Information Series 135

NAPA
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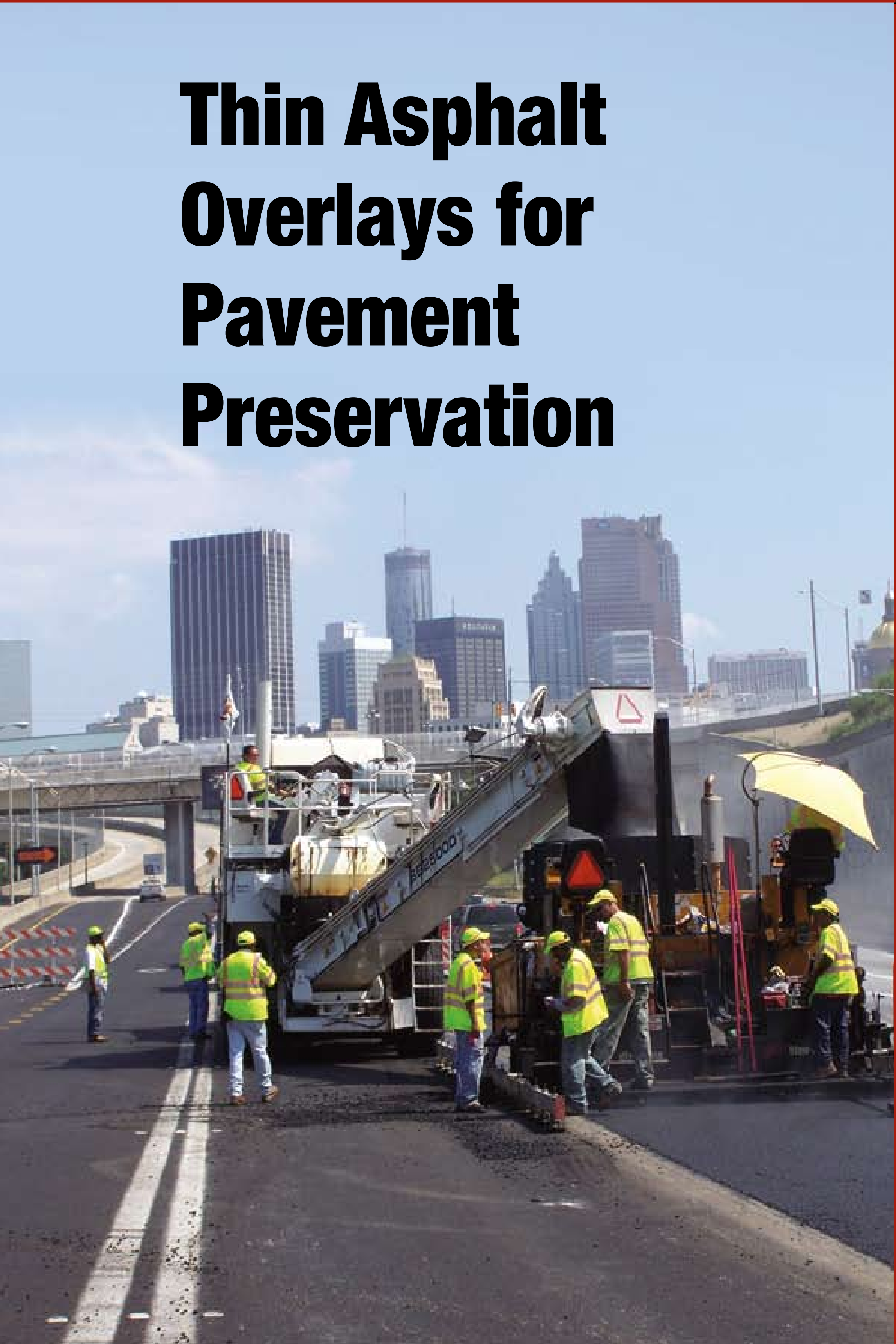
Thin Asphalt Overlays for Pavement Preservation



