15-5TR	Test Method	Min	Max
Viscosity @ 60C, P	ODOT TM430	1500	
Kinematic Viscosity @ 135C, cSt	AASHTO T201		2000
Penetration @ 25C, 100g, 5 sec, dmm	AASHTO T49	90	140
Elastic Recovery, %	ODOT TM429	55	
Force Ductility Ratio @ 4C, 5cm/min, cm	ODOT TM 427	0.30	
Cleveland Open Cup Flash Point (C)	AASHTO T48	260	