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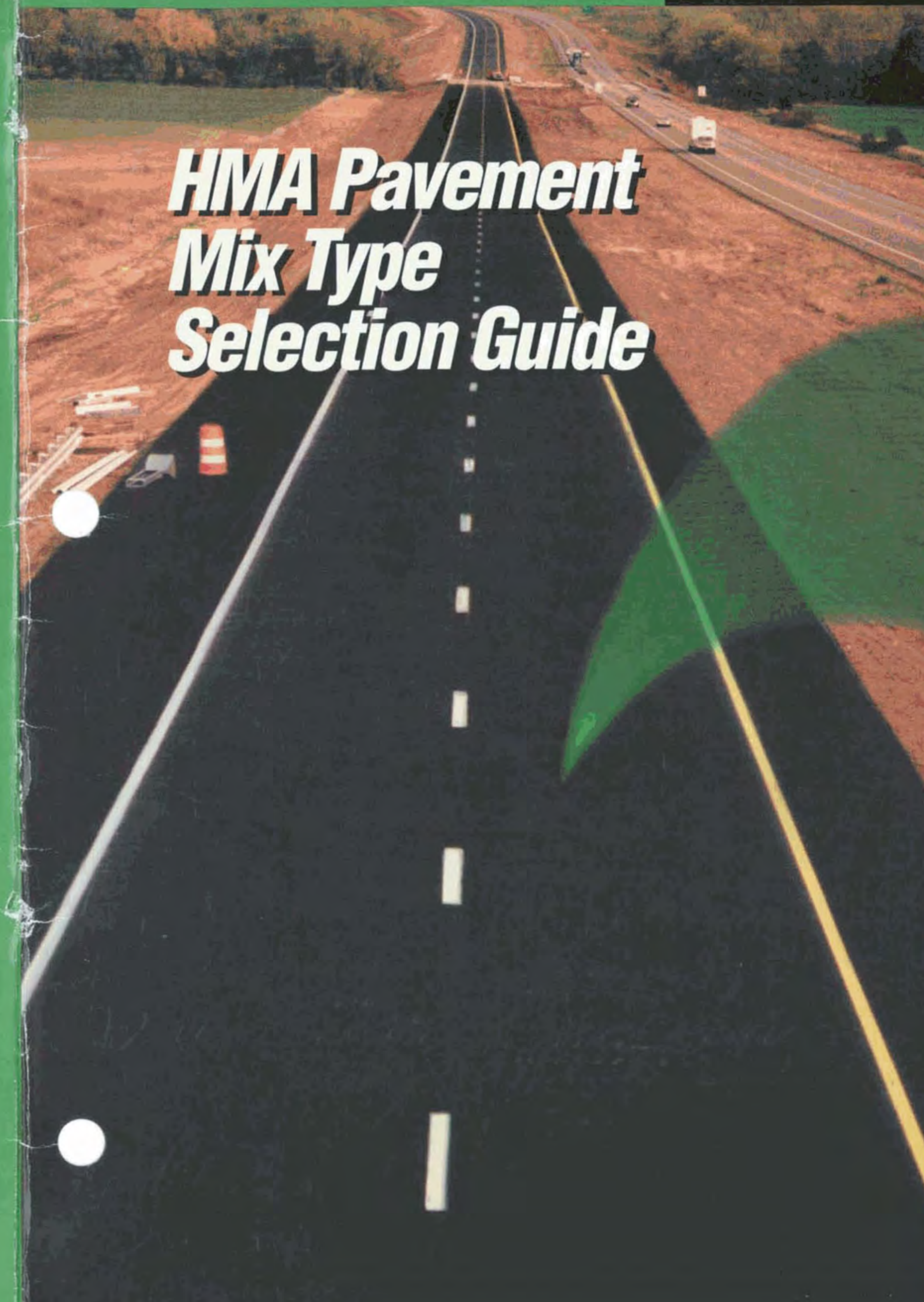
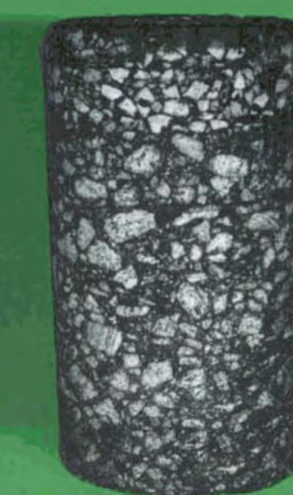
HMA Pavement Mix Type Selection Guide





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[8] NCHRP Synthesis 284, *Performance Survey on Open-Graded Friction Course Mixes*, Gerald Huber, National Academy Press, 2000.

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Appendix C — Glossary

break and seat—A fractured slab technique used in the rehabilitation of jointed reinforced concrete pavement that minimizes slab action by fracturing the PCC layer into smaller segments. This reduction in slab length (and de-bonding from the reinforcement steel) minimizes reflective cracking in new HMA overlays.

crack and seat—A fractured slab technique used in the rehabilitation of PCC pavements that minimizes slab action in a jointed concrete pavement by fracturing the PCC layer into smaller segments. This reduction in slab length minimizes reflective cracking in new HMA overlays.

draindown—The portion of the mixture (fines and AC) that separates and flows downward through the mixture.

durability—The property of the asphalt pavement that represents its ability to resist disintegration by weathering and traffic.

fatigue (alligator) cracking—Interconnected cracks forming a series of small blocks resembling an alligator's skin, and caused by excessive deflection of the surface over unstable subgrade or lower courses of the pavement.

full-depth HMA—A pavement structure that is designed and constructed so that all courses above the subgrade are asphalt concrete.

geotextile—Woven or non-woven synthetic fabrics that act as a separating layer in the pavement structure. The fabric's purpose is to provide a barrier to prevent soil contamination in drainage layers.

Hot Mix Asphalt (HMA)—High quality, thoroughly controlled hot mixture of AC (binder) and high quality aggregate, which can be compacted into a uniform mass.

HMA pavements—Pavements consisting of a surface course of HMA over supporting courses such as HMA bases, crushed stone, slag, gravel, or soil.

Hot Mix Asphalt (HMA) overlay—One or more courses of HMA over an existing pavement.

milling—The grinding and removal of layers of asphalt materials from pavements by a self-propelled unit having a cutting drum equipped with carbide-tipped tools.

open-graded—Porous HMA mixes with interconnected voids and high permeability. See open-graded friction course (OGFC and Asphalt Treated Permeable Base).

open-graded friction course (OGFC)—A pavement surface course that consists of a high-void, asphalt plant mix that permits rapid drainage of rainwater through the course and out the shoulder. The mixture is characterized by a large percentage of one-sized coarse aggregate. This course reduces hydroplaning and provides a skid-resistant pavement surface with significant noise reduction.

performance based specification—Specifies the qualities of the end product and enables the contractor to determine how these are to be met.

polished aggregate—Aggregate particles in a pavement surface that have been worn smooth by traffic.

polymer modified asphalt binder—Conventional AC to which materials have been added to improve performance.

prime coat—An application of asphalt primer to an unbound surface. The prime coat penetrates or is mixed into the surface of the base and plugs the voids, hardens the top, and helps bind it to the overlying asphalt course.

reclaimed asphalt pavement (RAP)—Excavated asphalt pavement that has been pulverized, usually by milling, and is used like an aggregate in the recycling of asphalt pavements.

reflection cracks—Cracks in the asphalt overlays that reflect the crack pattern in the pavement structure below it.

rubblization—The pulverization of a PCC pavement into smaller particles, creating a sound, structural base that will be compatible with an asphalt overlay while eliminating reflection cracking.

rutting—Depressed channel in the wheelpath of a HMA pavement.

spalling—The breaking or chipping of pavement at joints, cracks, or edges, usually resulting in fragments with feathered edges.

Stone Matrix Asphalt (SMA)—A premium gap-graded HMA requiring high quality materials. Cubical low abrasion crushed stone and manufactured sands are recommended. Manufactured sands, mineral fillers and additives (fibers and/or polymers) make a stiff matrix that is important to the rutting resistance of these mixes.

tack coat—A relatively thin application of asphalt binder applied to an existing HMA or PCC surface at a prescribed rate. Asphalt emulsion diluted with water is the preferred type. It is used to form a bond between an existing surface and the overlying course.

traveled way—The roadway portion which does not include the shoulders.

Acknowledgements

This document was developed by an expert task group. Its members were:

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Mr. Garcia and Mr. Hansen were the principal authors of this report.
Mr. David E. Newcomb was the NAPA staff manager for developing the publication.

Foreword

The *HMA Pavement Mix Type Selection Guide* provides designers with methods for selecting appropriate mix types while considering factors such as traffic, environment, subsurface pavement structure, existing pavement condition and preparation, and economics. The pavement mix types targeted are Open-Graded Friction Courses (OGFC), Stone Matrix Asphalt (SMA), and fine- and coarse-graded dense mixes. The Guide combines the selection criteria for these different pavement mix types into one document.

To develop this document, information was obtained from a combination of literature reviews, current State DOT/local government practices, and from an expert task group (ETG) of pavement experts, knowledgeable in the HMA industry, from private and public organizations. The experts represented different geographical areas of the country and were jointly selected for their expertise and perspectives in the topic of pavement mix types by the Federal Highway Administration (FHWA) and the National Asphalt Pavement Association (NAPA). The group identified the pertinent pavement mix type selection details during a technical workshop held in April 2000 at the NAPA offices in Lanham, Maryland.

This document consists of guidelines for maximizing the effectiveness of SMA, OGFC, fine- and coarse-graded dense mixes to ensure the success of each. This Guide is not intended to cover every situation that will be encountered. However, its purpose is to provide a valuable reference tool to both pavement designers and field personnel. It represents a joint product by FHWA and NAPA.