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Abstract

Owner agencies are seeking more alternatives to major rehabilitation in order to deal with the preservation of their individual systems. A time-proven method of extending the life of pavement structures that are still in serviceable shape is the application of thin asphalt overlays. These overlays are 1.5 inches or less in thickness, and comprised of aggregate having a small nominal maximum aggregate size, generally 12.5 mm or less. There are numerous advantages to using a thin overlay including:

- Long service life and low life-cycle cost when placed on structurally sound pavements
- Ability to maintain grade and slope with minimal drainage impact, particularly with small nominal maximum aggregate size mixtures
- An engineering approach to materials selection and design
- Ability to withstand heavy traffic and high shear stresses
- Smooth surface
- No loose stones after initial construction
- Very little or no dust generation during construction
- No curing time to delay opening
- Low tire-pavement noise generation
- No binder runoff
- Ability to recycle
- Can be used in stage construction
- Easily maintained

These asphalt mixtures should be placed on reasonably sound pavement structures that do not require a structural rehabilitation. Once a project has been slated for rehabilitation using a thin overlay, the materials should be selected according to specifications and project requirements. Good production and construction practices are paramount to obtaining good performance. Warm-mix asphalt may add further benefits by allowing the asphalt mix to be transported further or constructed in cooler weather. Reclaimed asphalt pavement (RAP) should be incorporated into surface mixes to maximize the economy and enhance performance, especially rut resistance. Milling of the existing pavement surface can enhance the overlay performance and provide recycled material for the future. It is expected that a thin asphalt overlay can last more than 10 years on a good, low-distress surface, and from six to ten years on a concrete pavement.

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Thin Asphalt Overlays for Pavement Preservation

CONTENTS

Introduction

Background

Over the last 30 years, transportation emphasis in the U.S. has changed from the construction of new facilities to the renewal and preservation of the infrastructure. As initial and stage construction of asphalt pavements was completed, it was increasingly found that structural enhancements to support traffic loads were not needed as much as functional improvements to provide safety and smoothness. This was especially true for well-constructed thick asphalt pavements where distresses were found to be confined to the upper layers. In order to keep a pavement in service, it was only necessary to remove the top one or two layers and replace them in a mill-and-fill operation. This type of asphalt pavement is referred to as a long-life or Perpetual Pavement. While refinements have been made in structural design that allow Perpetual Pavements to be optimized and constructed, other improvements have been made in materials selection, mix design, and construction of surface layers to improve their performance.

These improvements started in the 1980s with the introduction of polymers in surface mixes to help resist rutting. In 1990, stone matrix asphalt (SMA) was brought from Europe to the U.S. This premium surface

mix combined stone-on-stone contact with tough, angular aggregates to resist rutting and a binder-rich mastic to resist cracking. The result is a pavement surface that can last over 20 years without resurfacing. Also in the 1990s, the Superpave mix design system was introduced and refined. This procedure combined the best features of past practices with respect to materials selection and volumetric measurements with a new laboratory compaction procedure. The result was a mix design tailored to specific functions in the pavement such as resistance to skidding, rutting, and cracking. Other issues came to light in the 1990s that related to construction and performance of surface mixtures. For instance, when coarsely graded, large-aggregate mixes were specified in relatively thin lifts, agencies found that permeability often resulted in lower durability. Deterioration of longitudinal joints became problematic in surface mixes with coarse gradations. In certain instances, temperature differentials occurring in the surface mix resulted in a non-uniform mat and isolated premature failure of pavement surfaces. As these issues emerged, so did strategies for combating them, so that the design and construction of long-life surfaces could be realized.

Finally, in the early 2000s, new technologies were introduced that allowed asphalt mixture temperatures to be reduced as well as allowing for increased use of recycling. Warm mix asphalt has improved the already excellent environmental record of the asphalt industry. Lowering temperatures has decreased emissions and fuel consumption during the production of asphalt mixtures. Material handling processes and improved plant design have both contributed greatly to the increased use of reclaimed asphalt pavement (RAP). These new technologies will undoubtedly have crucial roles to fulfill in pavement preservation through the use of thin asphalt overlays.

