2016 ASPHALT PAVEMENT DESIGN GUIDE

WAPA

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Foreword

This 2016 Asphalt Pavement Design Guide has been prepared to assist readers in understanding asphalt mix pavement design, construction, and rehabilitation.

Quality asphalt pavement may be constructed in a wide range of soil, weather, and loading conditions. This guide presents examples of designs, procedures, and applications that have been proved successful in the state of Wisconsin. All asphalt mixtures presented in this design guide are proven mixes that are readily available throughout Wisconsin from companies experienced in producing and constructing quality asphalt pavements.

This design guide was developed based on information contained in the Wisconsin Department of Transportation's (WisDOT's) Standard Specifications and is intended for use by architects, engineers, developers, owners, and governmental officials. References to authorities and agencies do not constitute their endorsement of this design guide. If further clarification of the materials presented here is desired, readers are encouraged to contact the appropriate authority, review the references cited, or contact the Wisconsin Asphalt Pavement Association (WAPA, online at **wispave.org**) or a WAPA member in their area.

This design guide has been developed to provide basic information on asphalt pavements so readers can develop an understanding of topics critical in the design and construction of quality asphalt pavements. WAPA cautions that the information contained in this design guide may be insufficient when used alone. This design guide should be used in concert with additional sound and established pavement engineering principles, design guidance, and valid materials and traffic data. Other resource materials and authorities should be consulted when field conditions differ from those given in this design guide.

This design guide presents background information on asphalt pavements and pavement design considerations (Chapters 1 through 5). Thickness design tables (Chapter 6) are presented for a variety of roadway and other uses. Information on pavement management systems (Chapter 7), pavement rehabilitation (Chapter 8), special use asphalt (Chapter 9), and materials requirements (Chapter 10) is also provided.

Our Objectives

WAPA and its members are dedicated to fulfilling the following objectives:

- Cultivation of sound relationships and cooperative effort among members, governmental agencies, and other similar organizations and associations.
- Stimulation of public interest in the durability, sustainability, economic responsibility, safety features, and other benefits gained through the use of asphalt paving materials.
- Advocacy of sound planning in highway construction and maintenance to ensure maximum benefit from the expenditure of public funds.
- Dissemination of information gathered from all available sources, including extensive research, related to the manufacture and use of asphalt paving materials.

The ultimate quality of an asphalt paving project is directly related to the experience, skill, and equipment of the contractor doing the project. This is why WAPA urges consumers to be sure that bidders for their asphalt paving project are properly qualified asphalt pavers.

WAPA takes pride in presenting this 2016 Asphalt Pavement Design Guide and will be happy to provide readers with additional information.

Acknowledgments

This guide builds on the 2001 Asphalt Pavement Design Guide written and developed under the direction of Dr. James Crovetti, Marquette University, Department of Civil and Environmental Engineering.

WAPA Engineering Director Deborah Schwerman provided major updates for this edition of the guide.

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1 Introduction

Asphalt pavements have many advantages over pavement surfaces constructed using other materials. Ninety-four percent of the roads in America are surfaced with asphalt, and it's no surprise why. Asphalt pavements are:

Durable—Asphalt pavements have long lives. All asphalt pavements have a bridging action and are flexible, which means they can withstand occasional overloads without serious damage. Ice- and snow-removal chemicals do not harm them either.

Economical—Asphalt pavements can be designed for a range of intended uses. There's no need to use a predetermined pavement thickness when conditions permit otherwise. Asphalt also permits the use of local materials, which results in cost savings.

Safe—Asphalt pavements offer high skid resistance and provide high contrast and improved visibility for traffic markings. The dark color also reduces glare and melts ice and snow more rapidly than other pavement types. Asphalt pavement materials also eliminate potentially dangerous and expensive pavement blowups.

Constructable—Quality asphalt mix is more easily maintained during construction because the mixture is produced to strict specifications in a central plant and is not altered in transit.

Convenient—Asphalt pavements do not require curing or extensive site preparation. They can be paved just one lane at a time, minimizing disruption to the traveling public and local businesses. Traffic can use the pavement immediately following final rolling, reducing congestion through speedy construction processes and saving taxpayers in user delay costs.

Adaptable—Asphalt pavements can be designed to suit any conditions of traffic, soils, and materials. They need only periodic maintenance to remain in good shape indefinitely.

Smooth—Asphalt pavements provide a more uniform surface and a quiet ride unmatched by other pavements. Smooth asphalt roads also reduce rolling resistance (the friction between tires and pavement), which means better fuel economy and reduced carbon dioxide emissions. Smooth roads allow superior contact with vehicle tires for a safer—and more enjoyable—ride.

Attractive—Asphalt pavements have no built-in, unsightly cracks. They blend with and enhance the natural surroundings.

Recyclable—Asphalt pavements are 100 percent recyclable. Not only can the aggregate be reused, the asphalt cement binder retains its cementing properties. Cold milling, to remove a predetermined depth of asphalt material, will also furnish a ready supply of reclaimed mix for use in hot mix recycling—a process that can be repeated over and over as the need arises in the years ahead.

2 Quality Asphalt Pavements

Quality asphalt pavements are constructed using a designed paving mixture. The required amount of each mixture ingredient is typically established through a recognized mix design procedure as described in Chapter 4. To ensure quality asphalt pavements, a documented mix design report should be provided for each paving project.

Quality asphalt mixtures are produced in a mixing plant under controlled conditions. The mixture is transported, placed, and compacted while still hot. Specially designed paving machines place the mixture to the required thicknesses and grade specifications. After the mixture has been rolled to a desired compaction, it is ready for immediate use with traffic.

There are three main types of asphalt mixtures: traditional hot mix asphalt (HMA), warm mix asphalt (WMA), and stone matrix asphalt (SMA). WMA is a type of asphalt that uses a specific process (chemical or physical) to keep the mixture workable longer while the temperature of the material begins to drop. It can be used to either lower the overall mixture temperature or to aid in compaction during cold weather conditions. The mix design parameters are the same for both HMA and WMA and can be used interchangeably for projects throughout the state of Wisconsin.

SMA is a surface material that is designed for projects exceeding 5 million equivalent single axle loads (ESALs). The gradation is more "gap graded," which allows the mixture to be semiporous and to let water drain across the pavement (which also displaces road noise). The requirements are similar to HMA and WMA, and are found in the WisDOT Standard Specifications.

Please contact a WAPA member or the WAPA office if you would like additional information regarding mixtures produced within the state of Wisconsin.

Quality Management Program

A quality management program (QMP) represents a cooperative effort between the contractor and owner aimed at assuring the construction of quality asphalt pavements. The contractor provides and maintains quality control (QC) testing during the project to ensure continual production of a quality asphalt mixture that meets or exceeds project specifications. The owner provides quality verification (QV) by conducting tests on asphalt mix samples taken at the production plant. Samples are obtained from the truck box by the contractor under the observation of or in a manner approved by the owner. All QMP testing must be conducted by a WisDOT Certified Asphalt Technician (through the Highway Technician Certification Program).

Verification Testing

Verification testing may be requested by the owner to compare the owner's data with the contractor's QC test data. Verification tests may include any or all of the following tests: aggregate gradation, asphalt binder content, bulk specific gravity of compacted mixtures, maximum specific gravity, air voids content, and voids in the mineral aggregate. Verification tests are conducted by the owner on independent samples obtained by the contractor at the requested point during production. The material is considered to be acceptable to WisDOT if it falls within the limits the agency has established. In the event test results are outside established limits, WisDOT's current procedures governing verification testing should be followed.

Asphalt Pavement Structures

Asphalt with Aggregate Bases

Asphalt pavements with aggregate bases are appropriate for use where local aggregates and subsurface drainage conditions are suitable. These pavements are constructed by first placing and compacting an aggregate base on a prepared subgrade. The asphaltic materials are then placed and compacted in layers to complete the pavement structure. The thickness of each compacted layer is based on considerations of layer position and nominal maximum aggregate size (NMAS). Figure 2.1 illustrates the cross section of an asphalt pavement with an aggregate base.

Full-Depth Asphalt

Full-depth asphalt pavements have wide applications, ranging from residential driveways and parking areas to heavy-duty pavements where high volumes of heavy traffic are anticipated, such as Interstate highways and airport runways. A Full-depth asphalt pavement uses asphaltic materials for all layers above the subgrade. The thickness of each compacted layer is based on such considerations as layer position and NMAS. Figure 2.1 illustrates the cross section of a full-depth asphalt pavement.

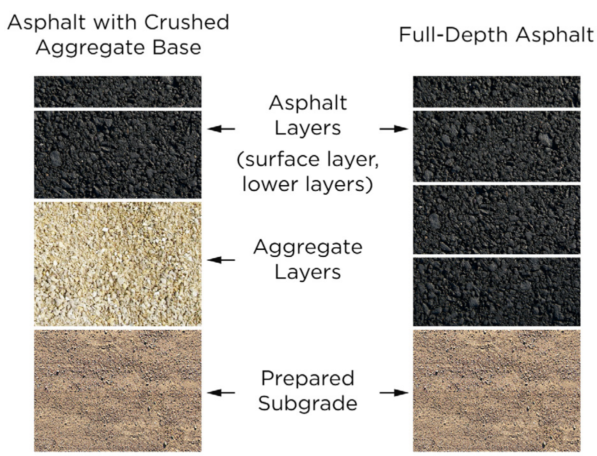


Figure 2.1. Asphalt Pavement Types

Pavement Smoothness

Initial pavement smoothness is a key factor in the performance and economics of a pavement structure.

All other things being equal, the smoother a pavement is built, the smoother it will stay over time. This extends the time it will serve and benefit the traveling public in terms of investment (initial construction and maintenance), vehicular wear costs, comfort, and safety.

Some of the benefits of smooth pavements are:

- Satisfied road users.
- Decrease in fuel consumption and vehicle maintenance costs.
- Longer service life (pavements that are built smoother remain smoother over time).
- Lower dynamic loadings.

International Roughness Index

National and local customer surveys have shown that pavement smoothness is one of the main factors when it comes to rating the nation's highways. State highway agencies recognized in the 1960s the importance of controlling initial pavement smoothness and began developing and implementing smoothness specifications.

Wisconsin uses the International Roughness Index (IRI) to measure pavement smoothness. The lower the calculated IRI, the smoother the pavement ride. The higher the IRI, the rougher the pavement ride.

The ride quality specification for Wisconsin is found in WisDOT Standard Specification, Section 440, "Ride Quality" (**wisconsindot.gov/rdwy/stndspec/ss-04-40.pdf**). This specification applies to final riding surfaces and includes both incentives and disincentives.

The specification is not intended for urban areas, rehabilitation, or maintenance projects. Moreover, projects designed to be short-term fixes may not warrant the additional costs associated with including and administering this item.

3 Materials for Asphalt Pavements

Asphalt Cement Binder

Asphalt cement binder is obtained by distilling crude petroleum using different refining techniques. At ambient air temperatures, asphalt binder is a black, sticky, highly viscous material. It is a strong and durable binder with excellent adhesive and waterproofing characteristics. The largest use of asphalt binder is for asphalt mixture production. Ninety-six percent of the hard-surfaced roads in the United States are paved using asphalt mixtures.

Asphalt binders can be readily liquefied by applying heat, which facilitates mixing with mineral aggregates and recycled materials to produce asphalt mixtures. Asphalt binders are very sticky and readily adhere to the surface of dry aggregate particles, binding them to form asphalt mixtures. After compacting and cooling to air temperature, asphalt mixes are a very strong paving material that can sustain heavy traffic loads.