Appendix B — Materials

aggregates—hard, inert materials used in graded sizes (fine to coarse). Materials considered aggregates include rock, gravel, mineral, crushed stone, slag, sand, rock dust, and fly ash. Aggregates may be used alone for unbound sub-layers or as part of the HMA pavement layers.

gravel—formed from the breakdown of natural rock. Gravel particles (4.75 mm to 150 mm) are found in existing or ancient waterways, and the particles are usually smooth and rounded by wear as the material is moved along by the action of water. Gravel may be crushed prior to use in HMA.

crushed gravel—processed natural gravel. Crushed gravel can be used successfully in pavement construction with little or no screening as long as product satisfies specification requirements.

crushed stone—quarried rock processed to make it suitable for HMA pavement use. Large stones are crushed resulting in fractured particle faces. The crushed stone is sized by screening, and the dust resulting from the crushing can be removed by washing.

manufactured sands—the finer material (minus 4.75mm) from the crushing of stone or gravel. It is typically unwashed with a hmore material passing the 0.075 mm sieve than natural sands.

natural sand—composed of the final residue of the deterioration of natural rocks. Sand deposits may contain silt and clay particles in different quantities. These sand deposits may require washing prior to use in HMA.

reclaimed materials (foundry sands, roofing shingles, slags)—waste and by-product materials for use in secondary applications such as HMA pavements. By-product materials include slags, foundry sands, and roofing shingles. Slag is a by-product of metallurgical processing. Blast furnace slag from the processing of steel is the most commonly used slag for HMA construction. Foundry sands are clean, uniformly sized, high quality silica sand or lake sand bonded to form molds for iron, steel, copper, aluminum, and brass metal castings. Foundry sand may be used as a substitute for fine aggregate in HMA. Roofing shingles, primarily from factory waste, have been successfully used in HMA. The materials used in roofing shingles (asphalt, sand, mineral filler, and fibers) are commonly used in HMA. These by-product materials do not represent the entire population of materials that can be used in HMA construction applications.

reclaimed asphalt pavement (RAP)—material removed from a pavement for reuse in new pavements. Can be applied to any project, which requires rehabilitation or major reconstruction. However, the HMA in place has to be evaluated to ensure its acceptability for recycling. For example, RAP is not desirable if the aggregate does not meet specified requirements for the new HMA. Additionally, no additive should be used in a HMA mix if this additive precludes the HMA mix from being recycled in the future.

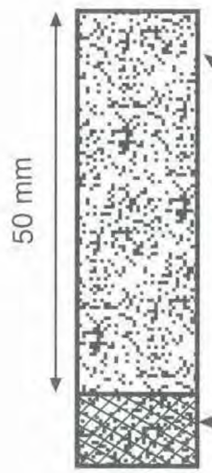
synthetics aggregate (lightweight, expanded clays, shales, slates)—produced by altering the physical and chemical characteristics of certain minerals. Included in this category are lightweight aggregates, expanded clays, shales, and slates.

binders—The asphalt binder is either an asphalt cement (AC) or a modified AC, which acts as a binding agent to glue aggregate particles into a cohesive mass. There are several grades of ACs (binders) that are available commercially. Performance-based specifications are most commonly used to classify asphalt binders into different grades in the United States.

PG grade—Performance Graded (PG) binders are becoming the standard for many areas of the country. The PG binder is the Superpave binder specification, which is performance-based. Binders are selected on the basis of climate and traffic in which they are to be used. The PG binders are defined by a term such as PG 58-28. The first number, 58 is the high temperature grade. This signifies that the binder has adequate physical properties up to at least 58 °C. This temperature corresponds with the high pavement temperature in the climate in which the binder is expected to serve. Similarly, the second number (-28) is the low temperature grade and signifies that the binder has adequate physical properties in pavements down to at least -28 °C. The PG asphalt binder specification differs from other asphalt specifications in that the tests used measure physical properties that can be directly related to field performance. (Specification Reference - AASHTO publication MP1, Specification for Performance Graded Binder)

antistrip additive—Added to mixture or binder to improve the resistance of HMA to moisture damage.

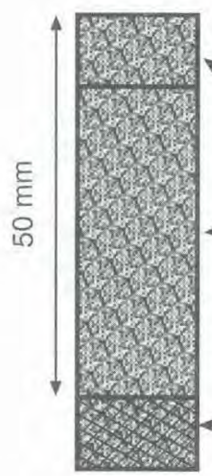
EXAMPLE 4: A pavement evaluation has determined that a 50 mm (2") overlay is required for a medium traffic roadway with 9.5 mm (3/8") rutting. The existing roadway is 150 mm (6") of HMA over granular base (15 years since last rehab). Surface shows signs of stripping.



State 1

First mill about 25 mm (1") to remove ruts and stripping surface layer.

Second choose a 9.5 or 12.5 mm dense, fine-graded HMA for a 75 mm (3") thick surface course.



State 2

First mill 37.5 mm (1-1/2") to remove ruts and stripped top layer

Next, a 12.5 or 9.5 mm dense-graded HMA is selected for a 37.5 mm (1-1/2") thick surface course.

Finally, use a 19.0 mm dense-graded HMA for the remaining 50 mm (2") as a binder course.

HMA Pavement Mix Type Selection Guide

Introduction

Background

Our nation's roadway system is critical to our economy. Hot Mix Asphalt (HMA) pavements constitute a large part of our nation's surfaced roads. HMA pavements serve in a multitude of traffic and environmental conditions, demanding that the materials and design meet specific engineering requirements. HMA pavement mix types include Open-Graded Friction Courses (OGFC), Stone Matrix Asphalt (SMA), and fine- and coarse graded dense mixes.

HMA pavement mixtures are expected to perform over extended periods of time under a variety of traffic and environmental conditions. Specialized mixes have been developed to meet particular needs. An example of this is the OGFC, which is designed to improve friction and minimize splash and spray from pavement while decreasing noise levels.

There is recognition in the transportation field that even as the future emphasis in HMA mixture design is on Superpave, attention must be given to better guidance on mixes designed to meet specific needs. HMA industry organizations have identified that while many of these pavement mix types have been used successfully in certain applications, some have also been placed in applications inappropriate for the mix type, such as placing an OGFC as an interlayer.

Additionally, HMA contractors have expressed concerns regarding state and local agencies incorporating high quality aggregates in their HMA mix type selection for both high volume and low volume traffic use, resulting in the unnecessary increase of construction costs in some cases. Furthermore, with the reductions in staff and retirement of experienced pavement specialists from many government agencies, there is a need to provide guidance to those responsible for designing and specifying the applications of HMA mix types.

A subsequent Federal Highway Administration (FHWA) headquarters inquiry to several states justified this need for reference guidelines addressing a variety of HMA mix types. Approximately 83 percent of the FHWA States/Division offices responding to the inquiry agreed that guidelines on pavement mix type selection would be beneficial. Among the examples provided for this need were:

- Addressing how the sub-surface pavement structure may affect the performance of the surface mix type;
- Use of a surface mix with poor performance history; and
- Poor pavement placement techniques related to the mix type being used.

Purpose

The *HMA Pavement Mix Type Selection Guide* provides designers with methods for selecting appropriate mix types while considering factors such as traffic, environment, subsurface pavement structure, existing pavement condition and preparation, and economics. The pavement mix types targeted are OGFC, SMA, and fine- and coarse-graded dense mixes. This Guide combines the selection criteria for these different pavement mix types into one document.

To develop this document, information was obtained from a combination of literature reviews, current State DOT/local government practices, and from a group of pavement experts, knowledgeable in the HMA industry, from private and public organizations. The experts represented different geographical areas of the country and were jointly selected for their expertise and perspectives on the topic of pavement mix types by FHWA and the National Asphalt Pavement Association (NAPA). The group identified the pertinent pavement mix type selection details during a technical workshop held in April 2000 at the NAPA offices in Lanham, Maryland.

This document consists of guidelines for maximizing the effectiveness of SMA, OGFC, and fine- and coarse-graded dense mixes to ensure the success of each. This Guide is not intended to cover every situation that will be encountered. However, its purpose is to provide a valuable reference tool to both pavement designers and field personnel. It represents a joint product by FHWA and NAPA.

Pavement Layers and Traffic Levels

This section defines the purpose of each pavement layer and defines traffic levels. Subsequent sections dicuss the selection process for specific HMA mix type applications, the recommended surface preparation, the benefits of each HMA mix type, and examples of the mix selection process for each HMA mix type.

Definitions

Flexible pavements maintain contact with and distribute loads to the prepared roadbed. Flexible pavements consist of layer(s) formed by one or more lifts of HMA and/or aggregate base placed above the prepared roadbed soil called the subgrade. The subgrade is the foundation layer, which consists of the existing soil or borrow material compacted to a specified density.

The pavement layers are generally divided into a surface course, intermediate or binder course, and a base course. The surface, binder, and base courses are typically different in composition and are placed in separate construction operations. The pavement layers for two common methods, full depth HMA and HMA over aggregate base, of HMA construction are shown in *Figure 1*.

Surface Layer

The surface layer normally contains the highest quality materials. It provides characteristics such as friction, smoothness, noise control, rut and shoving resistance, and drainage. In addition, it serves to prevent the entrance of excessive quantities of surface water into the underlying HMA layers, bases, and subgrade. This top structural layer of material can also be overlaid with a highly drainable OGFC and may be referred to as a wearing course.

Intermediate Layer

The intermediate layer, sometimes called binder course, consists of one or more lifts of structural HMA placed below the surface layer. Its purpose is to distribute traffic loads so that stresses transmitted to the pavement foundation will not result in permanent deformation of that layer. Additionally, it facilitates the construction of the surface layer. It may or may not be used, depending upon the application as explained in the Mix Types section of this document (see page 5).