According to a 1999 AASHTO survey by the Lead States Team on Pavement Preservation, thin asphalt overlays were the most popular preventative maintenance treatments for asphalt and composite pavements. This popularity has led to a number of studies on the materials, design, and construction of thin overlays in order to optimize pavement preservation strategies. Some excellent research overviews are available on thin-lift asphalt technology including Williams (2006), Cooley and Brown (2003), Xie et al. (2003), Walubita and Scullion (2008), and Chou et al. (2008).

Benefits of Thin Asphalt Overlays

Thin asphalt overlays provide many benefits over competing pavement preservation products, and they enjoy a high public acceptance. Their primary advantages are:

- Long service life and low life cycle cost when placed on structurally sound pavements
- Ability to maintain grade and slope with minimal drainage impact, particularly with small nominal maximum aggregate size mixtures
- An engineering approach to materials selection and design
- Ability to withstand heavy traffic and high shear stresses
- Smooth surface
- No loose stones after initial construction
- Very little or no dust generation during construction
- No curing time to delay opening
- Low tire-pavement noise generation
- No binder runoff
- Ability to recycle
- Can be used in stage construction
- Easily maintained

The relative importance of any of these benefits will vary according to the type of project, location, climate, and traffic. In residential areas, for example, the ability to maintain geometric features and curb reveals will be important, whereas low noise generation will be important on higher-volume urban roads. In any case, pavement preservation with thin asphalt overlays should always be considered for pavements with low to medium levels of surface distress.

Purpose

This technical guide provides information regarding the selection of projects suitable for pavement preservation by thin asphalt overlays, materials selection and mix design, construction practices including quality control, and the performance history of thin asphalt overlays. Thin asphalt overlays as used in this guide are surface mixes of 1.5 inches or less placed on a well prepared surface. The pavement being overlaid may be milled or unmilled, but it should not show signs of structural distress requiring a more extensive rehabilitation.

Pavement Evaluation and Project Selection

Introduction

The decision to apply a thin overlay to an existing pavement surface should be made only after a careful evaluation of the pavement condition and the elimination of the need to perform a structural rehabilitation. In addition to assessing the structural condition of the pavement, the drainage and functional (skid resistance and ride quality) condition of the pavement must also be determined.

Visual Rating

There are numerous pavement management tools and systems that are available to agencies and consultants to determine the condition of existing pavements. Most of these rely on a visual rating of the pavement distresses. These distresses may include:

Raveling (Figure 1) – A loss of fine aggregate in the pavement surface resulting in a coarse and weathered appearance. Expressed as a percent of the total pavement area.

FIGURE 1
Raveling
(courtesy of National Center for Asphalt Technology)

Longitudinal Cracking (not in the wheelpath) (Figure 2) — Cracking resulting from the deterioration of a longitudinal joint or as a result of a crack reflecting through the surface from a lower layer.

FIGURE 2
Longitudinal Cracking (not in the wheelpath)
(courtesy of National Center for Asphalt Technology)

Longitudinal Cracking in the Wheelpath (Figure 3) — Cracking resulting from the application of traffic loads causing excess tensile strains. These cracks may originate either at the surface of the pavement or at the interface with the lower pavement layer.

FIGURE 3
Longitudinal Cracking (not in the wheelpath)
(courtesy of National Center for Asphalt Technology)

FIGURE 4
Tranverse Cracking
(courtesy of Asphalt Paving Association of Iowa)

Transverse Cracking (Figure 4) — Cracking occurring at 90o to the direction of traffic, due to either the expansion and contraction of the pavement surface or as a result from cracks in lower layers reflecting through the surface.

FIGURE 5
Alligator or Fatigue Cracking
(courtesy of National Center for Asphalt Technology)

Alligator or Fatigue Cracking (Figure 5) — Interconnected cracks occurring in the wheelpath resulting from the applications of excessive traffic loads. These normally start as short transverse cracks occurring within the wheelpaths.

Rutting or Shoving (Figure 6) — A distortion of the pavement surface in the wheelpaths resulting from a lack of shear strength in one or more pavement layers.