Emulsified Asphalts

Emulsified asphalts (also called emulsions) are low-viscosity mixtures of tiny asphalt binder droplets, water, and emulsifying agents, as shown in Figure 3.1. The emulsifying agent coats the surfaces of the asphalt binder droplets and keeps them suspended in the water prior to application. After application, the asphalt binder coalesces (breaks) and the water evaporates. Emulsions are brownish in color during application, but after breaking, the coalesced asphalt binder returns to its original black color.

Emulsified asphalts are used for surface treatments, penetration macadams, open-graded cold asphalt/aggregate mixtures, tack coats, fog seals, dense-graded cold asphalt/aggregate mixtures, and slurry seals.

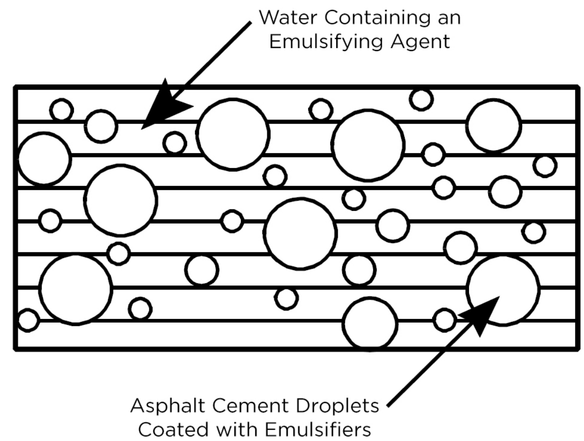


Figure 3.1. Emulsified Asphalt

Cutback Asphalts

Cutback asphalts are low viscosity-mixtures manufactured by diluting (cutting back) asphalt binders with petroleum solvents (cutter stock or diluent). After application, the petroleum solvent evaporates, leaving the asphalt binder residue.

Asphalt Binder Grading

Asphalt cement binders appropriate for pavement construction were previously graded based on resistance to penetration or by viscosity measures. Currently, asphalt binders are graded based on the temperature range over which the binder retains certain desirable characteristics. These desirable characteristics include adequate flexibility to resist cold temperature cracking and sufficient rigidity to resist warm temperature rutting. The current binder grading system is known as the performance grading (PG) system.

Performance Grading

PG specifications were developed as part of the first Strategic Highway Research Program (SHRP). Binders are specified on the basis of the climate and attendant pavement temperatures in which the binder is expected to serve. PG binders appropriate for use in Wisconsin are PG 58-28 binders and sometimes PG 58-34 binder if meeting the project construction criteria and located in the Northern Asphalt Zone of the state. The first number (here, 58) represents the average seven-day maximum pavement design temperature in degrees Celsius. This maximum temperature establishes the upper temperature limit for the binder to retain adequate rigidity to resist rutting. The second number (-28 or -34) represents the minimum pavement design temperature in degrees Celsius. This minimum temperature establishes the lower limit for the binder to retain sufficient flexibility to resist thermal cracking.

Physical properties of the binders are measured at various temperatures both before and after laboratory aging. The laboratory aging is conducted to simulate field conditions imposed during the asphalt production process as well as from long-term environmental exposure. Binder physical properties are measured using four devices:

- Dynamic shear rheometer.
- Rotational viscometer.
- Bending beam rheometer.
- Direct tension tester.

Dynamic Shear Rheometer (DSR)—The DSR is used to characterize the viscoelastic properties of the binder before and after aging. Specifications for test results control binder stiffness at high and intermediate temperatures. High-temperature specifications ensure the binder retains adequate stiffness to contribute significantly to the overall shear strength of an asphaltic mixture. Intermediate-temperature specifications help ensure the binder does not contribute to fatigue cracking of the mixture.

Rotational Viscometer (RV)—The RV is used to determine the viscosity of the original binder at 135°C (275°F). Specifications limit viscosity at 135°C to ensure that the binder can be pumped or otherwise handled during asphalt mixture manufacturing.

Bending Beam Rheometer (BBR)—The BBR is used to characterize the low-temperature properties of binders. Specifications limit the low-temperature stiffness to protect against cracking in cold weather.

Direct Tension Tester (DTT)—The DTT is used to measure the failure strain of binders at low temperatures. As with the BBR, the DTT specifications ensure that the binder's resistance to low-temperature cracking is maximized.

Wisconsin Specifications

Beginning in 2016, Wisconsin started performing a Multiple Stress Creep Recovery (MSCR) test on the asphalt binder that will better predict the level of polymer (if any) needed to provide rut resistance. The following represents the MSCR protocol binder designations:

- S—Standard.
- H—Heavy.
- V—Very heavy.
- E—Extremely heavy (not to be used in the state of Wisconsin).

S Grade—To be used in most situations below 8 million ESALs. This does not require any polymer modification of the asphalt binder.

H Grade—To be used in situations of 8 million to 30 million ESALs or slower-moving traffic at design speeds between 15 to 45 mph. This level of polymer modification should also be considered in areas of increased turning, slowing/stopping, accelerating, or parking movements (such as waysides, roundabouts, intersections, or heavy commercial vehicle parking lots—not passenger vehicle parking lots or park-and-ride facilities).

V Grade—To be used in situations with traffic exceeding 30 million ESALs or with anticipated traffic moving slower than 15 mph on a regular basis (such as daily rush hour).

E Grade—To be used in situations with traffic exceeding 30 million ESALs and standing traffic (such as toll plazas, weigh stations, port facilities, etc.). This level of modification is not applicable at this time in the state of Wisconsin.

In addition, the state of Wisconsin is divided into two zones: the Southern Asphalt Zone and the Northern Asphalt Zone. The zones have separate binder grade recommendations based on project type. These can be found either in the WisDOT Standard Specifications or on WAPA's website (**wispave.org**).

The following binders are recommended for the state:

- **Lower layers**: **58-28 S** (both zones).
- **Overlay projects**: **58-28 S**, **H**, or **V**.*
- **Upper layers**:
  - Southern Asphalt Zone: **58-28 S**, **H**, or **V**.*
  - Northern Asphalt Zone: **58-34**** **S**, **H**, or **V**.*

** V binder designation is to be used on greater than 8 million ESAL projects with slow-moving traffic and SMA projects.*

*** 58-34 is to be used for new construction, reconstruction, and pavement replacement projects (Northern Asphalt Zone upper layer only).*

For additional information and guidance, please refer to WAPA's website under "Wisconsin Asphalt Bid/Mix Specification Tool." See Table 3.1 for comparable mixes for projects under the old and new PG binder systems.

Table 3.1. Comparable Binder Grades	
Old PG Binder Grade	New MSCR Binder Grade
58-34	58-34 S
58-34 P	58-34 H
64-34 P	58-34 V
58-28	58-28 S
64-28 P	58-28 H
70-28 P	58-28 V

Note: These binders are generally comparable, but this table should not be used for like-for-like conversions or for making cost estimates.

Aggregates

Aggregates are any hard, inert materials that are used in graded sizes (fine to coarse). Aggregates are also referred to as rock, gravel, mineral, crushed stone, slag, sand, rock dust, and fly ash. Aggregates may be used alone for base course layers or as a part of the asphalt pavement layers. Several types of aggregate are available as described below. Aggregates, depending on use, have certain desired physical and chemical properties, described later in this chapter.

Natural Aggregates

Natural rocks occur either as outcrops at or near the surface or as gravel deposits, usually along old streambeds. They are classified into three groups—igneous, metamorphic, and sedimentary—based on the way the rocks were geologically formed. Natural aggregates can be pit- or bank-run aggregates or they can be processed aggregates.

Pit- or Bank-Run Aggregates—These include both gravel and sand, which are taken directly from the deposit without processing.

Processed Aggregates—These include pit- or bank-run aggregates and blasted outcrops that have been crushed to make them more suitable for use for HMA pavements. Crushing pit- or bank-run aggregates normally improves the particle shape by making the rounded particles more angular. Crushing can also improve the size distribution and range.

Crushed stone is also a processed aggregate. It is created when fragments of bedrock or large stone are crushed so that all particle faces are fractured. The crushed stone can be sized by screening, and the rock dust, which results from crushing, can be removed by washing.

Recycled Aggregates

Reclaimed asphalt materials (RAM) and concrete pavements both contain valuable aggregates. The aggregate, if of good quality when placed, is most likely still of good quality and can be recycled into asphalt pavement or base course layers. When recycled aggregates are used, it is important that asphalt mixtures containing recycled materials meet all specifications required of an asphalt mixture without recycled materials.

The contractor may use any combination of RAM products including reclaimed asphalt pavements (RAP), fractionated reclaimed asphalt pavements (FRAP), and recycled asphalt shingles (RAS) in the production of asphalt pavements. The stockpiles should be kept separate from one another as well as from virgin materials and should be listed independently on a mix design.

To control the RAM, the contractor must determine the amount of percent binder replacement (the ratio of recovered binder to the total binder) and conform to current WisDOT Standard Specifications. The allowable values are based off combination types and distinguished between upper and lower layers.

Synthetic Aggregates

Aggregates produced by altering both the physical and chemical properties of a material are called synthetic or artificial aggregates. Two examples of synthetic aggregates are lightweight aggregate, which is produced by heating clay to a very high temperature, and slag, which is normally produced in the blast furnace during steel production. Synthetic aggregates are sometimes used in asphalt production.

There are also a host of specialty mixes that contain products like crushed glass, ground tire rubber, different types of fibers, fly ash, and so forth. To learn more about these specialty mixes, please contact WAPA's offices or a local WAPA member.

Aggregates for Base Courses

Aggregates used for base courses are largely obtained from local supplies of processed natural rocks. The properties desired for aggregates used as base courses are given below.

Desirable Properties of Aggregates Used for Base Courses

Desirable properties of aggregates used for a base course are similar to those for asphalt pavements. These properties, as they apply to aggregates for base courses, are briefly discussed in this chapter. See "Aggregates for Asphalt Mixtures" (page 7) for a more complete definition of some of the properties.

Size—The maximum size of an aggregate is the sieve size through which essentially 100 percent of the material will pass. The maximum size is important to ensure good performance. It is also important that the desired gradation be maintained.

Gradation—Aggregate gradation describes the distribution of aggregate particle sizes. Proper gradation is important for stability, workability, and permeability. It is also desirable to have a base course that will not retain moisture or become unstable when wet. Crushed aggregate base course master gradation bands have been established by WisDOT for both crushed gravels and crushed stones, as shown in Table 3.2.

Cleanliness/Deleterious Materials—Cleanliness refers to the absence of certain foreign or deleterious materials which, when present, make the aggregate undesirable for use as a base course. Base course aggregates should be substantially free from vegetable matter, shale, and lumps or balls of clay.

Toughness/Hardness—Aggregates are subject to crushing and abrasive wear during manufacturing, placement, and compaction. Thus they must be hard and tough to resist crushing, degradation, and disintegration when stockpiled, placed, compacted with rollers, or traveled over with trucks.

Durability/Soundness—Aggregates must be resistant to breakdown or disintegration under action of wetting and drying as well as freezing and thawing.

Surface Texture—A rough, sandpaper-like surface texture, such as that found on the exposed faces of most crushed aggregates, tends to increase strength and stability.

Particle Shape—Aggregates that are cubical and angular will provide the greatest mechanical stability.