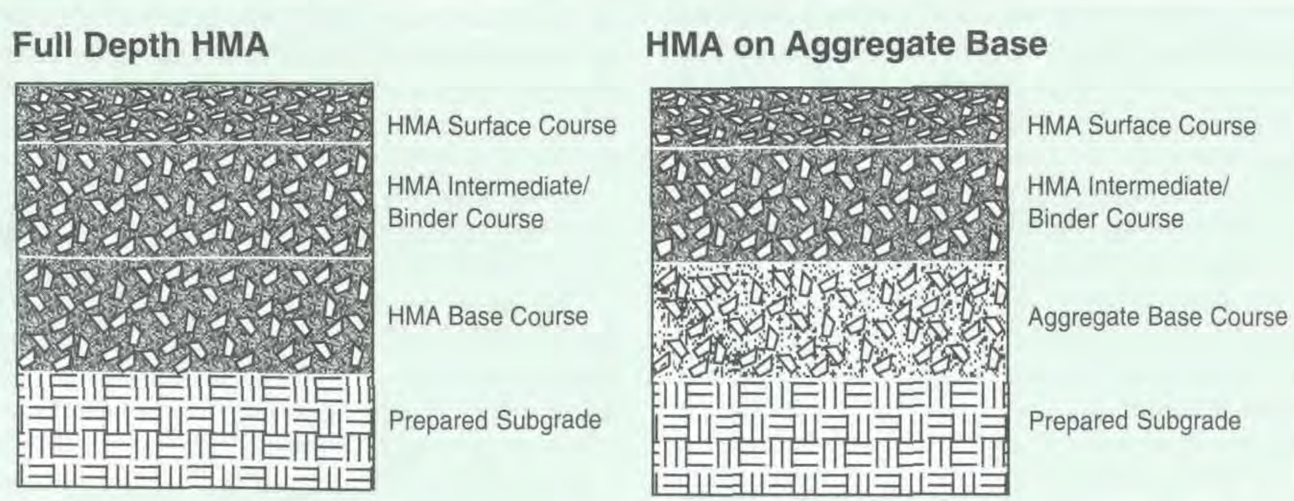
Base Layer

The base layer consists of one or more HMA lifts located at the bottom of the structural HMA layer or an aggregate base or stabilized base. Its major function is to provide the principal support of the pavement structure. It should contain durable aggregates, which would not be damaged by moisture or frost action.

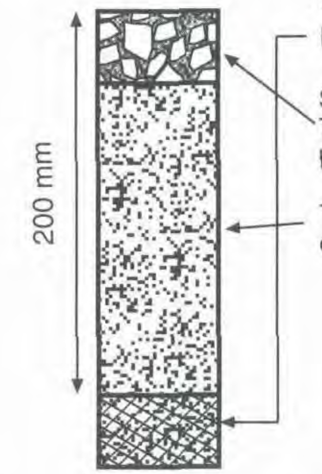
Leveling Course

The leveling course, as referenced in this document, is a thin layer of HMA used in rehabilitation to correct minor variations in the longitudinal and transverse profile of the pavement prior to placement of other pavement layers.

FIGURE 1: Pavement Layers



EXAMPLE 3: A 200 mm (8") structural overlay is required for rehabilitation of what is becoming a high volume urban highway. The existing condition is 10 percent low-medium alligator, 12.5 mm (1/2") rut. The pavement was constructed with no rehabilitation 10 years ago. Existing structure is 100 mm (4") HMA over 300 mm (12") aggregate base.

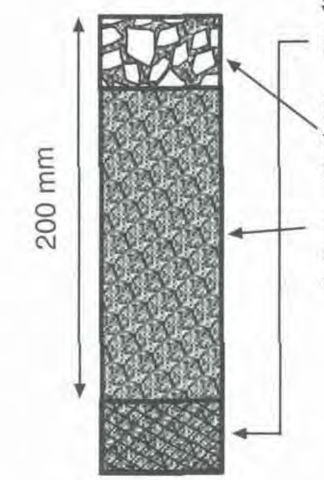


State 1

First, mill 25 to 37.5 mm (1" to 1-1/2") to remove ruts and surface layer.

Second, choose a 9.5 mm SMA as the surface course for resistance to rutting. The mix will be placed 37.5 mm (1.5") thick. The mix includes modified asphalt binder and fibers.

The remaining 200 mm (8") of pavement will consist of multiple layers of 19.0 or 25.0 mm dense coarse-graded mixes.



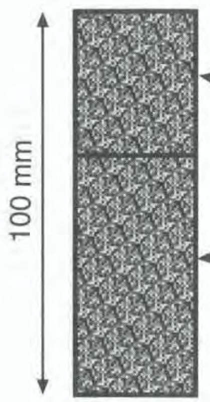
State 2

First, mill 25 to 37.5 mm (1" to 1-1/2") to remove rutting and top layer.

For the surface course, choose a 12.5 mm dense-graded HMA or SMA if heavy trucks are present. The mix will be 37.5 mm (1.5") thick. Mixes will use a polymer modified asphalt binder.

Finally, the remaining 200 mm (8") of pavement will be placed using a 19mm dense graded HMA placed in four 50 mm (2") thick lifts to allow traffic to keep using roadway during construction [maximum allowable drop-off 50 mm (2")].

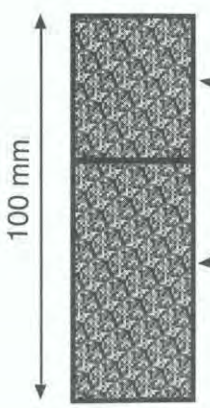
EXAMPLE 2: A structural evaluation for a new low volume rural road requires 100 mm (4") of HMA.



State 1

Step 1: First a surface layer using a 9.5 or 12.5 mm dense, fine-graded mix is selected. The thickness for the 9.5 mm and 12.5 mm mixes would be 25 mm (1") and 37.5 mm (1.5"), respectively

Step 2: Finally, the remaining thickness [75.0 mm (3") or 62.5 mm (2.5")] would use a 12.5 mm dense fine-graded mix.



State 2

Step 1: First a 9.5 or 12.5 mm dense, fine-graded HMA is selected for the surface course. This mix will be placed 37.5 mm (1.5") thick.

Step 2: Finally the remainder of pavement, 62.5 mm (2.5"), will use a 19.5 mm dense fine-graded.

Note: All mixes use unmodified asphalt binder.

Traffic

The number of traffic loads must be estimated to establish the required thickness and HMA mix types used in a pavement structure. Truck or heavy equipment loading on a HMA structure is the main factor affecting the design and performance of an HMA pavement. The American Association of State Highway and Transportation Officials (AASHTO) Road Test showed that the damaging effect of vehicle loads can be expressed by a number of 18-kip equivalent single axle loads (ESAL).

For the purposes of this document, traffic is defined according to the 20 year ESAL levels shown in *Table 1*.

Mix Types

Figure 2 presents the expert task groups' (ETG) relative ranking of which mix types are most appropriate for various layers based on general traffic categories. The figure can be used to select general mix types for further evaluation. Traffic levels are defined in *Table 1*. The ETG's recommendations for mix types based on their location in the pavement structure and traffic levels are presented in *Figure 3*. Recommended minimum lift thicknesses are provided. Minimum lift thicknesses are essential in obtaining the required densities for these mix types. Subsequent sections discuss the purpose of each layer, and discuss the benefits of each mix type.

Determining Appropriate Mix Types

The following presents the steps normally followed to determine appropriate mix types for specific applications:

1. Determine total thickness of HMA required.

   New Construction: Conduct a structural design in accordance with established procedures.
   Rehabilitation: Perform a pavement and structural design evaluation.

2. Determine the types of mixtures appropriate for the surface course based on traffic and cost.

   (a) Begin with *Figure 2*. Identify the general traffic category for your pavement. For a low traffic level, the ETG recommends only dense-graded mixes. For a moderate traffic level, dense-graded mixes again are the most highly recommended. However, you may want to consider a SMA or OGFC, especially as you approach the high traffic level. For high traffic levels, all mix types are appropriate. See subsequent sections in this Guide for a more complete description of each mix's benefits.

   (b) Second, determine what aggregate size to use for a mix. The main consideration for this is traffic loading. The higher the traffic loads, the more you should consider using a larger nominal maximum size aggregate mix.