Thin asphalt overlays are suitable for correcting pavement deficiencies raveling, longitudinal cracking that is not in the wheelpath, and transverse cracking, as these distresses most likely originate at the pavement surface. Longitudinal and transverse cracks should be cored to see how deep the cracking extends into the pavement. In the cases of longitudinal cracking in the wheelpath or alligator cracking, it is suggested that cores be taken from the cracked area to see if the cracking is progressing from the surface downwards, and if so, the depth of cracking. The depth of cracking will dictate the type and extent of surface preparation for the thin overlay. It is imperative that a thin overlay not be used to correct widespread structural

FIGURE 6
Rutting or Shoving
(courtesy of National Center for Asphalt Technology)

distresses such as alligator or longitudinal cracking in the wheelpath that originate deep in the pavement. Extensive structural distress requires a more aggressive rehabilitation approach. If structural problems are confined to a very limited area, then excavation and repair of the area could be conducted as part of the preparation for a thin overlay.

If rutting or shoving is present, it is suggested that the origin of the distortion be ascertained. If it is present only in the surface, then it may be possible to remove the surface and replace it with a thin overlay. If the distortion is deeper in the pavement, then a more extensive rehabilitation is required.

It is recommended that pavement preservation through the application of a thin overlay be considered when the extent of surface distress is as shown in Table 1. The surface preparation depends upon the level and depth of distress present as shown.

TABLE 1
Suggested Approaches to Surface Preparations Prior to Thin Overlay Based on Distresses

Distress Type	*Recommended Investigation*	*Extent*	*Surface Preparation Prior to Overlay*
Raveling	Visual Observation	Up to 100% of Pavement Area	Clean and Tack
Longitudinal Cracking (non-wheelpath)	Visual Observation Coring	Crack Depth Confined to Surface Layer	Mill to crack Depth, Clean, and Tack
Longitudinal Cracking (wheelpath)	Visual Observation Coring	Crack Depth Confined to Surface Layer	Mill to Crack Depth, Clean, and Tack
Transverse Cracking	Visual Observation Coring	Crack Depth Confined to Upper Layers	Mill Surface, Clean, Fill Exposed Cracks, and Tack
Alligator or Fatigue Cracking	Visual Observation Coring	Crack Depth Confined to Surface Layer	Mill to Crack Depth, Clean, and Tack
Rutting or Shoving	Visual Observation Transverse Trench or Coring	Rutting Confined to Surface Layer	Mill to Depth of Surface Layer, Clean, and Tack

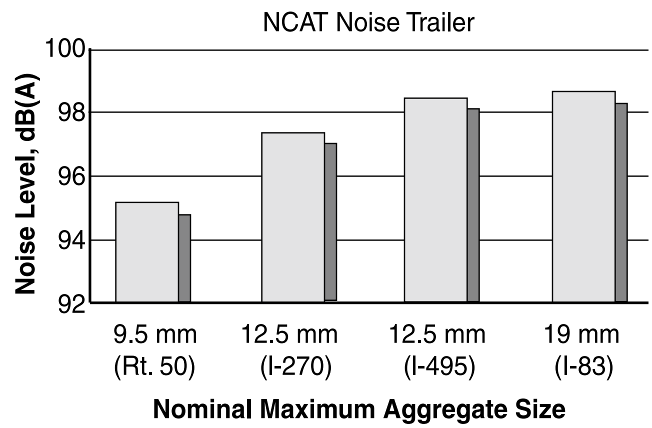
A thin asphalt overlay also may be applied to correct functional problems such as skid resistance, ride quality, and noise generation. Generally speaking, these types of problems are not localized but rather apply over a wide extent of the pavement. In the case of a localized ride quality problem, it may be advisable to conduct a geotechnical investigation to identify particular problems such as frost heave, swelling soil, or leaking water pipes or sewers.

If the existing pavement surface was constructed with a polishing aggregate, or has been subject to bleeding, it may be a candidate for improved friction. The amount of needed friction improvement will depend upon roadway classification, speed limit, geometric considerations, and the presence of cross traffic. Friction improvement can be accomplished with a thin overlay by using a skid-resistant aggregate and a gradation that falls below the line of maximum packing on the 0.45 power gradation chart. This will ensure the appropriate micro- and macro- texture.