Gradation

WisDOT Standard Specifications, Section 305, "Dense Graded Base" (**wisconsindot.gov/rdwy/stndspec/ss-03-05.pdf**), describes the construction of a dense-graded base using crushed stone, RAP, crushed gravel, reprocessed material, crushed concrete, or blended material.

Subsection 305.2.2, "Gradations," includes the guidance presented in Table 3.2. (Note: This guidance should be followed except when using RAP; in that case, refer to Subsection 305.2.2.2, "Reclaimed Asphaltic Pavement.")

Table 3.2. Base Course Aggregate: Gradation Requirements

Sieve	Percent Passing by Weight		
	3 Inch	1¼ Inch	¾ Inch
3 inch	90 - 100	—	—
1½ inch	60 - 85	—	—
1¼ inch	—	95 - 100	—
1 inch	—	—	100
¾ inch	40 - 65	70 - 93	95 - 100
⅜ inch	—	42 - 80	50 - 90
No. 4	15 - 40	25 - 63	35 - 70
No. 10	10 - 30	16 - 48	15 - 55
No. 40	5 - 20	8 - 28	10 - 35
No. 200	2.0 - 12.0	2.0 - 12.0 [1, 3]	5.0 - 1.50 [2]

[1] Limited to a maximum of 8.0 percent for base placed between old and new pavement.
[2] 8.0 - 15.0 percent if base is ≥ 50 percent crushed gravel.
[3] 4.0 - 10.0 percent if base is ≥ 50 percent crushed gravel.

Unless the plans or special provisions specify otherwise, the following guidelines apply to base selection:

- Use 1¼-inch base in top 4 or more inches of base. Use 3-inch base or 1¼-inch base in the lower base layers.
- Use ¾-inch base in the top 3 inches of the unpaved portion of the shoulder. Also, if using 3-inch base in the lower base layers, use ¾-inch base in the top 3 inches of the shoulder foreslopes. Use ¾-inch base or 1¼-inch base elsewhere in shoulders.

Aggregates for Asphalt Mixtures

Aggregates used in asphalt mixes are largely obtained from local supplies of natural rock, RAM, and concrete pavements. Other types of aggregate that are sometimes used in asphalt mixes are lightweight aggregates or slag, which are termed synthetic aggregates. The desired properties for aggregates to be used in asphalt mixes follow.

Typically, two or more aggregates are blended together to achieve all of the desirable properties listed below. The blended aggregates represent about 90 percent to 96 percent of the weight and about 65 percent to 85 percent of the volume of a compacted asphalt pavement layer.

Desirable Properties of Aggregates for Asphalt Pavements

Selection of an aggregate for use in asphalt pavements depends on the quality of the material, the type of pavement for which it is intended, availability, and cost. The following properties should be evaluated to determine the suitability of an aggregate for use in asphalt pavements:

Size—The maximum size of an aggregate is the sieve size through which essentially 100 percent of the material will pass. NMAS represents the smallest sieve size for which at least 90 percent of the material will pass. Aggregate size in a mixture is important to ensure good performance. If the nominal size is too small, the mix may be unstable; if it is too large, workability and segregation may be a problem.

Gradation—Aggregate gradation describes the distribution of aggregate particle sizes. Gradation affects all the important properties of an asphalt mixture, including stiffness, stability, durability, permeability, workability, fatigue resistance, skid resistance, and resistance to moisture damage. Aggregate master gradation bands have been established by WisDOT for asphalt upper and lower pavement layers. These are shown in Table 3.3, based on WisDOT Standard Specifications, Section 460, "Hot Mix Asphalt Pavement" (**wisconsindot.gov/rdwy/stndspec/ss-04-60.pdf**). Further guidance on the selection of a master gradation band best-suited to each project is provided in Chapter 4.

Cleanliness/Deleterious Materials—Cleanliness refers to absence of certain foreign or deleterious materials which, when present, make aggregates undesirable for asphalt mixtures. Washing dirty aggregate can usually reduce the amount of undesirable materials to an acceptable level. Typical objectionable materials include vegetation, shale, soft particles, clay lumps, clay coating on aggregate particles, and sometimes excess dust from the crushing operation.

Toughness/Hardness—Aggregates are subject to crushing and abrasive wear during the manufacturing, placement, and compaction of asphalt mixtures. They must be hard and tough to resist crushing, degradation, and disintegration when stockpiled, fed through an asphalt production facility, placed with paver, compacted with rollers, or traveled over with trucks.

Durability/Soundness—Aggregates must be resistant to breakdown or disintegration under the action of wetting and drying as well as freezing and thawing (weathering).

Surface Texture—A rough, sandpaper-like surface texture, such as that found on the exposed faces of most crushed stones, tends to promote the mechanical bond between the asphalt binder and the aggregate, and increases stability.

Particle Shape—Aggregate particles suitable for use in asphalt mixtures should be cubical rather than flat, thin, or elongated. In compacted asphalt mixes, angular-shaped particles exhibit greater interlock and internal friction, and, hence, result in greater mechanical stability than rounded particles.

Absorption—The porosity of an aggregate permits the aggregate to absorb asphalt binder, forming a bond between the particle and the asphalt. Some porosity is desired, but aggregates that are highly absorbent are generally not used since they would require a high amount of asphalt binder.

Affinity for Asphalt—Asphalt binder must wet the aggregate surface, stick to the aggregate, and resist stripping (separation of asphalt binder from the aggregate surface) in the presence of water. Dust coatings on aggregates can cause poor bonding of asphalt binder.

Table 3.3. Asphalt Mixture Aggregate Gradation Ranges

Sieve	Percents Passing Designated Sieves (Nominal Size)							
	37.5 mm (#1)	25.0 mm (#2)	19.0 mm (#3)	12.5 mm (#4)	9.5 mm (#5)	4.75 mm (#6)	SMA 12.5 mm (#4)	SMA 9.5 mm (#5)
50.0 mm	100							
37.5 mm	90 - 100	100						
25.0 mm	90 max	90 - 100	100					
19.0 mm	–	90 max	90 - 100	100			100	
12.5 mm	–	–	90 max	90 - 100	100		90 - 97	100
9.5 mm	–	–	–	90 max	90 - 100	100	58 - 72	90 - 100
4.75 mm	–	–	–	–	90 max	90 - 100	25 - 35	35 - 45
2.36 mm	15 - 41	19 - 45	23 - 49	28 - 58	32 - 67	85 max	15 - 25	18 - 28
75 µm	0 - 6.0	1.0 - 7.0	2.0 - 8.0	2.0 - 10.0	2.0 - 10.0	5.0 - 13.0	8.0 - 12.0	10.0 - 14.0
% Minimum Void in the Mineral Aggregate	11.0	12.0	13.0	14.0 [1]	15.0 [2]	16.0	16.0	17.0

[1] 14.5 for low traffic (LT) and medium traffic (MT) mixes. (See Table 4.1.)
[2] 15.5 for LT and MT mixes. (See Table 4.1.)

4 Asphalt Mix Design

What is an Asphalt Mix Design?

An asphalt mix design involves a series of laboratory tests that are performed on a particular set of HMA ingredients to determine whether, and in what proportions, these ingredients can be combined to meet project specifications. The Superpave—SUperior PERforming asphalt PAVEments—method of mix design is the procedure currently used in Wisconsin.

The Superpave method of mix design was developed to provide a national standard for asphalt pavements. Furthermore, the Superpave mix design method better simulates expected traffic loads during the mix design process and therefore produces pavement designs that perform better under actual traffic loadings.

The gyratory compactor is a piece of standardized equipment used to compact asphalt samples during the Superpave mix design method. This equipment is used to determine the proper blends of aggregates and binder to complete an asphalt mix design appropriate for expected traffic.

Special use asphalt mixes may also be designed to meet specific project requirements, such as high density, high flexibility, low permeability, or high skid resistance.

Properties Considered in Mix Design

Quality asphalt pavements can be achieved when they are properly designed, produced, placed, and compacted. Such steps ensure that desirable mix properties are in place after construction.

These desirable properties are:

- Durability.
- Stability.
- Impermeability.
- Workability.
- Flexibility.
- Fatigue resistance.
- Skid resistance.

Durability—Durability of an asphalt pavement includes its ability to resist factors such as oxidation of the asphalt cement, disintegration of the aggregate, and stripping of the asphalt cement from the surface of the aggregate. Such deterioration can result from weather conditions, traffic loadings, aggregate quality, or some combination of these.

Typically a durable mixture can be achieved by using the optimum asphalt cement content; using well-graded, quality aggregates; and compacting the designed mixture to the recommended density, which minimizes in-place permeability.

Stability—Stability of an asphalt pavement includes its ability to resist shoving and rutting under repeated traffic loadings. Stable asphalt pavements maintain their shape and smoothness, while unstable pavements deform under repeated loadings and may develop ruts, ripples, or other signs of pavement movement.

The stability of an asphalt pavement is related to the internal friction and cohesion of the mix.

Internal friction is directly related to the angularity and roughness of the aggregates. In compacted mixes, angular aggregates exhibit greater interlock and internal friction, resulting in greater mechanical stability. Rough, sandpaper-like aggregate surfaces, such as those found on the exposed faces of most crushed stones, also tend to increase stability.

Internal cohesion is related to the thickness of the asphalt films coating the aggregates. Cohesion increases to a point with an increase in the asphalt cement content.

Impermeability—Impermeability is the resistance of the asphalt pavement to the passage of air and water into and through it. Impermeability is related to both the quantity and arrangement of the air voids in the mix. Asphalt pavements with numerous interconnected voids that connect to the pavement surface have low impermeability.

Workability—Workability is the property of the asphalt that describes the ease with which it can be placed and compacted. A mix with good workability requires less compactive effort to obtain the required in-place density.

Flexibility—Flexibility is the ability of the asphalt pavement to adjust to gradual settlements and movements in the subgrade without cracking. This is a desirable characteristic since almost all subgrades will settle when subject to loading. Subgrade may also rise due to expansive-type soils. Generally, flexibility of an asphalt paving mixture is improved by using a high asphalt content and relatively open-graded aggregates.

Fatigue Resistance—Fatigue resistance is the ability of the asphalt pavement to withstand repeated bending without cracking when subjected to wheel loads. The fatigue resistance is affected by the asphalt binder content, air void content, asphalt aging, load magnitude, pavement thickness, pavement strength, and the support provided by underlying layers.

Skid Resistance—Skid resistance is the ability of the pavement to minimize the skidding or slipping of the tires of vehicles on the surface. This is of particular importance when the pavement surface is wet. Selecting an aggregate with a rough surface texture and using the proper asphalt content can improve the skid resistance. Hydroplaning can be reduced by proper surface drainage and by providing a durable friction course.

WisDOT Asphalt Pavement Types

Quality asphalt pavements must be designed and constructed to withstand a wide variety of traffic and environmental loadings. Pavements that are to be subjected to repeated, heavy truck loadings must be designed with a maximum internal stability to provide adequate resistance to rutting. By contrast, pavements that are expected to receive few, if any, heavy loadings, should be designed for maximum durability to resist the disintegrating effects of the climate.

It is imperative that the selection of mixture type be matched to the expected loadings to ensure the best pavement performance over its design life. In other words, do not select an asphalt mixture type designed for high traffic loadings if your pavement is expected to receive only low traffic, and vice versa.

In 2000, WisDOT began requiring all mixes to be designed by the Superpave method. WisDOT's Superpave specifications included charts that list traffic volumes and appropriate mix selections that are suitable for use when a detailed traffic analysis is performed. In this system, each mix designation began with the letter E, such as "E-3."