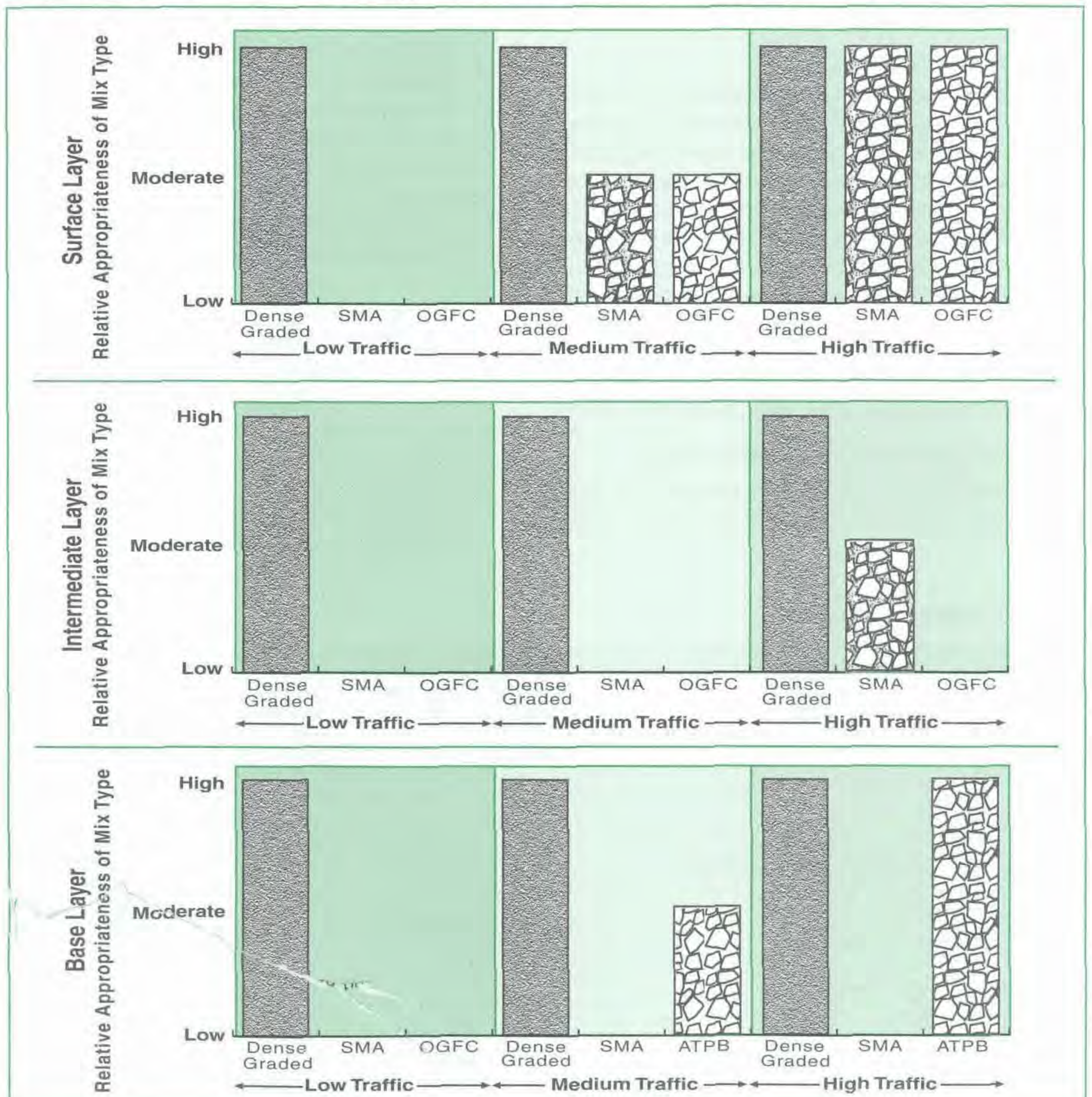
   (c) Third, consider appearance. Mixes with larger aggregates often have a coarser surface texture and may be more susceptible to segregation. Therefore, for a city street, you may want to use a finer mix such as a 9.5- or 12.5-mm dense-graded mix, while a 19.0-mm mix may be most appropriate for an industrial area. However, never substitute performance for appearance.

TABLE 1: Traffic Level Definitions

Traffic Designation	ESALs	Typical Roadway Applications
Low	<300,000	• Roadways with very light traffic volumes such as local roads, county roads, and city streets where truck traffic is prohibited or at minimum. • Traffic considered local in nature, not regional, intrastate, or interstate. • Special purpose roadways serving recreational sites or areas.
Moderate	300,000 to < 10,000,000	• Two-lane, multilane, divided, and partially or completely controlled access roadways. • Medium to highly trafficked city streets, state routes, U.S. highways, and some rural interstates.
High	> 10,000,000	• Two-lane, multilane, divided, and partially or completely controlled access roadways. • Medium to highly trafficked city streets, state routes, U.S. highways, and many of the interstates. • Truck-weighing stations or truck-climbing lanes on two-lane roadways.

(d) Finally, consider traffic flow. Another consideration for selecting the size of aggregate in a mix is minimizing the impact to traffic flow during rehabilitation of existing roadways. In many areas, off-peak construction is used to minimize user impacts. However, for a road to be released to traffic during peak hours, either the lane drop-off must be kept below a state specified value [typically less than 37.5 mm (1 1/2") (with proper signage)], or all lanes must be brought to the same level. Changing traffic control and moving paving equipment to pull lanes even by the end of the day takes valuable time away from paving, increasing construction time and costs. Therefore, selecting a finer gradation and placing the mix in two lifts may be more cost effective than a single lift. Again, don't compromise performance.

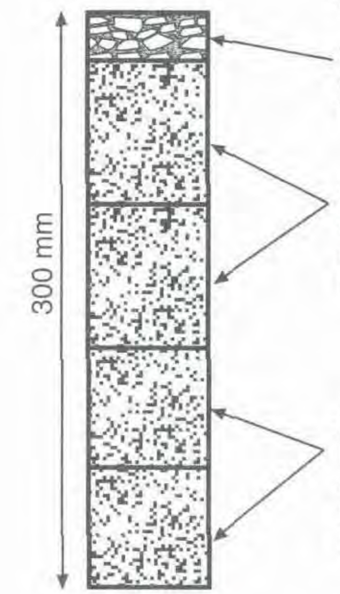
FIGURE 2: Recommended General Mix Types for Surface, Intermediate, and Base Courses



Appendix A — Examples

The following examples present two states' selection of appropriate mix types for four different scenarios:

EXAMPLE 1: A structural evaluation for a new pavement on a high volume, urban highway with heavy truck traffic requires a total thickness of 300 mm (12") of HMA.

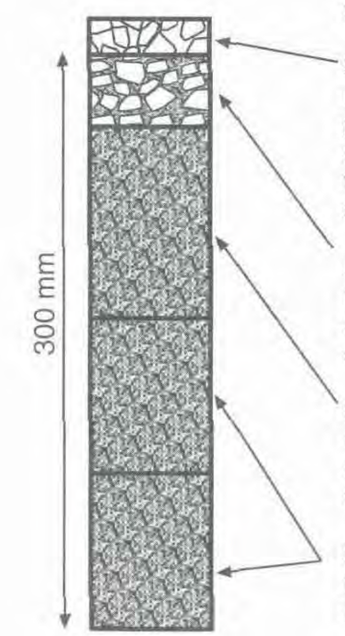


State 1

Step 1: A 9.5 mm SMA surface is selected for its durability and resistance to rutting from the heavy traffic. The mix will be placed 25 mm (1") thick. The mix would include modified asphalt binder and fibers.

Step 2: A 19.0 mm dense coarse graded mix with modified binder is selected for its resistance to rutting for the intermediate course. The mix will be placed in two lifts 75 mm (3") thick each, for a total depth of 150 mm (6").

Step 3: The remaining 125 mm (5") of the structural section will use two lifts of a 19.0 mm dense, coarse-graded mix with an unmodified binder as a HMA base course. An unmodified binder is used for this layer since temperatures and compressive stresses that influence rutting are lower than upper layers.



State 2

Step 1: A 9.5 mm OGFC is selected for friction and splash and spray reduction. This mix will be placed 19.0 mm (3/4") thick and will use a polymer modified asphalt binder. Note, this mix is not used for low speeds and where cross roads are present. Also note that this mix is added to the thickness of the structural section since it is not considered a structural layer.

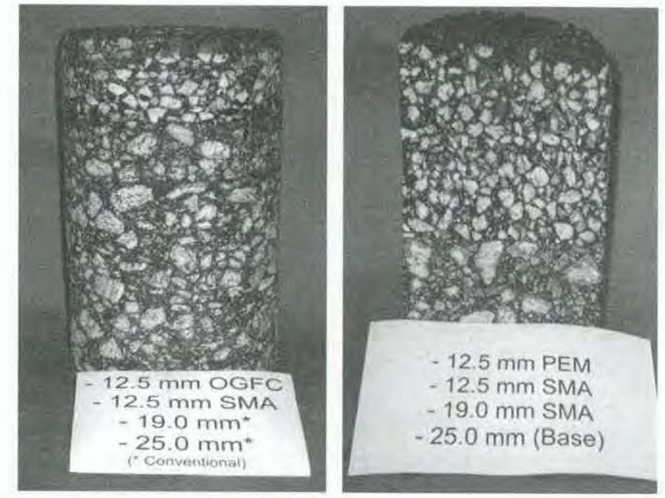
A 9.5 mm SMA structural surface is selected for its durability and resistance to rutting from the heavy traffic. The mix will be placed 37.5 mm (1 1/2") thick. The mix would include modified asphalt binder and fibers.

Step 2: A 19.0 mm dense-graded mix is selected for its resistance to rutting for the intermediate course. It is left up to the contractor whether to use a fine- or coarse-graded mix. The total thickness is 100 mm (4") which may be placed in one or two lifts at the descretion of the contractor.

Step 3: The remaining 162.5 mm (6.5") of the structural section will use two lifts of a 25.0 mm dense, fine- or coarse-graded mix as an HMA base course.

3. Subtract the thickness of the surface course from the total thickness, and determine what mix or mixes are appropriate for intermediate and/or base courses. (See *Figure 2* and *Figure 3*)
4. Continue to subtract intermediate/base course mixes from total thickness until mixes and layer thickness have been selected for the required pavement section.

An example of the mix selection process is shown in *Figure 4* for two pavements that require 150 mm (6") of HMA each. One pavement is a downtown city street in a shopping district with moderate traffic. The other is for an industrial area with moderate traffic but a higher percentage of truck traffic. Other examples of the mix selection process are given in *Appendix A*.



Cores showing different mixes for different layers.