Pavement roughness may be due to a number of factors including surface distresses, subgrade behavior, settlement, and utility cuts. The opportunity to improve ride quality with thin overlays improves appreciably with the aid of milling prior to the placement of the overlay. Milling is recommended to improve smoothness because it provides an initial surface leveling, removes surface distresses, provides material that may be recycled, and provides a uniform surface for the overlay construction. Milling can also be used to help maintain drainage features such as curbs and storm-water inlets or drains, and will help avoid edge of pavement drop-offs, loss of bridge clearances, and manhole adjustments due to build-up of pavement overlays. Proper placement and compaction techniques are needed to ensure that the final product provides the maximum service life as smooth pavements last longer. Furthermore, results from the WesTrack experiment (Sime et al., 2000) proved that smooth pavements result in better fuel mileage.

Pavement-tire noise generation is largely a function of the pavement surface macro-texture. Specifically, the coarser the macro-texture of the surface, the noisier the traffic passing over the pavement will be. This is illustrated in Figure 7 where it can be seen that the greater the nominal maximum aggregate size (NMAS), the greater the sound measurement (Hanson et al., 2004).

FIGURE 7
Relationship between NMAS and Tire-Pavement Noise Level
(after Hanson, James, and NeSmith, 2004)



In addition to structural and functional evaluations, an assessment of the drainage conditions should also be conducted. Areas of ponding or poor subsurface drainage need to be identified and corrected by the appropriate grade adjustments or subsurface drainage features prior to overlay.

Once it has been determined that a thin asphalt overlay is viable for the particular application, the surface preparation, materials, and thickness of the overlay should be designed for the climate and traffic anticipated. The surface preparation should be dictated by the distresses that are prevalent in the existing pavement as shown in Table 1, the degree of roughness, or considerations for curb reveal or surface drainage. A tack coat should always be applied in preparation of a thin overlay on an unmilled surface, although it may not be necessary on a milled surface according to some researchers (Tashman et al., 2006) (West et al., 2005). As will be discussed in the Construction section, it may be either modified or unmodified, and the rate of application will be dictated by existing surface requirements. Materials for the overlay should be selected according to the guidance found in the next section, and the NMAS for the mixture should be dictated by the planned thickness.

Materials and Mix Design

Introduction

The proper selection of materials and the mix design approach to thin overlays are crucial to the success of the pavement. Logically, thin overlays will dictate aggregate gradations with smaller NMAS which will require a higher asphalt content than mixes with larger NMAS gradations. The aggregate must be capable of withstanding the design traffic loads without displacement resulting in rutting. Because of the higher aggregate surface area due to the finer aggregate particles, a higher asphalt content is needed to properly coat and bind the aggregate. However, the asphalt content and asphalt grade must be selected so that flushing, rutting, or shoving does not result. The information in this section reflects the results of research and practical experience in producing small aggregate size asphalt mixtures for surface course applications. Although mix design for small NMAS mixtures can range from tried recipes to performance-based rutting criteria, this publication focuses primarily on Superpave volumetric mix design since it is the most commonly used method at this time.

Materials Selection

Aggregate

Table 2 shows the gradation and aggregate quality requirements for a variety of state highway agencies. It should be noted that not all requirements for the different states are listed. For instance, some intermediate sieve sizes are omitted, and in some instances quality measures such as Micro-Deval loss have been omitted. However, one can get a general idea of the mix requirements used in different parts of the country. Also, the table does not show all requirements for all mixture sizes. For instance, mixtures are available for smaller than 12.5 mm NMAS in Alabama and North Carolina.

By definition the aggregate used in a thin asphalt overlay will need to be of a small nominal maximum aggregate size. Since this publication focuses on overlays that are 1.5 inches (37.5 mm) or less, the NMAS must be 12.5 mm or smaller in order for the lift thickness to NMAS ratio to be maintained in the range of 3:1 to 5:1 in order to ensure adequate compaction (Brown et al., 2004). For the 12.5 mm size,

the gradation must be maintained on the upper (fine) side of the maximum density line in order to achieve compaction in a 1.5 inch (37.5 mm) overlay thickness. Other NMAS mixtures typically specified for thin overlays include 9.5 mm, 6.3 mm (New York), and 4.75 mm. Table 2 presents a number of gradations used by various agencies to specify small aggregate sized mixtures.