As discussed in Chapter 3, WisDOT updated its Superpave mix design specifications in 2015. Four mix type classifications—low traffic (LT), medium traffic (MT), high traffic (HT), and SMA—with a cross-reference to the older system of "E" mixes, are shown in Table 4.1. For details on how to use the new specifications, please refer to WAPA's website (**wispave.org/wisconsin-asphalt-bid-mix-specification-tool**).

Table 4.1. WisDOT Asphalt Pavement Classification by Traffic Level (20-year ESAL)

Current (New) Classification	ESAL Level	Former Classification: "E" Mixes	ESAL Level
LT	Low traffic < 2 million	E-0.3	< 300,000
		E-1	300,000 to < 1 million
MT	Medium traffic 2 - 8 million	E-3	1 million to < 3 million
		E-10	3 million to < 10 million
HT	High traffic > 8 million	E-30	10 million to < 30 million
		E-30X	≥ 30 million
SMA	Consider for ≥ 5 million	SMA	–

Aggregates for Asphalt Layers

Aggregates used for asphalt mixtures should be hard, durable particles of crushed gravel, crushed stone, manufactured sand, natural sand, mineral filler, or a combination of these. The desirable gradation of the aggregates in recycled asphaltic materials is based on the nominal size of the aggregate. Master gradation ranges for aggregates used in asphalt mixtures are specified by WisDOT as shown in Table 3.3.

Asphalt Layer Thickness

To ensure proper compaction of individual asphalt layers, the minimum and maximum layer thickness for Superpave mixes are specified by WisDOT based on nominal aggregate size, as shown in Table 4.2. These values appear in WisDOT Standard Specifications, Section 460, "Hot Mix Asphalt Pavement" (**wisconsindot.gov/rdwy/stndspec/ss-04-60.pdf**).

Table 4.2. WisDOT Thickness Specifications for Individual Asphalt Layers

Nominal Size (mm)	Minimum Layer Thickness (inches)	Maximum Layer Thickness (inches)		
		Lower Layer [1]	Upper Layer [2]	Single Layer [3]
37.5 (#1)	3.5	5	4.5	6
25.0 (#2)	3.25	5	3	6
19.0 (#3)	2.25	4	3	5
12.5 (#4) [4]	1.75	3 [5]	2.5	4
9.5 (#5) [4]	1.5	3 [5]	2	3

[1] The most common gradations for lower layers are 25.0 mm (#2), 19.0 mm (#3), and 12.5 mm (#4).
[2] The most appropriate gradations for upper layers are 12.5 mm (#4), 9.5 mm (#5), and 4.75 mm (#6).
[3] For use on crossovers and shoulders.
[4] SMA mixtures use nominal size 12.5 mm (#4) or 9.5 mm (#5).
[5] SMA mixtures with nominal sizes of 12.5 mm (#4) and 9.5 mm (#5) have no maximum lower layer thickness specified.

Job Mix Formula

The Job Mix Formula (JMF) is the standard to which a produced asphalt mixture is compared during the QMP. The JMF identifies the selected aggregate gradation, the design binder content, and gyratory test results for the compacted asphalt mixture, including the air voids content and the percent void in the mineral aggregate (VMA). Since it is not practical to meet the exact JMF values throughout production, appropriate tolerances must be established based on the number of tests performed and the probable error in each test. The current WisDOT QMP specifications should be consulted for guidance on establishing appropriate tolerances.

WisDOT Asphalt Design Specifications

WisDOT design specifications for compacted asphalt pavements are based on the selected asphalt mixture type and aggregate gradation.

Aggregate Gradation is shown in Table 3.3.

Minimum VMA is also shown in Table 3.3 in the bottom row.

Mixture Requirements are shown in Table 4.3. These are consistent with WisDOT's current Standardized Special Provisions and will appear as Table 460-2 in WisDOT's 2017 Standard Specifications.

Table 4.3. Asphalt Mixture Requirements

Test or Parameter	Mixture Type			
	LT	MT	HT	SMA
ESALs x 10^6 (20-year design life)	< 2	2 to < 8	> 8	> 5
LA wear (AASHTO T96) • 100 revolutions (max % loss) • 500 revolutions (max % loss)	 13 50	 13 45	 13 45	 13 40
Soundness (AASHTO T104) (sodium sulfate, max % loss)	12	12	12	12
Freeze/thaw (AASHTO T103) (specified counties, max % loss)	18	18	18	18
Fractured faces (ASTM 5821) (1 face/2 faces, % by count)	65 / —	75 / 60	98 / 90	100 / 90
Flat and elongated (ASTM D4791) (max %, by weight)	5 (5:1 ratio)	5 (5:1 ratio)	5 (5:1 ratio)	20 (3:1 ratio)
Fine aggregate angularity (AASHTO T304, method A) (min)	40	43	45	45
Sand equivalency (AASHTO T176) (min)	40	40	45	50
Gyratory compaction • Gyrations for N_{ini} • Gyrations for N_{des} • Gyrations for N_{max}	 6 40 60	 7 75 115	 8 100 160	 8 65 160
Air voids, $\%V_a$ ($\% G_{mm} N_{des}$)	4.0 (96.0)	4.0 (96.0)	4.0 (96.0)	4.0 (96.0)
$\% G_{mm} N_{ini}$	≤ 91.5 [1]	≤ 89.0 [1]	≤ 89.0	—
$\% G_{mm} N_{max}$	≤ 98.0	≤ 98.0	≤ 98.0	—
Dust to binder ratio [2] (% passing $0.075/P_{be}$)	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	1.2 - 2.0
Voids filled with binder (VFB, %) (same as VFA, voids filled with asphalt)	60 - 80 [4, 5]	65 - 75 [3, 4]	65 - 75 [3, 4]	70 - 80
Tensile strength ratio (TSR) (ASTM 4867) • No antistripping additive • With antistripping additive	 0.75 0.80	 0.75 0.80	 0.75 0.80	 0.75 0.80
Draindown at production temperature (%)	—	—	—	0.30

[1] The percent maximum density at initial compaction is only a guideline.
[2] For a gradation that passes below the boundaries of the caution zone (refer to AASHTO MP3), the dust to binder ratio limits are 0.6 to 1.6.
[3] For #5 (9.5 mm) and #4 (12.5 mm) nominal maximum size mixes, the specified VFB range is 70 to 76 percent.
[4] For #2 (25.0 mm) nominal maximum size mixes, the specified VFB lower limit is 67 percent.
[5] For #1 (37.5 mm) nominal maximum size mixes, the specified VFB lower limit is 67 percent.

Asphalt Compaction

Compaction of an asphalt mixture is performed to seal the surface against the penetration of water and air, and to maximize the stability of the mix. Permeability will be decreased for mixtures constructed with smaller NMAS (commonly overlays), even for mixtures with higher percentage air voids. This will improve the performance of an overlay by reducing the amount of access that air and water have to the mixture.

WisDOT's compaction requirements are expressed in terms of minimum density and appear in Table 460-3 of

WisDOT's Standard Specifications (**wisconsindot.gov/rdwy/stndspec/ss-04-60.pdf**). The 2017 specifications with the new mixture classifications (LT, MT, and HT) are presented in Table 4.4 below.

Table 4.4. Minimum Required Density [1]

Location	Layer	Percent of Target Maximum Density		
		Mixture Type		
		LT and MT	HT	SMA [5]
Traffic lanes [2]	Lower	91.5 [3]	92.0 [4]	–
	Upper	91.5	92.0	–
Side roads, cross-overs, turn lanes, and ramps	Lower	91.5 [3]	92.0 [4]	–
	Upper	91.5	92.0	–
Shoulders and appurtenances	Lower	89.5	89.5	–
	Upper	90.5	90.5	–

[1] The table values are for average lot density. If any individual density test result falls more than 3.0 percent below the minimum required target maximum density, the engineer may investigate the acceptability of that material.
[2] Includes parking lanes as determined by the engineer.
[3] Minimum reduced by 2.0 percent for a lower layer constructed directly on crushed aggregate or recycled base courses.
[4] Minimum reduced by 1.0 percent for a lower layer constructed directly on crushed aggregate or recycled base courses.
[5] The minimum required densities for SMA mixtures are determined according to WisDOT Construction & Materials Manual 8-15.

Air Void Regression

Beginning with pilot projects in 2016, WisDOT has begun employing air void regression in its mixtures to increase the percentage of asphalt binder. The concept of regression is to design a mix for 4.0 percent air voids, which is current WisDOT practice, and then predict the amount of additional virgin asphalt binder needed to obtain 3.5 percent or 3.0 percent air voids. This will increase design asphalt content up to 0.4 percent from current WisDOT mix designs.

Air void regression will increase the in-place density of the mixture, dependent on traffic level. It will also increase the aesthetics of handwork, increase impermeability, decrease porosity, increase durability, and increase film thickness.

Specialty Mixes

The asphalt pavement mix designs detailed in this chapter are suitable for the majority of roadway applications. However, specially designed asphalt mixes have been developed to meet a variety of needs. Four of these are noted here without complete design guidance. Please contact WAPA for more information about these types of asphalt pavements.

Warm Mix Asphalt

The introduction of mix additives allows placement of asphalt at lower temperatures. WMA is typically 60ºF to 90ºF cooler than traditional HMA. WMA offers a number of benefits, which include:

- Enhanced cold weather performance.
- Less oxidization of the asphalt cement, which reduces elasticity loss, premature aging, and transverse cracking.
- Savings on process fuel used during mix production.
- Reduction in carbon emissions.
- Increased comfort of paving crews.

The use of WMA is becoming increasingly common in Wisconsin. For state projects, WisDOT does not differentiate between WMA and HMA in its specifications; contractors are free to use WMA and often do so.

Extensive WMA resources are available on the website **warmmixasphalt.org**.

Porous Asphalt

The layers of a porous asphalt pavement have interconnected voids that allow water to flow through the pavement down to the subsoil. In addition to the environmental benefits of reduced stormwater runoff, porous asphalt pavement reduces the risk of ponding and vehicle hydroplaning. See WAPA's Technical Bulletin, *Porous Asphalt Pavements* (**wispave.org/wp-content/uploads/dlm_uploads/WAPA_Tech_Bulletin_Porous_Asphalt_Pavements_2015-09.pdf**) for design details.

Crack-Relief Interlayers

An asphalt interlayer reduces the reflective cracking of an asphalt overlay over an aging roadway. An asphalt interlayer is a fine-graded, high asphalt content, polymerized asphalt. It is placed in a nominal 1-inch thickness and then overlaid with a minimum of 2.5 inches of traditional asphalt. It is placed in the same manner as traditional asphalt except that the mix is only static (nonvibratory) rolled.

Fiber-Reinforced Asphalt

In a fiber-reinforced asphalt pavement, fibers are distributed throughout the asphalt paving material. This increases the strength and durability of the mat while helping it resist premature cracking and rutting. These fibers are becoming a cost-effective tool in the road agency's pavement enhancement toolbox.

5 Pavement Design Considerations

The structural design of a pavement system is a detailed process that must fully address the interactions of materials, traffic loads, and environmental effects. For the users of this design guide, much of this design work has already been done during the preparation of the thickness design charts presented in Chapter 6.

To use these charts effectively, a designer must establish important design inputs, including traffic loadings (truck volumes and weights) and subgrade support (including drainage considerations).

Beyond this design guide, additional helpful design programs are available:

- **PaveXpress** (**www.pavexpressdesign.com**).
- **WisPave Pavement Design**—Follow the instructions in WisDOT's Facilities Development Manual (FDM), Section 14-15-10 (**wisconsindot.gov/rdwy/fdm/fd-14-15.pdf#fd14-15-10**).