FIGURE 3: Recommended Mix Types for Surface, Intermediate and Base Courses

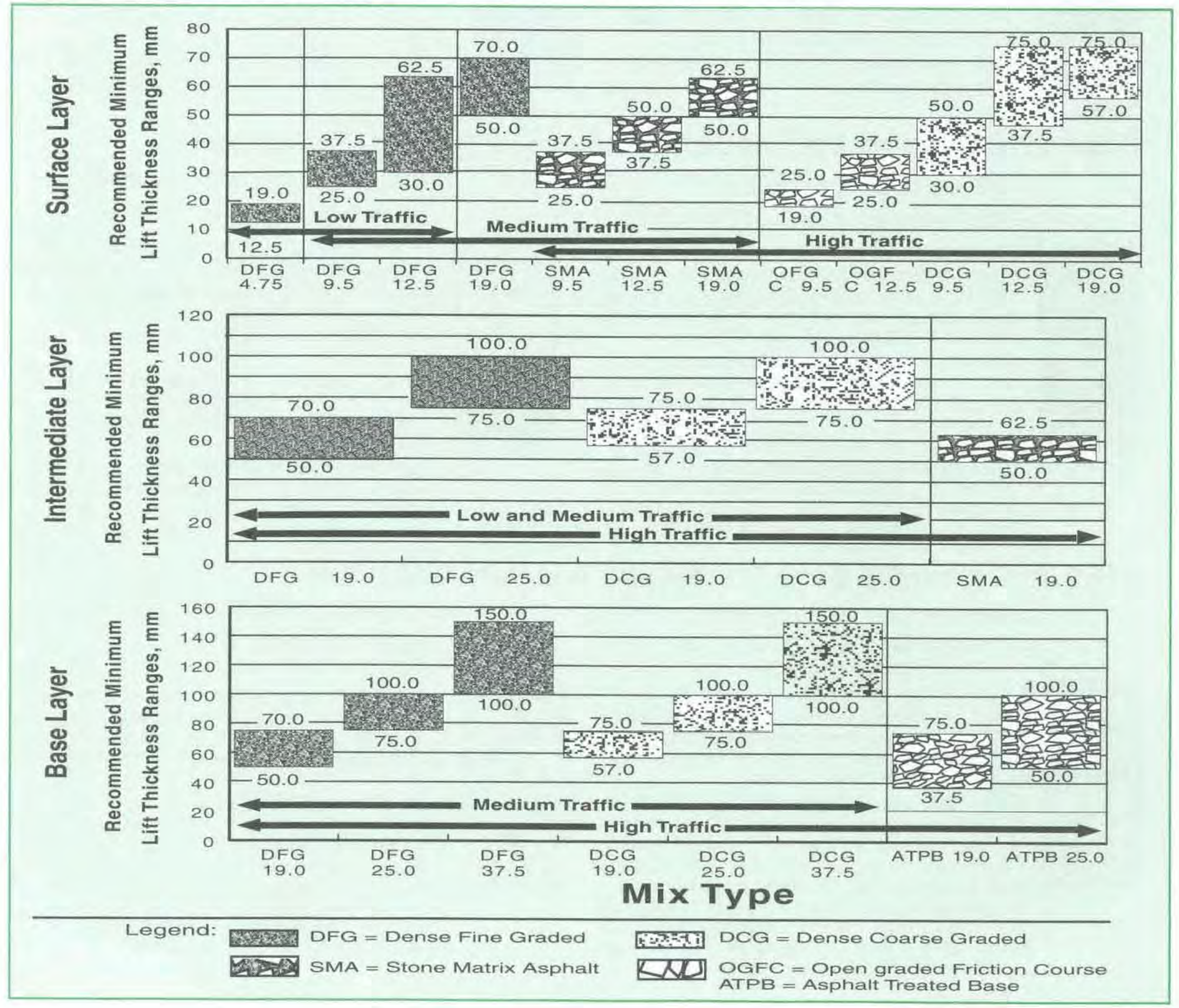
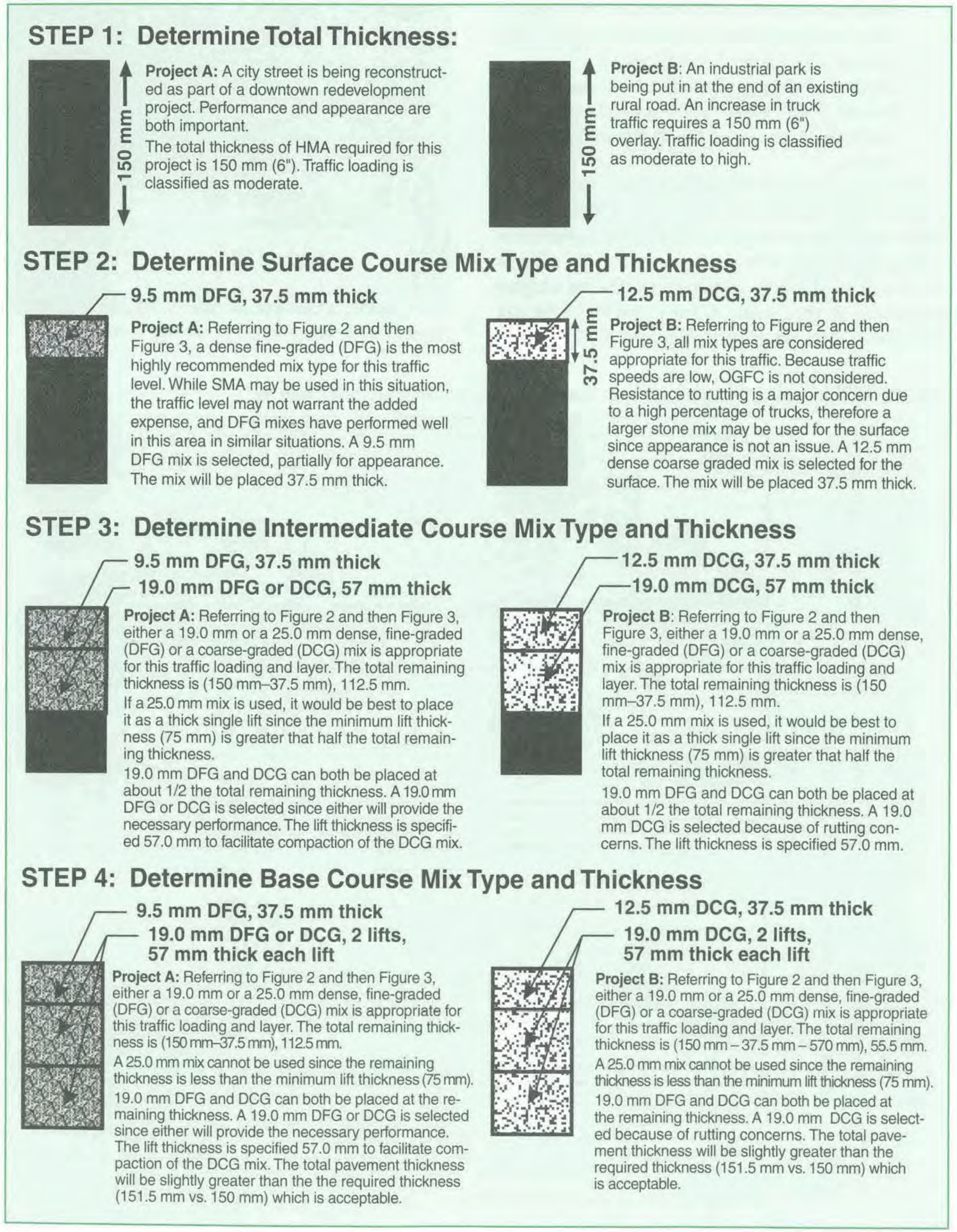


FIGURE 4: Mix Selection Example



Mix Types

Figure 7 shows the range of the recommended minimum lift thicknesses for the different open-graded mixes.

Table 9 presents which mixes are appropriate for different layers and for what purpose you may use the mix.

TABLE 9: Appropriate Layers and Purpose of Open-graded Mixes

	Mix Purpose		
Layer	9.5 mm	12.5 mm	19 mm
Surface	• Wearing surface • Friction • Noise reduction • Splash/spray reduction		N/A
Base	N/A	N/A	• Drainage

Sublayer Conditions

New Construction

OGFC 9.5 mm and 12.5 mm

Moderate and High Traffic — Place mix type on properly prepared HMA base or binder course.

ATB 12.5 mm and 19.0 mm

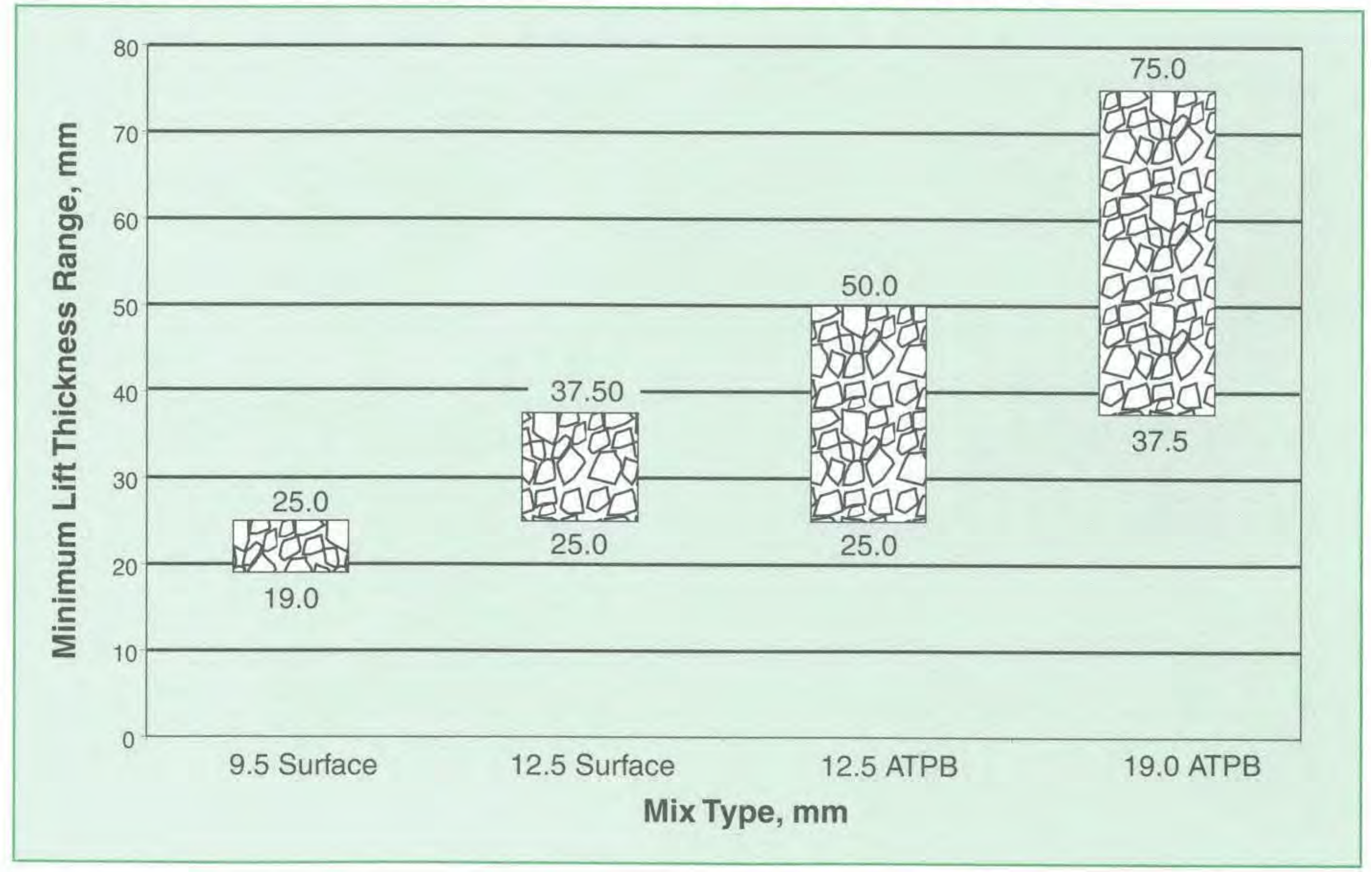
Use mix type only as the lowest course in an HMA pavement for drainage. Place on properly prepared base or subgrade. Use of geotextile or filter layer to prevent contamination by soil is recommended.