The quality of aggregate needed is dependent upon the type of pavement being overlaid, the anticipated traffic, and the speed of vehicles using the pavement. Quality for both the coarse aggregate and fine aggregate fractions needs to be specified for 9.5 and 12.5 mm mixes, whereas only the fine aggregate fraction is of concern for the 6.3 and 4.75 mm mixes. Durability in terms of Los Angeles abrasion and sulfate soundness as well as aggregate angularity and shape in terms of the number of crushed faces and flat or elongated particles are commonly specified for coarse aggregates. For fine aggregates, some measures of cleanliness such as sand equivalent values or plasticity index along with fine aggregate angularity are normally specified. As can be seen in Table 2, the requirements for coarse and fine aggregates vary according to locally available materials as well as traffic levels.

Binder

In most cases, the grade of binder is specified according to climate and level of traffic for a particular application. The performance grade (PG) binder system allows the selection of asphalt cement according to the high and low service temperatures and the level of equivalent single axle loads (ESAL). States vary in their practices of specifying either straight or modified binders. Minnesota specifies a straight asphalt binder in its thin lift mixtures. Ohio requires the use of either a polymer modified PG 64-22 or a PG 76-22 grade of asphalt. Although New York specifies a PG 64-22 binder, which would not normally be polymer modified, in their upstate region and a PG 76-22 in their downstate region, an elastic recovery requirement of 60% ensures that only modified binders will be used in either climate. New Jersey also uses a PG 76-22 polymer modified binder for its high performance thin overlay mixtures. It is not unusual to require a polymer modified binder in Europe for small aggregate mixtures according to Litzka et al. (1994). North Carolina specifies the grade of asphalt for surface mixes according to the anticipated ESAL level, using a PG 76-22 grade for the highest and PG 64-22 for the lowest level. It should be noted that currently in North Carolina, the 4.75 mm mixes are specified only for less than 300,000 ESAL and so only PG 64-22 is listed for a binder with these mixes. Most states have taken the general requirements developed under the Strategic Highway Research Program and modified them according to their own needs.

RAP

Small NMAS mixtures lend themselves to the incorporation of fine RAP. The maximum size of RAP should correspond to the NMAS used in the mix. RAP can be used to the degree that will allow the mixture to be produced and still meet the requirements for asphalt mixtures in terms of volumetric properties and performance. It is especially important that aggregate gradation be maintained in RAP mixtures. Generally speaking, when RAP is comprised of only the 4.75 mm and smaller particles, the polishing resistance of the RAP aggregate is not critical since the friction is controlled more by the coarse aggregate in the mixture.

Mix Design for Dense-Graded Aggregates

Normally, small NMAS mixtures to be used in surface courses compact relatively easily due to the fine aggregate size and the higher asphalt content. The compaction and volumetric requirements for 4.75 mm to 12.5 mm mixes for a sampling of states is shown in Table 2. In Maryland and Georgia, 50 gyrations in a Superpave gyratory compactor are required for 4.75 mm mixes to be used on lower volume roadways. Maryland stipulates 65 gyrations for higher volume roads. New York uses 75 gyrations for the 6.3 mm mix, and Alabama uses 60 for all Superpave mix designs. In Utah, the gyration level is set according to traffic level with 50 being the lowest and 125 gyrations being the highest. In thin lift construction on a sound pavement, this means that compaction would be achieved by means of a static compactor in relatively few passes (see Construction and Quality Control section). Thus, a gyration level that is sufficient to achieve aggregate interlock without degradation of the aggregate is desirable.