Traffic Loadings

Traffic loading information is necessary to establish both the required thickness of the pavement structure and the appropriate asphalt mix type.

Truck or heavy equipment loading on the pavement structure is the principal factor affecting the design and performance of an asphalt pavement. For example, studies have shown that one heavily loaded Interstate transport truck can cause pavement damage equivalent to that of 5,000 passenger cars. Because of this large discrepancy in induced damage, automobiles and light trucks are typically not considered during the development of required pavement thickness.

For the purposes of this design guide, design traffic is defined as the expected number of 18,000-pound ESALs that the pavement is expected to carry in the design lane over 20 years: **20-year design ESALs**.

Procedures for estimating 20-year design ESALs, ranging from detailed analyses of truck types, volumes, and axle weights to simplified estimations based on pavement usage classification, are provided in this chapter. Collecting of detailed traffic data may not be practical for all pavement projects, but such data may be required for specific projects. The user is encouraged to use as detailed a procedure as the available data allows.

Traffic Classifications

For this design guide, traffic has been classified and designated per WisDOT guidelines as shown in Table 5.1.

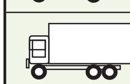
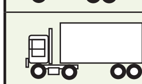
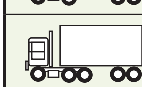
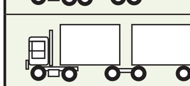
Table 5.1. WisDOT Truck Types and Designations

Truck Type	Configuration	Designation
Heavy single unit truck	2 axles, 6 tires	2D
	3 axles	3SU
Tractor-semitrailer	3 or 4 axles	2S-1, 2S-2
	5 or more axles	3S-2
Tractor-semitrailer-trailer	5 or more axles	2-S1-2

Note that farm vehicles (known as implements of husbandry or IoH) have a different impact on pavements than the conventional trucks described here. Additional pavement design consideration should be used when IoH traffic is anticipated. Please contact WAPA for more information.

Normal traffic streams consist of a random mixture of vehicles with different axle loads and number of axles. For ease of computation, vehicle and axle weight data may be

Table 5.2. Pavement ESAL Factors

Truck Profile	Designation	Application	ESAL Factor
	2D	Local delivery School buses	0.3
	3SU	General delivery Refuse	0.8
	2S-1, 2S-2	General delivery	0.5
	3S-2	Interstate transport Mass transit buses	0.9
	2-S1-2	Interstate transport	2.0

reduced to the common denominator of the ESAL. Table 5.2 illustrates the ESAL factors appropriate for each truck designation used within this design guide.

ESAL Calculations

Calculation Procedure 1

For detailed calculations, the average daily total number of each truck designation first must be established for the design lane. These totals are multiplied by their respective ESAL factors to determine the daily ESALs applied by each truck designation. These daily ESALs are then summed up to arrive at the design daily ESALs for the design lane as shown. Finally, this figure is multiplied by the number of days in 20 years to arrive at the 20-year design ESALs.

Example Calculation Procedure 1

	Truck Type (Designation)	Number [1]		ESAL Factor		Daily ESALs
	3-axle single unit (3SU)	25	×	0.8	=	20.0
+	3-axle semitrailer (2S-2)	15	×	0.5	=	7.5
+	3-axle tractor-semitrailer-trailer (2-S1-2)	10	×	2.0	=	20.0
	Sum to design daily ESALs				=	47.5

Daily × 365 days per year × 20 years = 346,750, round up

20-year design ESALs = 350,000

[1] Example average daily truck count, by designation, within design lane.

Calculation Procedure 2

When detailed truck classification data are not available, the design daily ESALs may be estimated by assuming each truck can be represented by a single ESAL factor. In these instances, the average daily total number of trucks, excluding light pickup trucks, in the design lane should be multiplied by an ESAL factor of 0.9 to determine the design daily ESALs and subsequently the 20-year design ESALs.

Example Calculation Procedure 2

Truck Type	Number [1]		ESAL Factor		Daily ESALs
All trucks	50	×	0.9	=	45

Daily × 365 days per year × 20 years = 328,500, round up

20-year design ESALs = 330,000

[1] Example average total daily trucks within design lane.

Simplified Procedure

The simplified procedure assigns ESAL values based solely on the type or usage classification of the pavement. Five traffic classes (TCs) are used in this design guide, each corresponding to a range of 20-year design ESALs.

Guidance for selecting traffic class and 20-year design ESALs based solely on usage classification is provided in Table 5.3 and Figure 5.1. Users must exercise caution when using this simplified procedure.

- If the pavement experiences significantly *more* truck loadings than those assumed, the excessive loadings may lead to premature failure.
- If the pavement experiences significantly *fewer* truck loadings than those assumed, the pavement will not experience the required additional vehicle compaction that occurs after construction. This can significantly shorten pavement life. Such pavements will also be overdesigned and more costly to construct.

Table 5.3. Simplified Assignment of Traffic Class and 20-Year Design ESALs

Traffic Class	Pavement Class (see Table 4.1)	20-Year Design ESALs Range	Typical Use
I	LT	< 2 million	Residential driveways School and recreational areas Playgrounds and tracks Bike paths Sidewalks Parking lots
II	LT	< 2 million	Low-volume roadways Subdivision streets Collector streets Town roads County roads
III	MT	2-8 million	Medium-volume roadways Arterial streets Town roads County roads Bus stops
IV	MT	2-8 million	Roundabouts Slow-moving traffic Town roads (slow-moving) County roads (slow-moving) Industrial parking lots Loading docks
V	HT [1,2]	> 8 million	Truck terminals Industrial roadways Arterials

[1] Under certain traffic conditions at the high end of the ESAL range (e.g., heavy loads at slow speeds or excessive stop-and-go conditions), consideration should be given to changing the binder designation. See wispave.org/new-asphalt-bid-mix-specifications-guidance-and-web-tool for additional information, or contact WAPA or your local WAPA contractor.
[2] Designs for extreme traffic conditions not covered in the table are available by contacting WAPA or your local WAPA contractor.

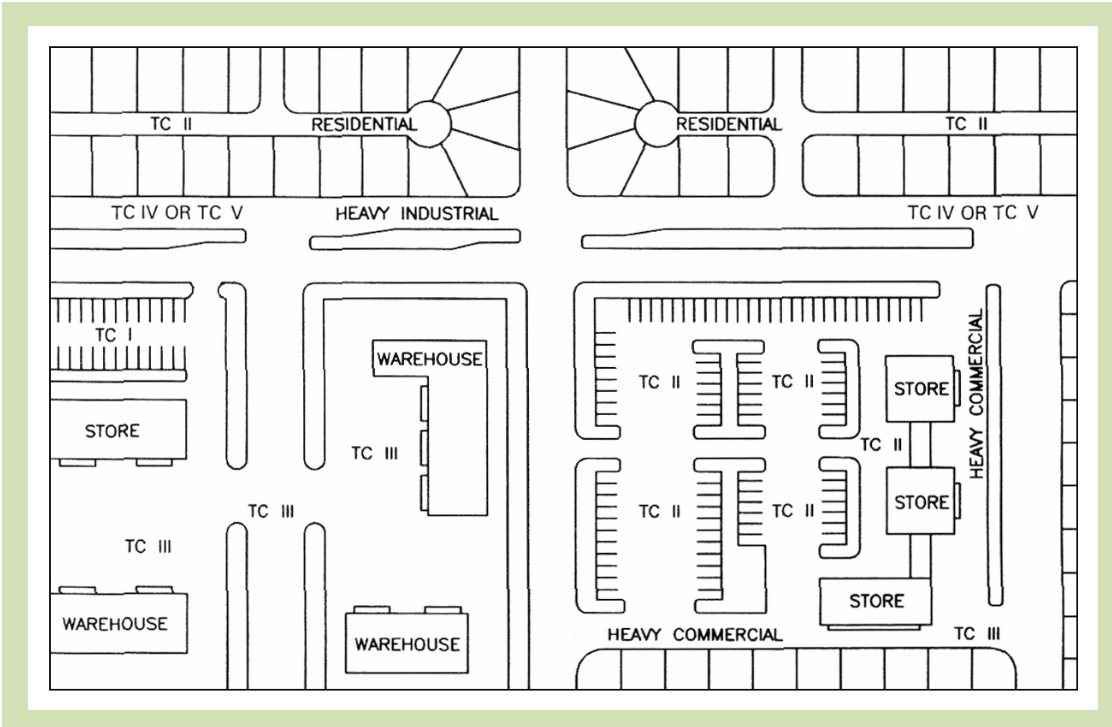


Figure 5.1. Typical Zones of Traffic Classes (TCs)

Subgrade Support

Drainage and soil support values (SSVs) are major factors in pavement life. Thickness design recommendations are provided in this design guide for soils classified into three broad classes: **excellent-to-good**, **medium**, and **poor**. Soil descriptions and typical California bearing ratios (CBRs) for each class are provided here. (The CBR test provides a measurement of the strength and support value of an aggregate base or subgrade soil.) Design values for SSVs used in this design guide are also provided.

Organic soils or soils with CBR values less than 2 should either be avoided, removed and replaced with suitable materials, or stabilized with an appropriate stabilizing agent to ensure a good compaction platform. A geotechnical engineer should be consulted in these instances to determine the most appropriate course of action.

Subgrade Soil Classification

When possible, field or laboratory tests should be used to evaluate the load-supporting capabilities of subgrade soils. One common method for determining the relative strength of the subgrade is the CBR method. However, this or other tests may not be readily available or may be too costly for small projects. In such instances, a field evaluation should be conducted by a geotechnical engineer, who can then assign the subgrade soils to the appropriate categories as defined below.

Excellent-to-Good Soils—Excellent soils retain a substantial amount of their load-supporting capacity when wet and are affected little by frost. Excellent soils include clean and sharp sands, sands, and gravels, particularly those that are well-graded.

Good soils retain a substantial amount of the load-supporting capacity when wet. Included are clean sands, sand-gravels, and soils that are free of detrimental amounts of plastic materials.

Soils classified as excellent would have a CBR greater than 20 while good soils would have a CBR from 10 to 20. For the purposes of this design guide, **excellent-to-good soils** have been assigned an SSV of **5.0**.

Medium Soils—These soils retain a moderate degree of firmness under adverse moisture conditions. Included are such soils as loams, silty sands, and sand-gravel mixtures containing moderate amounts of clay and fine silt. Soils classified as **medium soils** would have a CBR of 6 to 10 and have been assigned an SSV of **4.0**.

Poor Soils—These soils become quite soft and plastic when wet. Included are those soils having appreciable amounts of clay and fine silt (50 percent or more passing No. 200

sieve). The coarser silts and sand loams also may exhibit poor bearing properties in areas where frost penetration into the subgrade or base is a factor. "Sugary" (rounded and incompactable) sands are likewise considered a poor soil. Soils classified as **poor soils** would typically have CBR values of 2 to 5 and have been assigned an SSV of **2.5**.

Drainage

An important consideration in designing a high-quality pavement is providing adequate drainage. Good drainage helps ensure the success of durable pavements. Any drainage deficiencies should be corrected prior to construction. To ensure adequate drainage, it is necessary that sufficient slope is provided in the design of the pavement surface and that the water that enters the base or subbase is not retained. There are two basic categories of drainage: surface and subsurface.