Rehabilitation

OGFC 9.5 mm and 12.5 mm

Place mix type only on sound pavement structure. Existing surface should have little or no cracking. Structural deficiencies must be repaired prior to placement and cracks sealed. Best if placed on crack free surface. If ruts are present, use leveling course or mill.

FIGURE 7: Recommended Minimum Lift Thicknesses Ranges for Open-graded Mixes



MIX TYPE:

Open-Graded Mixes

Open-graded mixes are designed to be permeable to water, which differentiates them from dense-graded and SMA mixtures that are relatively impermeable. These mixtures use only crushed stone or, in some cases, crushed gravel with a small percentage of manufactured sands. The use of modified asphalts and possibly fibers is highly recommended for surface mixtures. This increases the amount of asphalt that can be used with these mixes, improving their durability and performance.

Purpose

Three types of open-graded mixes are used in the United States: Open Graded Friction Courses (OGFC), Porous European Mixes (PEM), and Asphalt Treated Permeable Bases (ATPB). OGFC and PEM are used for surface or wearing courses only.

Surface Courses

The following significant differences exist between PEM and OGFC[8]:

1. Air voids of OGFC tend to be lower than PEM (15 percent vs. 18 percent to 22 percent).
2. All European agencies specify minimum air voids, whereas few U.S. agencies do.
3. European gradations generally allow for more gap-graded mixtures, but not always.
4. European agencies use modified binders almost exclusively.
5. U.S. agencies are shifting toward modified binders.
6. Aggregate standards are higher in Europe.
7. The higher air void contents specified in European mixtures require hard aggregates with a minimal tendency to break or degrade during construction.

As previously stated, both OGFC and PEM are used as surface mixtures only. They reduce splash/spray from tires in wet weather and typically result in a smoother surface than dense-graded HMA. Both are more expensive per ton than dense-graded HMA, but the unit weight of the mix in-place is lower, which partially offsets this higher cost. Both mixtures should only be used on high- or medium-traffic volume roadways with posted high speeds only. Higher speed traffic helps to keep the pores from clogging.

In freezing climates, OGFC and PEM mixtures require a different approach for winter maintenance. The open pore structure causes these mixes to cool faster and therefore freeze sooner than less permeable mixtures. Sand should not be mixed with deicing materials since the sand will plug the pores and decrease the effectiveness of these mixtures. These surfaces also require more frequent application of deicing materials although at a decreased rate each time.

Asphalt Treated Permeable Base

ATPB is used only below dense-graded HMA, SMA, or PCC to quickly remove water from below the pavement surface. A subdrain system is required when using ATPB.

Materials

Table 8 provides general guidelines for materials used in open-graded mixtures. See *Appendix A* for a more complete description of materials.

Mix Design

Mix design for open-graded mixes is less structured than for dense-graded or SMA mixtures. The main components of OGFC design are:

- Selection of materials;
- Gradation;
- Compaction and void determination; and
- Binder draindown evaluation.

The National Center for Asphalt Technology (NCAT) Report 99-3, *Design of New-Generation Open Graded Friction Courses*, provides a recommended mix design procedure for OGFCs.

TABLE 8: Materials for Open-graded Mixes

Layer	Traffic	Medium	High
Surface OGFC or PEB	Aggregate	• Crushed stone • Crushed gravel • Manufactured sands	
	Asphalt Binder	• Modified binder	
	Other	• Fibers • Antistrip as determined by testing	
Base ATPB	Aggregate	• Crushed stone • Crushed gravel • Manufactured sands	
	Asphalt Binder	• Unmodified	
	Other	• Antistrip as determined by testing	

General Recommendations for Surface Preparation

New Construction/Reconstruction

Perform structural design in accordance with established procedures such as AASHTO[1] or the Asphalt Institute[2] (AI).

Subgrade and untreated bases must be properly compacted to provide a firm, uniform working surface. Do not attempt to place HMA over materials that yield, such as soft soils. A tack coat is applied at the interface between HMA layers. A prime coat may be applied between HMA and aggregate base layers. A seal coat may be used for the surface (top) layer.

Rehabilitation

Performing pavement preservation will extend a pavement's useful life; however, even with pavement preservation, disintegration will occur over time and require rehabilitation. A common rehabilitation method is to provide necessary repairs to the existing pavement, then overlay it with a new structural-wearing surface. This method is discussed in the following paragraphs.

HMA

Thin Overlay [≤ 50 mm (2")] Functional

Place a thin overlay only on sound pavements with little or no cracking. Any structural distresses such as alligator cracking or potholes should be cut out and patched prior to overlay.

If rutting of 12.5 mm (1/2") or more is present, consider removing and replacing the layers responsible for rutting. For ruts less than 1/2 inch, other remedies such as milling, leveling, etc. may be warranted.

For pavements with poor ride quality, milling or leveling should be considered prior to overlay. Clean and tack existing surface prior to placing overlay. Crack filling may be considered for transverse cracks more than 9.5 mm (3/8") wide. Crack filling is different than crack sealing in the preparation given to the crack before treatment. Crack filling is applied on more worn pavements with wider, more random cracking.

Structural Overlay

Perform structural overlay design in accordance with established procedures such as AASHTO[1] or AI[3], taking into account the condition of the existing pavement. Structural distresses such as fatigue (alligator) cracking or potholes should be cut out and patched prior to overlay.

If rutting of 12.5 mm (1/2") or more exists, consideration should be given to removing and replacing layers responsible for rutting. For rough or rutted pavements, profile milling should be considered as a means to improve the final smoothness and density.

PCC

In many rehabilitation cases, slab fracturing is recommended on Portland Cement Concrete (PCC) pavements as a method of reducing or preventing reflection cracking.

The thermal- or moisture-induced movement of the PCC slab beneath the asphalt concrete often causes reflection cracking. By reducing the effective slab length, this movement can be minimized. This rehabilitation can be applied on pavements exhibiting significant spalling, cracking, or patching. It can also be used as an economical way of salvaging deteriorated pavements from complete reconstruction.

Concrete slab fracturing includes cracking and seating, breaking and seating, and rubblization. All these methods offset reflection cracking by reducing the effective slab length of PCC pavements. The choice of method is dependent on the type of PCC pavement and subgrade support. For more information on slab fracturing, refer to NAPA publication number IS-117, Guidelines for Use of HMA Overlay to Rehabilitate PCC Pavements[4]. No matter which technique is used, soft areas must be repaired prior to overlay.

Drainage

Drainage plays an integral role in pavement design. Good drainage enhances pavement durability. In order to identify problem areas, it is essential that drainage be evaluated prior to pavement placement. Drainage provisions should be made in areas where water can collect.

Drainage is categorized into two types: surface and subsurface. The removal of surface water from the traveled way and shoulders is termed surface drainage. Measures to facilitate surface drainage include the roadway crown, side slopes, longitudinal ditches, and culverts. Subsurface drainage pertains to the control of ground water and is an important consideration in pavement design. Subsurface drainage serves several purposes, such as controlling seepage in cuts and lowering the ground water table in areas where the water level lies near the surface of the ground.

Mix Design for Mix Types

A mix design should be required for every mix. The mix design will typically include material proportions and characteristics as well as select mixture properties (volumetrics, strength tests, etc.). There are three common procedures for designing HMA mixtures. These are Marshall, Hveem (AI publication MS-2[5]), and most recently Superpave (AI publication SP-2[6]). All these mix design procedures can be used to design quality mixtures. References for appropriate mix design procedures are provided for each mix type.

MIX TYPE:

Dense-Graded Mixes

A dense-graded mix is a well-graded (even distribution of aggregate particles from coarse to fine), dense HMA mixture consisting of aggregates and asphalt binder. Properly designed and constructed mixtures are relatively impermeable.

- **Nominal Maximum Size (NMS):** For the purposes of consistency, all dense graded mixes in this document are designated by the nominal maximum aggregate size of the aggregate in the mix. This is defined in the Superpave mix design system as, "one sieve size larger than the first sieve to retain more than 10 percent."
- **Fine- and Coarse-Graded Mixes:** Dense-graded mixes can further be classified as either fine-graded or coarse-graded. Simply put, fine-graded mixes have more fine sand size particles than coarse-graded mixes. *Table 2* can be used to define whether a mix is coarse or fine-graded. The relative advantages of the mixes are presented in *Table 3*.

Purpose

Dense-graded mixes are considered the workhorse of HMA since they may be used effectively in all pavement layers, for all traffic conditions.