The volumetric property requirements from the various states in Table 2 shows a range of values and approaches that have been developed for the specific experiences, climates, and locally available materials. Smaller NMAS mix designs are usually characterized by higher asphalt contents, and sometimes, higher air

TABLE 2
Gradations, Aggregate Quality, and Mix Design Requirements for Small NMAS Dense-Graded Asphalt Mixtures

NMAS	***12.5 mm***		***9.5 mm***		***6.3 mm***	***4.75 mm***		
Agency	***Alabama***	***North Carolina***	***Nevada***	***Utah***	***New York***	***Maryland***	***Georgia***	***Ohio***
Gradation								
Sieve Size	**% Passing**							
19 mm	100	100						
12.5 mm	90 - 100	85 - 100	100	100			100	100
9.5 mm	<90	60 - 80	85 - 100	90 - 100	100	100	90 - 100	95 - 100
4.75 mm		28 - 38	50 - 75	<90	90 - 100	80 - 100	75 - 95	85 - 95
2.36 mm	28 - 58	19 - 32		32 - 67	37 - 70	36 - 76	60 - 65	53 - 63
0.30 mm		8 - 13					20 - 50	4 - 19
0.075 mm	2 - 10	4 - 7	3 - 8	2 - 10	2 - 10	2 - 12	4 - 12	3 - 8
Aggregate Quality								
LA Abrasion, % loss	48 max	35 max	37 max	35/40 max[1]				40 max
Sodium Sulfate Soundness, % loss	10 max	15 max	12 max	16/16 max[1]				12
% 2 or More Fractured Faces		85 min	80 min	90/90 min[1]				
% 1 Fractured Face		100 min		95/90 min[1]				10/100 min[1]
Sand Equivalent, % (Fine Aggregate)		45 min		60/45 min[1]	45 min		28/40[2]	
Uncompacted Void Content, % (Fine Aggregate)	43/45 min[1]	40 min			43 min	40 min		
Mix Design								
N_{design}	60		N/A	50 to 125[3]	75	50/65[1]	50	50/75[4]
Design Air Voids			3 - 6	3.5	4.0	4.0	4.0 - 7.0	3.5
%VMA	15.5 min		12 - 22		16 min			15.0 min
%VFA, range				70 – 80	70 - 78		50 - 80	
Asphalt Content	5.5 min	4.6 - 5.6				5.0 - 8.0	6.0 - 7.5	6.4 min

[1] Low or Medium Volume/High Volume
[2] Carbonate/Other Aggregates
[3] N_{design} based on traffic level
[4] Marshall Blows

voids. The minimum value for voids in mineral aggregate (VMA) is increased as aggregate size decreases. Three of the agencies listed in Table 2 specify a range for voids filled with asphalt (VFA). Four out of the seven listed specify either a minimum asphalt content or an asphalt content range. Utah uses a lower design air void content along with a VFA requirement as a means to ensure adequate asphalt content. In some cases, agencies specify a range in air void contents rather than a specific value. As will be discussed in the Performance section of this publication, a higher air void content for a small NMAS mixture is usually not as critical as it is for a larger size mixture because small size mixtures tend to be much less permeable (Brown et al., 2004). For any agency proposing a specification for small NMAS mixtures, it is important to ensure that the mix has sufficient void space to hold the asphalt needed to bind the aggregate together.

Other Mix Types

Thin-lift overlays are not constrained only to Superpave dense-graded asphalt mixes. Marshall mix designs also provide excellent thin overlay mixes as shown by the Ohio Smoothseal specification listed in Table 2. Some of the best performing surface mixtures include 9.5 mm stone matrix asphalt (SMA) as well as 12.5 and 9.5 mm open-graded friction courses (OGFC). SMA mixtures have been recognized as providing a premium pavement surface in terms of its rut resistance, cracking resistance, and durability. A small NMAS provides even less permeability than an SMA made from larger stone. OGFC mixtures are known for providing outstanding safety in their improvement of wet weather visibility, skid resistance, and low tire-pavement noise.

Both SMA and OGFC mixes usually incorporate some form of binder modification, whether it is polymer or asphalt-rubber. In California, polymer modification is specified for binders in thin wearing surfaces. The California Department of Transportation (Caltrans) also specifies a base binder grade for rubberized asphalt mixtures that is one high temperature grade lower and one low temperature grade higher than what is specified for their polymer modified mixtures (Caltrans, 2007).

California (Caltrans, 2007) has a mix which could be considered similar in their gap-graded bonded wear course and rubberized bonded wear course. These have maximum aggregate sizes ranging from 4.75 mm to 12.5 mm. California further requires the assessment of moisture susceptibility using the American Association of State Highway and Transportation Officials test method T-283.