Surface Drainage

Surface drainage includes the removal of all water present on the pavement, shoulder, and adjacent ground surfaces. For good surface drainage, the pavement and shoulders must be properly crowned or cross-sloped to ensure the rapid flow of water off the roadway to curbs and gutters or to adjacent drainage ditches. Roads and longer driveways with two or more lanes should be crowned with a cross-slope of at least 2 percent.

For parking and play areas, a minimum cross-slope of 1 percent is necessary to ensure adequate drainage of surface water and to avoid standing water that may seep into the soil. Cross-slopes greater than 1 percent may be advisable if surfaces to be paved cannot be checked to close tolerances.

Where minimum cross-slopes are used, proper consideration must be given to plan elevation data at key intersections, crossovers, and transitions between grade lines to ensure that this minimum slope is maintained during construction and to avoid standing water. It is important that leaching basins (or "bird baths") are not created. Pavements in these locations will typically fail in a short time unless internal drainage is provided to drain the low spots.

Subsurface Drainage

Subsurface water is water that seeps through the pavement or is contained in the soil beneath the surface. When it emerges or escapes from the soil, it is referred to as seepage water. Subsurface water usually is present as free water that flows under the force of gravity or as capillary water that moves under capillary action in the soil.

Subdrains are required in areas where water may collect in the structural elements of the pavement. The technical expertise of an engineer is required to identify these areas and to design adequate drainage provisions.

Synthetic Subgrade Improvements

Geotextiles and geogrids are part of a broad class of geosynthetics, which are fabric-like materials made from polymers such as polyester, polyethylene, polypropylene, nylon, and others. Geosynthetic use in civil engineering construction is over 40 years old and still advancing.

Geotextiles and geogrids are available in woven, nonwoven, knitted, welded, extruded punched-and-drawn, slit film, monofilament, multifilament, needle punched, PVC, and polymer coatings. They range in thickness from about 0.01 to 0.3 inches. The engineering properties of geotextiles vary significantly from one form to another and also vary within form classes based on the polymer used, thickness, and bonding technique. The proper choice and design of a geotextile fabric requires special skills; a geotechnical engineer should be contacted to determine the appropriate geotextile for your pavement.

Geotextiles and geogrids are used to enhance the stiffness and resiliency of aggregates and angular fill, load distribution, and rutting resistance under repeated loads. They can reduce aggregate thickness, reduce or eliminate undercutting, and expedite the speed of construction. They are used to perform one or more of the following functions:

- Separation.
- Reinforcement.
- Filtration.
- Drainage.

Separation—Geotextiles may be used to keep various soil or aggregate layers separate after construction. For example, a clayey subgrade soil can be kept separate from an aggregate base course by placing a geotextile over the subgrade prior to base course placement.

Reinforcement—The tensile strength of geotextiles can be advantageously used to increase the load-bearing capacity and settlement resistance of the soil.

Filtration—When placed between fine-grained and coarse-grained material layers, the fabric allows free seepage of water from one layer to the other while at the same time protecting the fine-grained materials from being washed into the coarse-grained materials.

Drainage—The fabrics can rapidly channel water from soils to various outlets.

6 Thickness Guides for Asphalt Pavements

The pavement thickness recommendations address various combinations of traffic class and subgrade type. The pavement layer thicknesses provided were developed to be adequate for the combinations of maximum 20-year design ESALs within each traffic class and minimum subgrade support value within each subgrade rating.

How to Use the Design Tables

1. Determine the 20-year design ESALs (page 14, Calculation Procedure 1 or 2) or the Traffic Class (page 14, Simplified Procedure) that best describes the use of the intended pavement, and then use the appropriate table from Tables 6.1 through 6.5 below.
2. Next, select the row representing the appropriate subgrade soil classification (page 15, "Subgrade Support").
3. Read across to the recommended total pavement thickness, base thickness, and surface layer PG binder designation. See Table 4.2 for guidance on designing individual layers to achieve the total thickness.

For more guidance on proper pavement design, see WAPA's Technical Bulletin, *Pavement Structure Design* (**wispave.org/wp-content/uploads/dlm_uploads/WAPATechBulletinPavementStructureDesign.pdf**), for a more detailed look at how to calculate structural numbers and determine proper pavement thicknesses. Feel free to contact WAPA or your local WAPA member for additional assistance.

Table 6.1. Pavement Thickness for Traffic Class I

20-Year Design ESALs	Typical Use	Asphalt Mixture Type	Subgrade Type		Asphalt with Crushed Aggregate Base		Recommended Surface Layer PG Binder Designation
			Rating	Description	Total Asphalt Thickness (in.)	Base Thickness (in.)	
< 2 million	Residential driveways School and recreational areas Playgrounds and tracks Bike paths Sidewalks Parking lots	LT	Good-to-excellent	Gravels and coarse sands. SSV ≥ 5.0	3.0	6.0 – 8.0	S
			Medium	Clays and silts with low plasticity. SSV = 4.0 - 4.9.	3.5	6.0 – 10.0	S
			Poor	Clays and silts with high plasticity; sugary (incompactable) sands. SSV = 2.5 - 3.9.	4.0	9.0 – 12.0	S

Table 6.2. Pavement Thickness for Traffic Class II

20-Year Design ESALs	Typical Use	Asphalt Mixture Type	Subgrade Type		Asphalt with Crushed Aggregate Base		Recommended Surface Layer PG Binder Designation
			Rating	Description	Total Asphalt Thickness (in.)	Base Thickness (in.)	
< 2 million	Low-volume roadways Subdivision streets Collector streets Town roads County roads	LT	Good-to-excellent	Gravels and coarse sands. SSV ≥ 5.0	3.0 – 3.5	6.0 – 10.0	S or H
			Medium	Clays and silts with low plasticity. SSV = 4.0 - 4.9.	3.5 – 4.0	6.0 – 12.0	S or H
			Poor	Clays and silts with high plasticity; sugary (incompactable) sands. SSV = 2.5 - 3.9.	4.0 – 4.5	9.0 – 14.0	S or H

Table 6.3. Pavement Thickness for Traffic Class III

20-Year Design ESALs	Typical Use	Asphalt Mixture Type	Subgrade Type		Asphalt with Crushed Aggregate Base		Recommended Surface Layer PG Binder Designation
			Rating	Description	Total Asphalt Thickness (in.)	Base Thickness (in.)	
2 - 8 million	Medium-volume roadways Arterial streets Town roads County roads Bus stops	MT	Good-to-excellent	Gravels and coarse sands. SSV ≥ 5.0	4.0 – 6.0	9.0 – 14.0	S
			Medium	Clays and silts with low plasticity. SSV = 4.0 - 4.9.	5.0 – 7.0	9.0 – 14.0	S
			Poor	Clays and silts with high plasticity; sugary (incompactable) sands. SSV = 2.5 - 3.9.	6.0 – 8.0	10.0 – 18.0	S

Table 6.4. Pavement Thickness for Traffic Class IV

20-Year Design ESALs	Typical Use	Asphalt Mixture Type	Subgrade Type		Asphalt with Crushed Aggregate Base		Recommended Surface Layer PG Binder Designation
			Rating	Description	Total Asphalt Thickness (in.)	Base Thickness (in.)	
2 - 8 million	Roundabouts Slow-moving traffic Town roads (slow-moving) County roads (slow-moving) Industrial parking lots Loading docks	MT	Good-to-excellent	Gravels and coarse sands. SSV ≥ 5.0	4.0 – 6.0	9.0 – 14.0	S or H
			Medium	Clays and silts with low plasticity. SSV = 4.0 - 4.9.	5.0 – 7.0	9.0 – 14.0	S or H
			Poor	Clays and silts with high plasticity; sugary (incompactable) sands. SSV = 2.5 - 3.9.	6.0 – 8.0	10.0 – 18.0	S or H

Table 6.5. Pavement Thickness for Traffic Class V

20-Year Design ESALs	Typical Use	Asphalt Mixture Type	Subgrade Type		Asphalt with Crushed Aggregate Base		Recommended Surface Layer PG Binder Designation
			Rating	Description	Total Asphalt Thickness (in.)	Base Thickness (in.)	
> 8 million	Truck terminals Industrial roadways Arterials	HT	Good-to-excellent	Gravels and coarse sands. SSV ≥ 5.0	8.0	10.0 – 14.0	H or V
			Medium	Clays and silts with low plasticity. SSV = 4.0 - 4.9.	9.0	11.0 – 14.0	H or V
			Poor	Clays and silts with high plasticity; sugary (incompactable) sands. SSV = 2.5 - 3.9.	10.5	14.0 – 18.0	H or V

7 Pavement Management Systems

Establishing a Pavement Management System

Many agencies and owners have developed informal procedures for identifying, budgeting, and scheduling pavement maintenance needs. These ad hoc approaches may have been successful because of the knowledge, good judgment, and, most importantly, the experience of those in decision-making positions. Today, however, due to higher traffic volumes and increasingly tighter budgets, a more systematic approach is warranted.

Implementing a structured **pavement management system** (PMS) can help to establish and prioritize maintenance needs and to plan budget allocations. A PMS need not be overly complex or expensive to acquire and operate. Many PMS programs, such as the PASER (Pavement Surface Evaluation and Rating) software developed by the Transportation Information Center at the University of Wisconsin–Madison, only require a portable computer to run efficiently. Implementing a PMS is cost-effective, regardless of the size of the pavement network being managed. Networks as large as a statewide primary road system or as small as a single parking lot can be better managed with a PMS.

A PMS can provide easy access to information such as:

- Condition of all pavements within the network.
- Best time to schedule repairs.
- Most cost-effective repair or reconstruction procedure.
- Cost if repairs are delayed.

A structured PMS has the following basic components:

- Record-keeping database.
- Condition rating system.
- Condition rating projection.
- Correlations of repair procedures and costs based on pavement condition rating.
- Priority ranking.
- Budget planning.

Record-Keeping Database—Record-keeping methods can be simple or complex, depending on the resources available to the agency. It is important that once established, pavement records be updated on a regular basis.

Condition Rating System—Condition rating systems are necessary so that pavement distress is properly evaluated. Some types of distress have more effect on the pavement performance than others. Therefore, it is necessary that a rating system be established that will properly score the various types of pavement distress. The Asphalt PASER Manual (described in detail on page 20) provides such a system. In the PASER system, a 10 is assigned to new construction and a 1 is assigned to a pavement surface with severe distress and with extensive loss of surface integrity.

All that is needed to establish a pavement rating is to have an individual with knowledge of the types of pavement distress walk the road and assign a number based on the PASER rating scale. Once this has been done for all pavement surfaces in an agency's jurisdiction, a numerical value is available with which to compare pavement surfaces.

Condition Rating Projection—The future condition of a pavement section can be projected based on the age, pavement type, and current condition of the section using a variety of techniques. These projections are necessary to determine the optimum time to repair a pavement or to determine the effectiveness of applied maintenance treatments.

Correlations of Repair Procedures and Costs Based on Pavement Condition Rating—The Asphalt PASER Manual can serve as a guide to the type of repair or reconstruction that is recommended for a pavement based on the type and severity of existing distress.

Priority Ranking—The numerical score (PASER number) can be used as one parameter in the priority ranking of pavements. This ranking may also include other factors such as traffic volume, budget, and effect of delaying maintenance on pavement deterioration.

The cost of rehabilitating a pavement will increase with use (traffic) and age (weathering). Figure 7.1 illustrates the cost implications of delaying the rehabilitation of a pavement until it has reached the end of its useful life. As shown, costs can be significantly reduced if repairs are applied while the pavement is still in good to fair condition.