TABLE 2: Definition of Fine- and Coarse Dense-graded Mixtures

Mixture NMS	Coarse-Graded	Fine-Graded
37.5 mm (1 1/2")	< 35% Passing 4.75 Sieve	> 35% Passing 4.75 Sieve
25.0 mm (1")	< 40% Passing 4.75 Sieve	> 40% Passing 4.75 Sieve
19.0 mm (3/4")	< 35% Passing 2.36 Sieve	> 35% Passing 2.36 Sieve
12.5 mm (1/2")	< 40% Passing 2.36 Sieve	> 40% Passing 2.36 Sieve
9.5 mm (3/8")	< 45% Passing 2.36 Sieve	> 45% Passing 2.36 Sieve
4.75 mm (No. 4 Sieve)	N/A (No standard Superpave gradation)	

TABLE 3: Advantages of Fine- and Coarse Dense-graded Mixtures

Fine-Graded	Coarse-Graded
Lower permeability	Allows thicker lifts (< 25 mm (1") NMS)
Workability (< 25 mm (1") NMS)	Increased macro texture (< 25 mm (1") NMS)
Thinner lifts (< 25 mm (1") NMS)	
Greater durability for low volume roads(< 25 mm (1") NMS)	
Smooth texture (< 25 mm (1") NMS)	

Mix Types

Figure 6 shows the range of the recommended minimum lift thicknesses for the different SMA mixes.

Table 7 presents which mixes are appropriate for different layers and for what purpose you may use the mix. Because SMA is mostly used for surface courses, choice in mix is almost always based on lift thickness.

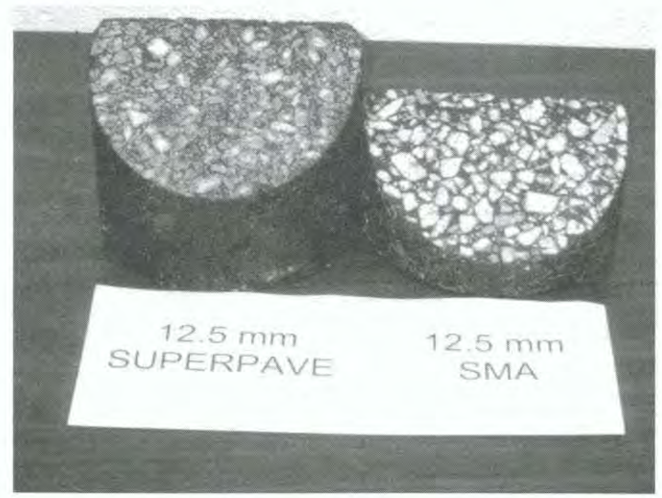
Sublayer Conditions — All Mixes

New Construction

Moderate and High traffic—Place mix type on properly prepared HMA base or binder course.

Rehabilitation

Place mix type only on sound pavement structure. The existing surface should have little or no cracking. Structural deficiencies must be repaired prior to placement.



The difference in aggregate structure between dense-graded and SMA is shown in these core samples.

FIGURE 6: Recommended Minimum Lift Thickness Ranges for SMA

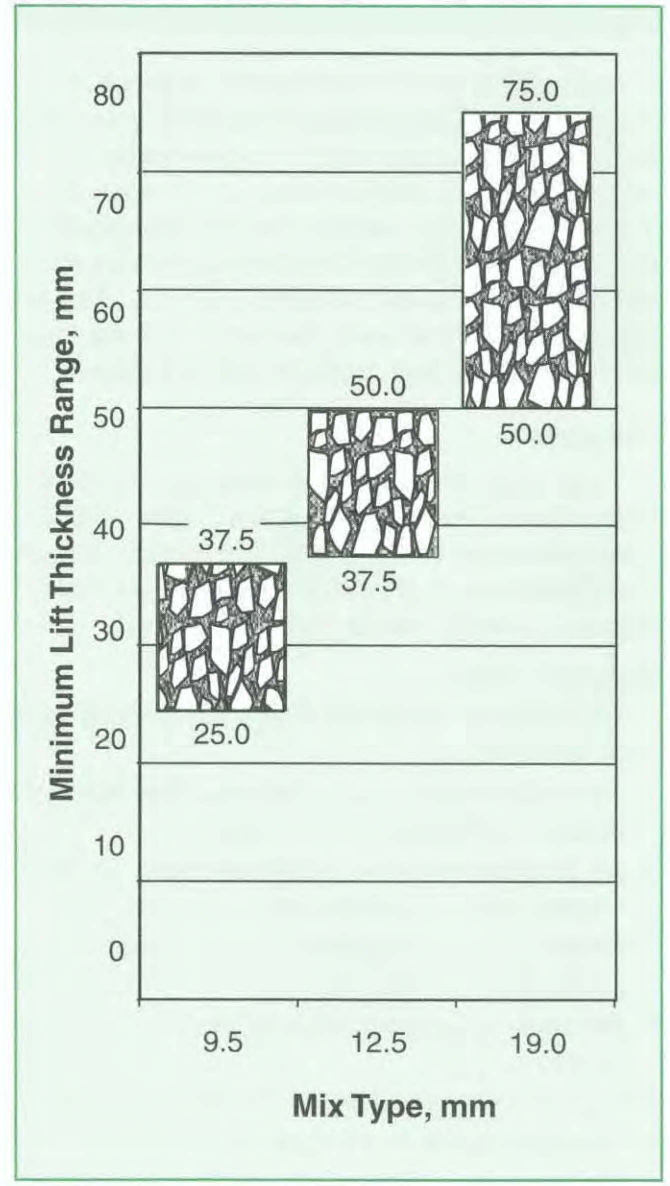


TABLE 7: Appropriate Layers and Purpose of SMA

	Mix Purpose		
Nominal Max. Agg.	9.5 mm	12.5 mm	19 mm
Layer			
Surface	• Wearing surface • Friction • Structure • Smoothness		
Intermediate	N/A	N/A	• Structure

MIX TYPE:

Stone Matrix Asphalt (SMA) Mixes

SMA is a gap-graded HMA that maximizes rutting resistance and durability with a stable stone-on-stone skeleton held together by a rich mixture of AC, filler, and stabilizing agents such as fibers and/or asphalt modifiers. SMA was developed in Europe to resist rutting (permanent deformation) and studded tire wear.

SMA is often considered a premium mix because of higher initial costs due to increased asphalt contents and the use of more durable aggregates. However, this higher initial cost may be more than offset by improved performance for medium and high traffic loading situations. In addition to improved durability, fatigue, and rutting resistance, other reported benefits include improved wet weather friction, due to a coarser surface texture, and lower tire noise. Reflective cracking in a SMA mixture is often not as severe as dense-graded mixtures since cracks have less tendency to spall[7].

Purpose

As previously mentioned, the primary purpose of SMA mixes is improved rut resistance and durability. Therefore, these mixes are almost exclusively used for surface courses on high volume interstates and U.S. highways. Special cases such as heavy, slow-moving vehicles may warrant the use of SMA for intermediate and base layers. One state, Georgia, commonly uses SMAs as a surface mix with an OGFC as a wearing surface.

Materials for SMA

SMA is a premium mix requiring high quality materials. Cubical, low abrasion, crushed stone and manufactured sands are recommended because the mixture gains most of its strength from the stone-on-stone aggregate skeleton. Aggregates should have 100 percent of the particles with one or more fractured faces. Natural sands should not be used. Aggregates should also have high polish values to retain good skid resistance where SMA is the final surface.

The matrix of sand, asphalt, mineral filler, and additives is also important to performance. Manufactured sands, mineral fillers, and additives (fibers and/or polymers) make a stiff matrix that is important to the rutting resistance of these mixes. Mineral fillers and additives also reduce the amount of asphalt drain down in the mix during construction, increasing the amount of asphalt used in the mix, improving its durability.

Table 6 provides general guidelines for materials used in SMA mixtures. See *Appendix A* for a complete description of materials.

Mix Design

Marshall and Superpave compaction procedures can be used to design SMA mixtures. For information on designing SMA mixtures, refer to the National Cooperative Highway Research Program (NCHRP) Report 425, Designing Stone Matrix Asphalt Mixtures for Rut-Resistant Pavements.

TABLE 6: Materials for SMA Mixtures

Layer	Material	Medium Traffic	High Traffic
Surface and Intermediate/Binder	Aggregate	• Crushed stone • Crushed gravel • Manufactured sands • Mineral filler	
	Asphalt Binder	• Modified binder typically used • Unmodified may be used at lower traffic levels	• Modification likely • Unmodified asphalts based on local experience
	Other	• Fibers • Antistrip as determined by testing	

A dense-graded mix may be used to fulfill any or all of the following pavement designers' needs:

- **Structural** — This is the primary purpose of dense-graded mixes and is primarily a function of the thickness of the layer. However, select materials may improve the structural value of mixes.
- **Friction** — This is an important consideration for surface courses. Friction is a function of aggregate and mix properties.
- **Leveling** — This mix may be used in thin or thick layers to fill depressions in roadways.
- **Patching** — The mixture should meet the same requirements as if used for new construction.

Materials

Table 4 provides general guidelines for materials used in dense-graded mixtures. See *Appendix B* for a more complete description of materials.