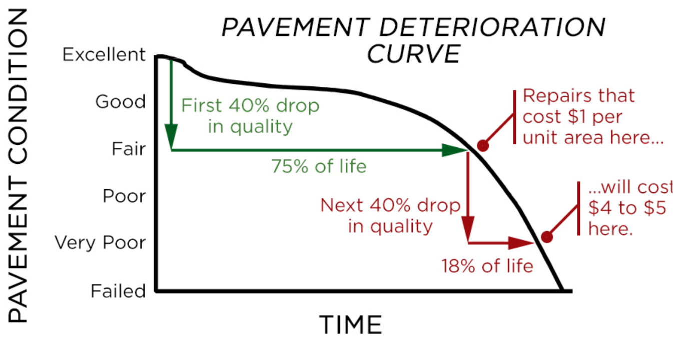


Figure 7.1. Relationship of Asphalt Deterioration and Rehabilitation

Budget Planning—A planned maintenance and rehabilitation program should include budget considerations. Financial resources available over a given period of years (such as 5 or 10) should match year by year the projected cost of maintenance and rehabilitation work proposed. The ultimate goal is to maintain the entire pavement network in good condition at the lowest cost. To do this, it is essential that work be completed at the optimum time and that all repairs be of high quality. Stretching budget dollars by providing a lesser quality product that covers more pavement surface is not, in the long run, an effective strategy.

Asphalt PASER Manual

The PASER system is a structured procedure for visually rating pavement conditions that can be used independently or within a structured PMS. The PASER system also provides guidance for determining the required level of maintenance or rehabilitation based on the obtained pavement rating.

The Asphalt PASER Manual is available online at **epdfiles.engr.wisc.edu/pdf_web_files/tic/manuals/Asphalt-PASER_02.pdf**.

A copy of the Asphalt PASER Manual may be obtained for a nominal charge by contacting:

Transportation Information Center
University of Wisconsin–Madison
432 N. Lake Street
Madison, WI 53706
Phone: 800-442-4615
Fax: 608-263-3160
tic@epd.engr.wisc.edu

How to Use the PASER System

The first step in establishing a rating for a pavement section is to identify the types of defects that exist. The PASER system provides photographs of those types of surface defects that can occur in HMA pavements.

The second step is to select a rating. The rating scale established is from 10 (excellent) to 1 (failed). Photographs and tables are provided to assist in the selection of a pavement rating.

8 Pavement Rehabilitation

Pavement rehabilitation can be accomplished using a variety of methods. This chapter provides only a general overview of rehabilitation methods available for pavements and is not intended as a guide on how to do the work.

These rehabilitation methods are not applicable to every pavement surface, so it is highly recommended that you contact a person with experience in pavement rehabilitation to determine the rehabilitation technique most appropriate for your pavement.

A key principle in rehabilitation is that the method and approach must address the root cause of the pavement distress while remaining cost-effective.

This chapter presents information on the following asphaltic overlays and methods for surface preparation.

Asphalt Overlays

- Thin lift overlays.
- Structural asphalt overlays.
- Open-graded friction courses.

Surface Preparations

- Localized surface preparation.
- Asphalt cold milling.
- In-place recycling (pulverizing or full-depth reclamation).
- Cold in-place recycling.
- Concrete pavement preparation.

The complete rehabilitation of a pavement will typically involve one or more of the above procedures. For example, it may be necessary to crack and seat a concrete pavement prior to placing a structural overlay.

Asphalt Overlays

Asphalt overlays are commonly used to restore an aged pavement to like-new condition. Asphalt overlays can be placed with minor traffic disruptions, and when properly designed and constructed, the overlaid pavement will provide a smooth, durable surface for many years. The overlay thickness, which must meet the pavement's intended function, can be determined based on a number of analysis techniques that will not be discussed here. However, further resources on the design of asphalt overlays can be found in Chapter 11 of this design guide.

The performance of an asphalt overlay is significantly affected by movements in the underlying pavement layer. Because it is not possible to completely arrest this movement, procedures to provide an asphalt overlay that is more tolerant of pavement movements have been investigated. These include:

- Use of softer asphalt binders or rubber or polymer modified asphalt binders.
- Use of reinforcement interlayers within the asphalt overlay.
- Use of synthetic fabrics within the asphalt overlay as reflective crack arresters.

The use of softer asphalt binders has proven not to be suitable for use on high-volume roadways due to potential stability problems. Additives and reinforcement interlayers are still being researched and some potential advantages have been observed.

Thin Lift Overlays

Thin lift asphalt overlays, commonly placed in thicknesses less than 1½ inches, are used to protect a deteriorated pavement, reduce roughness, and restore skid resistance. When thin lift asphalt overlays are used, it is important to ensure that:

- The maximum aggregate size is appropriate for the overlay thickness—typically 9.5 mm or 4.75 mm NMAS.
- A proper tack coat is applied.
- Work is carried out in warm weather so that desired level of compaction is achieved.
- Good asphalt construction quality control is maintained.

Use of a polymer modified PG binder grade is recommended, and a WMA additive can also be beneficial.

In deciding whether a thin overlay is applicable, a designer should conduct a visual survey to determine the extent and severity of existing distresses, a structural evaluation to validate that structural improvements are not needed, a drainage evaluation to ascertain if grade and slope need to be changed, a functional assessment of ride quality and skid resistance, and a consultation with pavement maintenance personnel. WisDOT currently has a specification for thin lift overlays as a special provision item.

Thin lift overlays are generally best-suited for the following distresses:

- Raveling.
- Longitudinal cracking (in wheel path).
- Transverse cracking.
- Alligator cracking.
- Rutting.

Structural Asphalt Overlays

Structural overlays are used to increase or restore the structural integrity of a pavement. Structural overlays may be required where there is a dramatic increase in heavy truck traffic or where existing pavements are approaching the end of their designed service life. Overlays will increase pavement life, reduce maintenance cost, provide a smoother riding surface, and improve skid resistance.

Open-Graded Friction Courses

An open-graded friction course (OGFC) is a high-void asphalt wearing course that contains a high percentage of one-sized aggregates. OGFC can rehabilitate asphalt pavements that have lost their skid resistance as a result of aggregate polishing or flushing of asphalt binder. They are effective in reducing hydroplaning and wet-pavement accidents and can also help to reduce road noise.

Surface Preparation Methods

To ensure good performance of an asphaltic overlay, the existing pavement surface must be properly prepared. In general, uncorrected problems existing in the pavement surface will become problems in the asphalt overlay. The type and extent of surface preparation should be carefully matched to the existing pavement condition and the asphalt overlay type.

Localized Surface Preparation

Localized surface preparation includes patching of deteriorated pavement areas and treatment of existing cracks.

Patching Deteriorated Pavement Areas—Patching is one of the most common methods for repairing localized areas that have intensive cracking as a result of excessive loadings (resulting in "alligatoring") or other factors. Patching can be either partial depth or full depth. Partial depth patching involves the removal of only the surface layer and replacement with asphalt. Full depth patching involves complete pavement removal down to the subgrade or an intermediate base layer that is intact.

Regardless of the patch depth, it is important to remove all deteriorated areas of the existing pavement. Some areas of deterioration may not be visible on the surface but will become exposed during the removal process. In these cases, it is important to extend the patch boundaries to include these previously unseen areas of deterioration.

Treatment of Existing Cracks—In this procedure, transverse and longitudinal cracks, which are opened up between ¼ to ½ inch, are cleaned and filled with a sealant material. Larger cracks should be cleaned and filled with an asphaltic patch material.

Asphalt Cold Milling

Cold milling is the process of removing a desired pavement thickness with a specially designed milling machine. A milling machine has a rotating drum mounted with carbide bits. These bits strike the pavement surface and remove the material (concrete or asphalt) to a predetermined depth. Any desired pavement thickness can be removed and any size material desired can be produced. If the milled material is to be reused as aggregate, steps taken to produce desired material size during milling may make later crushing unnecessary.

Milling provides a level, roughened surface that has good skid resistance and provides an excellent bond with the overlay. Most pavement distortions, such as rutting, bumps, and shoving, can be removed. This process does not harm the underlying material. Milling makes it possible to maintain the original pavement elevations. By removing material at the surface, no adjustments are required in the elevation at manholes, curbs and gutters, storm sewer inlets, and other connecting pavement surfaces.

Some of the benefits of asphalt cold milling include:

- Improved pavement profile and cross section.
- Restored drainage flow.
- Adjustments to overhead clearances under bridges and overpasses unnecessary.
- Adjustments to curb level unnecessary.
- Enhanced skid control and improved bonding with new asphalt surface lifts.
- Minimized traffic interruption.

- Reclaimed material for future use.
- Lower costs, extending the maintenance budget to provide more miles of pavement rehabilitation.

In-Place Recycling (Pulverizing or Full-Depth Reclamation)

In-place recycling is the pulverization or reclaiming of the full depth of existing pavement (6 to 10 inches) followed by reshaping and compaction. As the material is being reclaimed, additives such as foamed asphalt cement, emulsion or fly ash may be added to help improve overall pavement structure.

A reclaimer vehicle is followed by a blade or road maintainer and compaction equipment necessary to achieve the desired cross-slope and in-place density. The process does not require the use of new aggregate, and surface deficiencies can be eliminated.

After compaction, the resulting mixture is covered by a structural layer of asphalt. The recycled base can provide a structural capacity greater than the original base, thereby making the pavement capable of carrying a higher level of traffic.

Some of the benefits of in-place recycling include:

- Improved pavement profile.
- Minimal traffic disruption.
- Removal of major pavement distresses such as cracks and pavement fatigue.
- Pulverization of pavement surface with underlying base course to meet design needs (alter overall width, depth, and structure).

Cold In-Place Recycling

Cold in-place recycling (CIR) takes the project's existing materials and recycles them into a new base course structure. The process utilizes 100 percent recycling by milling the existing pavement (3 to 4 inches) into RAP. Steps include sizing/proportioning the material, adding virgin foamed asphalt or emulsion, relaying the material through a paver, compacting it to a specified density, and overlaying it with a traditional asphalt overlay.

CIR is generally best-suited for the following distresses:

- Longitudinal cracking.
- Transverse cracking.
- Surface potholes.
- Fatigue cracking not related to base or subbase.
- Weathered and raveled pavement.

Projects for consideration must have at least 3 inches of in-place asphalt mixture; low or medium traffic volumes; and identifiable pre-existing utilities, manholes, and valves. Geometric constraints that might require milling to match the profile should also be reviewed. WisDOT currently has a specification for CIR as a special provision item.

Some of the benefits of CIR include:

- Environmentally friendly practice.
- Improved quality of the recycled layer.
- Improved structural integrity.
- Minimal subgrade disturbance.
- Shorter construction time.
- Safe process for live traffic.
- Cost-effective practice.

Concrete Pavement Preparation

Cracks will typically develop in an asphalt overlay placed on a concrete pavement. Reducing or minimizing the occurrence of these cracks is generally a high priority if the service life of the pavement is to be extended. Cracks that develop in an asphalt overlay directly above existing cracks and joints in the concrete pavement are called reflective cracking. Almost any joint or crack spacing in the concrete pavement produces localized high stress in the asphalt overlay. This results from temperature-induced movements and vertical displacements due to load. The temperature-induced movements are more likely to be the more significant of the two.

Many methods have been tried in an attempt to eliminate reflective cracks. One concept in trying to eliminate or retard reflective cracking is to spread the strain that would occur over one crack to several cracks. In this way, no one cross section of the pavement is subjected to large strains. Described below are several methods that have been used over the past 30 years to retard or eliminate reflective cracking.

Cracking and Seating—In this method, a drop hammer or similar device is used to develop tight cracks in the concrete pavement, typically at about 24 to 30 inches on center. Tight cracks are those in which the aggregate still interlocks and load can be transferred through the crack. After cracking, a 10-ton steel drum vibratory roller makes several passes over the cracked pavement to seat the concrete. This will eliminate voids that may have existed below the concrete pavement. It is important that the roller not be oversized for the field site since it is possible to overstress the subbase. Cracking and seating is most applicable to jointed concrete pavements, which are structurally sound but have high roughness and significant amounts of patching and spalling.

Breaking and Seating—In this method, a drop hammer or similar device is used to develop cracks in the concrete at least 12 inches on center. Steel reinforcement within the concrete is broken and/or the bond between the concrete and the reinforcement is destroyed. After breaking, the concrete blocks are seated by using several passes of a 10-ton steel drum vibratory roller. Breaking and seating is also most applicable to jointed reinforced concrete pavements.

Rubblizing—In this method, specially designed equipment essentially reduces the concrete pavement to crushed aggregate. The slab action is completely destroyed and the concrete-to-steel bond is destroyed. Rubblizing is applicable to plain jointed, jointed reinforced and continuously reinforced concrete pavements that have deteriorated to the point that there is little potential to retain slab integrity and structural capacity. After rubblizing, the materials are compacted with two passes of a 10-ton steel drum vibratory roller (a Z-grid steel drum roller is used in some instances), followed by single passes of a 10-ton rubber tire roller and a 10-ton steel drum vibratory roller.

9 Asphalt for Recreational and Industrial Uses

This chapter provides general information and suggestions on the use of asphalt for recreational or other uses, including sidewalks and walkways, bicycle and golf cart paths, play areas, tennis courts, running tracks, curbs, reservoir liners, and railroad track beds. To achieve satisfactory results, the designed asphalt mix must be matched to the pavement use. For example, an asphalt mix designed for a highway is most likely not appropriate for used as a tennis court. Please contact WAPA or a WAPA member for more information about the design of asphalt pavements described here.

Sidewalks and Walkways

Sidewalks and walkways constructed of asphalt can be blended into the contours of the existing ground to preserve aesthetics and to reduce impact on the environment. Whenever possible, it is desirable to have surface drainage flow from these pathways. The width will typically be dictated by the expected foot traffic. When access for maintenance vehicles, repair vehicles, construction equipment, or emergency vehicles may be required, a wider pavement surface may be needed.

Bicycle and Golf Cart Paths

The construction of bicycle and golf cart paths is essentially the same except that they are usually built in different widths. A bicycle path should be at least 8 feet wide to allow bicycles to pass in two directions. Golf cart paths should be at least 5 feet wide. It may be necessary in remote areas, difficult terrain, or where damage to grounds may occur to construct wider pavements to allow for maintenance or emergency vehicle passage.

Bicycle and golf cart paths should have a minimum slope of 2 percent (¼ inch per foot) and should be constructed so that water will not collect at the pavement edge. It may be necessary to construct an underdrain system to carry water away.

Play Areas

Play areas may include basketball courts and paved surfaces surrounding playground equipment. Both surface and subsurface drainage should be investigated to ensure that excessive moisture is not allowed to accumulate under the pavement and shorten the life of the play area surface.

Curbs

Asphalt curbs can be an integral part of the pavement or they can be laid separately on an existing pavement by use of a slip form paver. These curbs serve to control drainage, delineate the pavement edges, help prevent vehicular encroachment on adjacent areas, maintain pavement edges, and enhance the overall appearance of streets and highways.

Tennis Courts

It is most important that both surface and subsurface drainage is thoroughly investigated to ensure a smooth, non-cracked playing surface is maintained. If subsurface drainage is not satisfactory, it is recommended that perimeter drains be installed or that an asphalt base on a suitable subgrade soil be used.

It is also important that tennis court surfaces properly drain. To accomplish this, the court surface should have a minimum slope of 1 inch per 10 feet on a true plane from side to side, end to end, or corner to corner. The surface should not slope away in two directions from the net.

Asphalt-Rubber Running Tracks

High schools and colleges are increasingly using asphalt-rubber surfaces for outdoor and indoor running tracks and for long jump, high jump, and pole vault runways. It is recommended that these be constructed over an asphalt or coarse aggregate base.

Rubber for use in asphalt-rubber mixes is available from several manufacturers. Information about these manufacturers can be obtained from WAPA and its members.

Asphalt for Hydraulic Structures

Since asphalt does not contaminate water, asphalt may be used to line reservoirs, dams, and retention ponds, and for potable water storage. Special care is required in the preparation of the soil surface prior to paving, and it is necessary that a proper drainage system be installed to prevent excessive hydrostatic pressures.

Asphalt mixtures for hydraulic linings can differ significantly from asphalt for pavements or roadways. It is necessary that a dense mix be used if the lining is to be impervious. This typically requires a higher asphalt binder content and increased minus 200-sieve material. The higher asphalt binder content increases the durability of the mix and the additional minus 200-sieve material increases the impermeability to water.

Conventional pavers and rollers are used to construct asphalt linings on mild slopes. On steep slopes, cables may be necessary to winch equipment up and down the slope, and special pavers and rollers may be required. It may also be necessary to use a PG binder to ensure that adequate asphalt stability is obtained.

Agricultural Applications

Paving cattle pens, feedlots, silage platforms, and bunker and stack silos with asphalt is a sanitary and effective practice. Asphalt is resistant to silage acids and sanitary wastes, and does not readily deteriorate.

The pavement structure of a paved barnyard or feeding area typically consists of a prepared subgrade, an aggregate base, an HMA base, and an HMA surface. The aggregate base may be composed of either bank-run gravel or crushed stone. The thickness of the aggregate base and HMA base depend on the strength of the subgrade and the anticipated vehicle use. When the aggregate subbase is placed over a heavy clay or plastic soil, a 3-inch insulation blanket of sand or fine gravel may be placed between the subgrade and the aggregate base as a construction platform.

Railroad Track Beds

Asphaltic pavements have been used successfully as an underlayment system for railroad track beds. The asphalt layer is topped by a ballast that supports the ties and the rails. The asphalt underlayment helps to spread the load, confine the ballast, waterproof the subgrade, and prevent pumping. It can be cost-effective, especially where a poor base course exists.

10 Materials Requirements Table

To determine material needs for a paving project, select the column in Table 10.1 that corresponds to the unit weight of materials to be used and the row that indicates the pavement thickness. Multiply the tabulated value by the total square yardage to be paved to determine the required weight of materials (in U.S. tons).

Example Calculation Procedure

Determine asphalt tonnage requirement for a 5-inch layer thickness covering 5,000 square yards, assuming a material unit weight of 115 lb/yd^2-in.

From Table 10.1, an asphalt a unit weight of 115 lb/yd^2-in and a thickness of 5 inches would weigh approximately 0.288 ton/yd^2.

The total tonnage required is calculated as:

0.288 ton/yd^2 × 5,000 yd^2 = **1,440 tons required**

Table 10.1. Approximate Asphalt Material Weight (U.S. tons per square yards of coverage)

Pavement thickness (in.)	Asphalt Material Unit Weight (lb/yd^2-in)						
	100	105	110	115	120	125	130
1	0.050	0.053	0.055	0.058	0.060	0.063	0.065
2	0.100	0.105	0.110	0.115	0.120	0.125	0.130
3	0.150	0.158	0.165	0.173	0.180	0.188	0.195
4	0.200	0.210	0.220	0.230	0.240	0.250	0.260
5	0.250	0.263	0.275	0.288	0.300	0.313	0.325
6	0.300	0.315	0.330	0.345	0.360	0.375	0.390
7	0.350	0.368	0.385	0.403	0.420	0.438	0.455
8	0.400	0.420	0.440	0.460	0.480	0.500	0.520
9	0.450	0.473	0.495	0.518	0.540	0.563	0.585
10	0.500	0.525	0.550	0.575	0.600	0.625	0.650
11	0.550	0.578	0.605	0.633	0.660	0.688	0.715
12	0.600	0.630	0.660	0.690	0.720	0.750	0.780

11 References

Wisconsin Department of Transportation (WisDOT)

WisDOT Local Roads Improvement Program (LRIP).
wisconsindot.gov/Pages/doing-bus/local-gov/astnce-pgms/highway/lrip.aspx

WisDOT Research and Library.
wisconsindot.gov/Pages/about-wisdot/research/default.aspx

WisDOT Roadway Standards.
wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/rdwy/default.aspx

- Standard Specifications for Road and Bridge Construction, 2016 Edition.
- Facilities Development Manual, 2015 Edition.
- Construction & Materials Manual, 2015 Edition.

Transportation Information Center, University of Wisconsin

Pavement Surface Evaluation and Rating (Asphalt PASER Manual), 2002.
epdfiles.engr.wisc.edu/pdf_web_files/tic/manuals/Asphalt-PASER_02.pdf

Additional Government Resources

American Association of State Highway and Transportation Officials (AASHTO).
www.transportation.org

AASHTO Materials Reference Laboratory (AMRL).
www.amrl.net

American Public Works Association (APWA)–Wisconsin Chapter.
wisconsin.apwa.net

ASTM International.
www.astm.org

Federal Aviation Administration (FAA) Airport Engineering Division.
www.faa.gov/airports/engineering

Federal Highway Administration (FHWA).
www.fhwa.dot.gov

Federal Highway Agency (FHWA) Pavement Technology Program.
www.fhwa.dot.gov/pavement

League of Wisconsin Municipalities.
www.lwm-info.org

U.S. Environmental Protection Agency (EPA).
www.epa.gov

Wisconsin Counties Association (WCA).
www.wicounties.org

Wisconsin County Highway Association (WCHA).
www.wiscohwy.org

Wisconsin Department of Natural Resources (WDNR): Recycling Asphalt Shingles
dnr.wi.gov/topic/Demo/Shingles.html

Wisconsin Towns Association.
www.wisctowns.com

Additional Engineering and Research Resources

American Society of Civil Engineers (ASCE).
www.asce.org

Asphalt Research Consortium (ARC).
www.arc.unr.edu

Association of Asphalt Paving Technologists (AAPT).
www.asphalttechnology.org

Institute of Transportation Engineers (ITE).
www.ite.org

MnROAD.
www.dot.state.mn.us/mnroad

Modified Asphalt Research Center (MARC)
uwmarc.wisc.edu

National Center for Asphalt Technology (NCAT).
www.ncat.us

National Cooperative Highway Research Program (NCHRP).
www.trb.org/NCHRP/Public/NCHRP.aspx

North Central Asphalt User/Producer Group (NCAUPG).
cobweb.ecn.purdue.edu/~spave/NCAUPG

North Central Superpave Center (NCSC).
www.engineering.purdue.edu/NCSC

Transportation Research Board (TRB).
www.trb.org

Wisconsin Highway Research Program (WHRP).
wisconsindot.gov/Pages/about-wisdot/research/whrp.aspx

Additional Industry Resources

Aggregate Producers of Wisconsin (APW).
www.aggregateproducers.org

American Road and Transportation Builders Association (ARTBA).
www.artba.org

Asphalt Contractor magazine.
www.forconstructionpros.com/cover/Asphalt-Contractor/2FCP

Asphalt Institute (AI).
www.asphaltinstitute.org

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