Mix Design

Dense-graded mixes may be designed using Marshall, Hveem, and Superpave procedures. For further information on Marshall and Hveem mix design procedures, refer to the AI's publication MS-2, Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types. For information on designing mixes using the Superpave system, refer to the AI's publication SP-2, Superpave

TABLE 4: Materials for Dense-graded Mixtures

Layer	Material	Low Traffic	Medium Traffic	High Traffic
Surface	Aggregate	• Gravel (limited) • Crushed gravel and stone • Manufactured sands and natural sand	• Crushed gravel and stone • Manufactured sands and natural sand	
	Asphalt Binder	• Typically unmodified • Modification may be necessary for heavier traffic, intersections at higher traffic levels.	• Typically unmodified	• Modification likely • Unmodified asphalts based on local experience
	Other	• RAP (Reclaimed Asphalt Pavement) • Antistrip as determined by testing		
Intermediate/ Binder	Aggregate	• Gravel (limited) • Crushed gravel and stone • Manufactured sands and natural sand	• Crushed gravel and stone • Manufactured sands and natural sand	
	Asphalt Binder	• Typically unmodified		• Unmodified except for very heavy loading situations or when traffic will travel on layer for extended periods
	Other	• RAP (Reclaimed Asphalt Pavement) • Antistrip as determined by testing		
Base	Aggregate	N/A	• Crushed gravel and stone • Manufactured sands and natural sand	
	Asphalt Binder	N/A	• Typically unmodified	• Unmodified except for very heavy loading situations or when traffic will travel on layer for extended periods
	Other	N/A	• RAP (Reclaimed asphalt pavement)	• Antistrip as determined by testing

Mix Design. The Superpave system is recommended for designing dense-graded HMA.

Mix Types

Figure 5 shows the range of the recommended minimum lift thicknesses for different dense-graded mixes.

Table 5 presents which mixes are appropriate for different layers and the purpose of each mix. For example, if your analysis shows that you do not need structural improvement, and there is little or no cracking, but ride and/or skid need to be improved, you could possibly use a 4.75 mm (No. 4 sieve), 9.5 mm (3/8"), or 12.5 mm (1/2") mix.

Sublayer Conditions

The recommended sublayer conditions prior to placement of the different mix types are shown on the facing page. The reader should also refer to the section on *General Recommendations for Surface Preparation* (see page 7).

FIGURE 5: Recommended Minimum Lift Thickness Ranges for Dense-graded Mixes

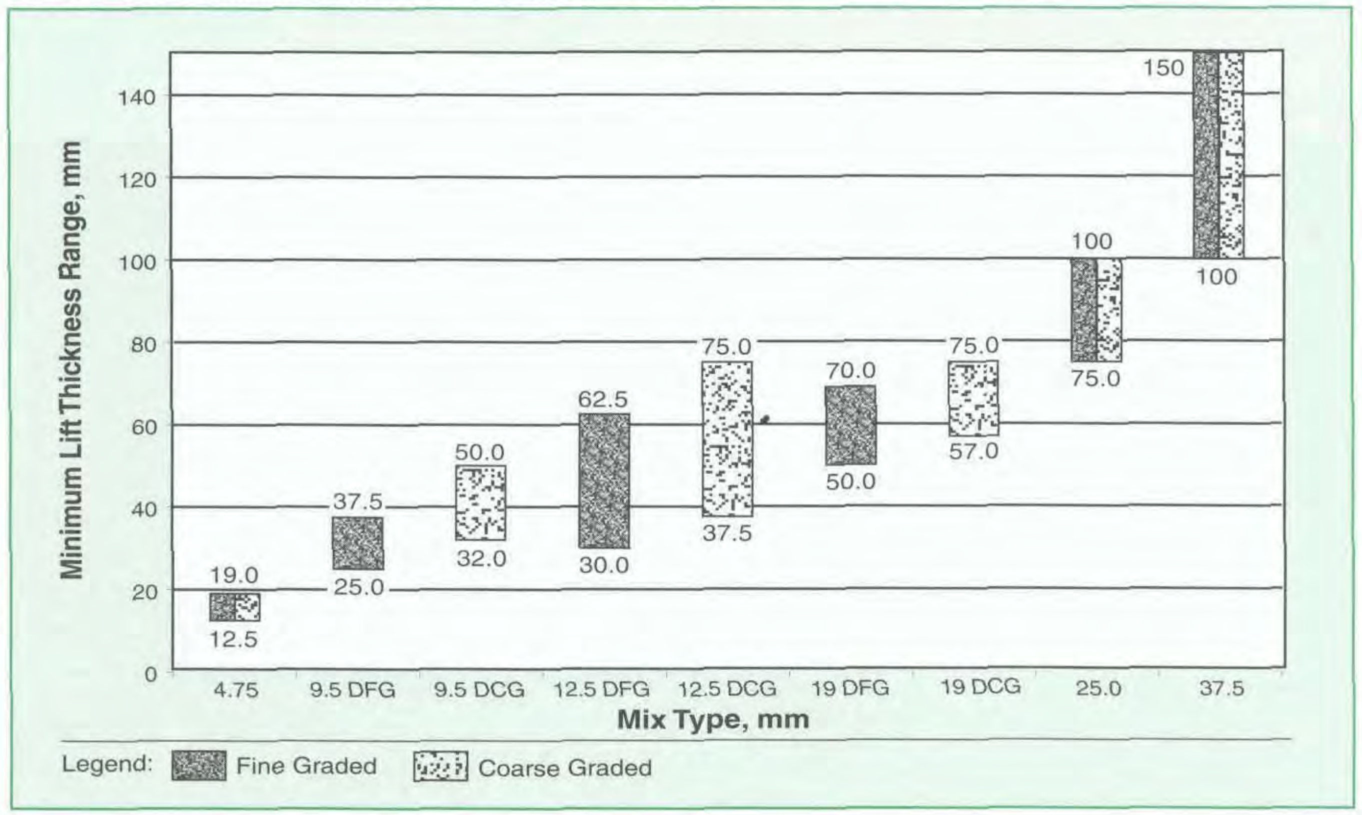


TABLE 5 : Appropriate Layers and Purpose of Dense-graded Mix

Nominal Max. Agg.	4.75 and 9.5 mm	12.5 mm	19 mm	25.0 and 37.5 mm
Layer				
Surface	• Wearing surface • Friction • Smoothness	• Wearing surface • Friction • Smoothness • Structure	• Friction • Structure	N/A
Intermediate	• Leveling • Smoothness	• Structure • Smoothness	• Structure	
Base	N/A			

New Construction Sublayer

4.75 mm

All traffic — Place mix type only on properly prepared HMA surface. See general recommendations for surface preparation.

9.5 mm

Low traffic — The mix type may be placed on a properly prepared aggregate or treated base or HMA base. When placed on non-HMA base, it is recommended that the mix be placed in two lifts for improved smoothness.

Moderate and high traffic — Place mix type on properly prepared HMA base or binder course.

12.5 mm

Low traffic — Mix type may be placed on properly prepared aggregate or treated base (1 or 2 lifts) or HMA base. When placed in a single lift over aggregate base, the final smoothness may not be as good as that placed over an HMA base.

Moderate and high traffic — Place mix type on properly prepared HMA base or binder course.

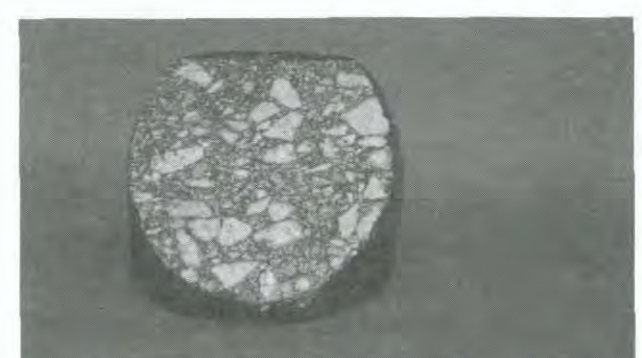
19.0 mm

Low traffic — Mix type may be placed on properly prepared aggregate or treated base (1 or 2 lifts) or HMA base. When placed in a single lift over aggregate base, the final smoothness may not be as good as that placed over HMA base.

Moderate and high traffic — In most cases, this mix will be used as a binder or base course where it should be placed on a properly prepared subgrade, aggregate, or treated base.

25.0 mm and 37.5 mm

Follow general recommendations for surface preparation.



A core sample of 25.0 mm shows a dense-graded mix.

Rehabilitation Sublayer

4.75 mm

Place mix type only on sound pavement structure. Existing surface should have little or no cracking or rutting. Structural deficiencies must be repaired prior to placement. Follow general recommendation for thin overlay surface preparation.

9.5 mm

Place mix type only on sound pavement structure. Existing surface should have little or no cracking. Structural deficiencies must be repaired prior to placement.

12.5 mm

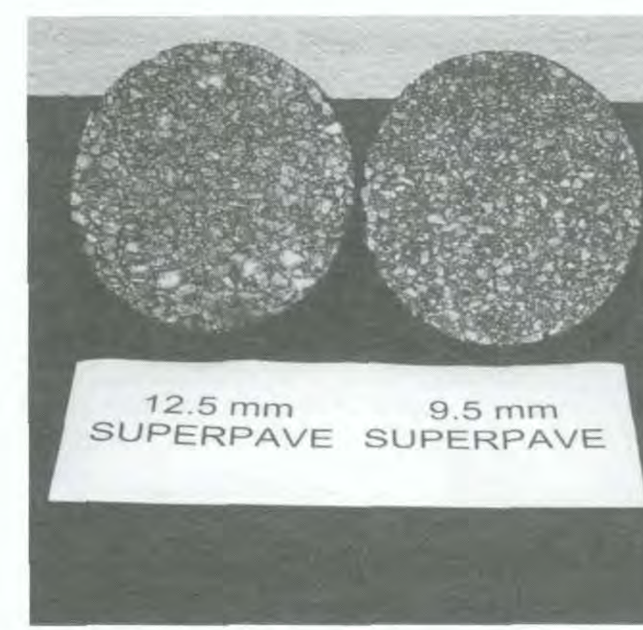
Place mix type only on sound pavement structure. Existing surface should have little or no cracking. Structural deficiencies must be repaired prior to placement.

19.0 mm

When used for surface, place mix type only on sound pavement structure. Existing surface should have little or no cracking. Structural deficiencies must be repaired prior to placement. Mix type can be used as a base or binder course for rehabilitation of asphalt and PCC pavement. Follow general recommendations for surface preparation.

25.0 mm and 37.5 mm

Follow general recommendations for surface preparation.



Samples of 9.5 and 12.5 mm dense-graded mixs.