OGFC thin-lift mixtures are made normally with either 9.5 or 12.5 mm NMAS stone. They tend to be more costly per ton than dense-graded mixes because they do not contain other size fractions, but they provide substantial safety benefits. In California (Caltrans, 2007), OGFC mixtures, according to the agency, should contain lime as an anti-stripping agent, regardless of whether it has a polymer modified binder or a rubber modified binder.

Construction and Quality Control

Introduction

Mixes designed for use in thin overlays are essentially standard asphalt mixtures that have a small NMAS stone. In that sense, they are not much different from what a plant produces on a daily basis. However, there are some peculiarities of production, placement, and testing that require special attention due to the behavior of small NMAS mixtures and thin-lift construction. This section will focus on the special issues for thin overlay construction.

Construction

Production

Small NMAS asphalt mixtures have a relatively minor amount, if any, coarse aggregate content. Thus, aggregates are taken out of one or two stockpiles for the most part. Usually, if multiple stockpiles are involved, it has to do with blending natural and manufactured sand. It is important that stockpiling be done correctly in order to maintain the proper gradation. For instance, stockpile segregation from using a stacking conveyor can create gradation variability during production. Excessive gradation variability will create a corresponding volumetric variability leading to portions of the mix that may rut and others that may ravel.

It must also be recognized that fine aggregate usually contains much more moisture than coarse aggregate, and good stockpiling practices should be used to control moisture. Good practice includes: 1) paving underneath the stockpile, 2) sloping the pad away from the plant to drain water, 3) building the stockpile from the wet side and taking from the dry side for truck built piles, and 4) covering the stockpile if necessary to protect it from precipitation. The need to minimize water is more important for plant costs and operations than for product quality.

The plant is generally run slower for small NMAS mixtures than those having larger stone. The reasons for this are 1) coating the fine aggregate which has a greater surface area requiring more asphalt, 2) generally higher moisture content in fine aggregate requiring a longer drying time, and 3) a thicker aggregate veil in the drying or production drum. Removing moisture in the stockpile will benefit plant operations because less fuel will be required to heat the aggregate and this will help increase production. It should be remembered that there is about a 10 percent savings in fuel with every one percent decrease in moisture content. In regular hot mix operations, plant temperatures are generally higher than for other larger stone mixes. This is an instance where warm mix technology might be used to decrease plant temperatures while maintaining quality. When using warm mix technology, it is all the more important to ensure complete drying of the aggregate.

If RAP is to be added to the mixture, then it should be processed for size and consistency. Crushing and screening of the RAP should ensure that the maximum RAP size does not exceed the NMAS of the mixture. The asphalt content of the RAP and the gradation of the RAP should be measured and checked to make sure they are consistent. The lower the variability of the RAP material is for these measures, the greater the quantity of RAP that can be used in the mixture.

Storage of small NMAS mixtures should follow the practice for any asphalt mixture. Silos should be insulated to minimize the temperature drop of the mixture if it is to be held for a number of hours or even overnight. Although segregation is less of a problem in these mixtures, it can nonetheless occur. Thus, it is suggested that truck loading be completed in multiple drops of 3 to 5, depending on the size of the truck. Depending upon the ambient temperature and haul distance, it may be advisable to place a tarp over the bed of the truck to avoid excessive temperature loss or the formation of a surface crust that might lead to temperature segregation during paving.

Warm mix asphalt technologies may be especially advantageous in the production and construction of thin-lift asphalt mixtures. These technologies make

FIGURE 8
Residential Street Where Debonding Occurred at Intersection
(courtesy of David E. Newcomb)

asphalt mixtures more workable and compactable at lower temperatures than traditional hot mix asphalt. Warm mix offers the opportunity to potentially 1) increase the haul distances, 2) pave in slightly cooler temperatures even with thinner lifts, 3) achieve density at lower temperatures, 4) extend the paving season, and 5) pave over crack sealing material while minimizing bumps often associated with these types of overlays. There are a number of other operational and environmental benefits to using warm mix asphalt as outlined in Prowell and Hurley (2007).

Paving

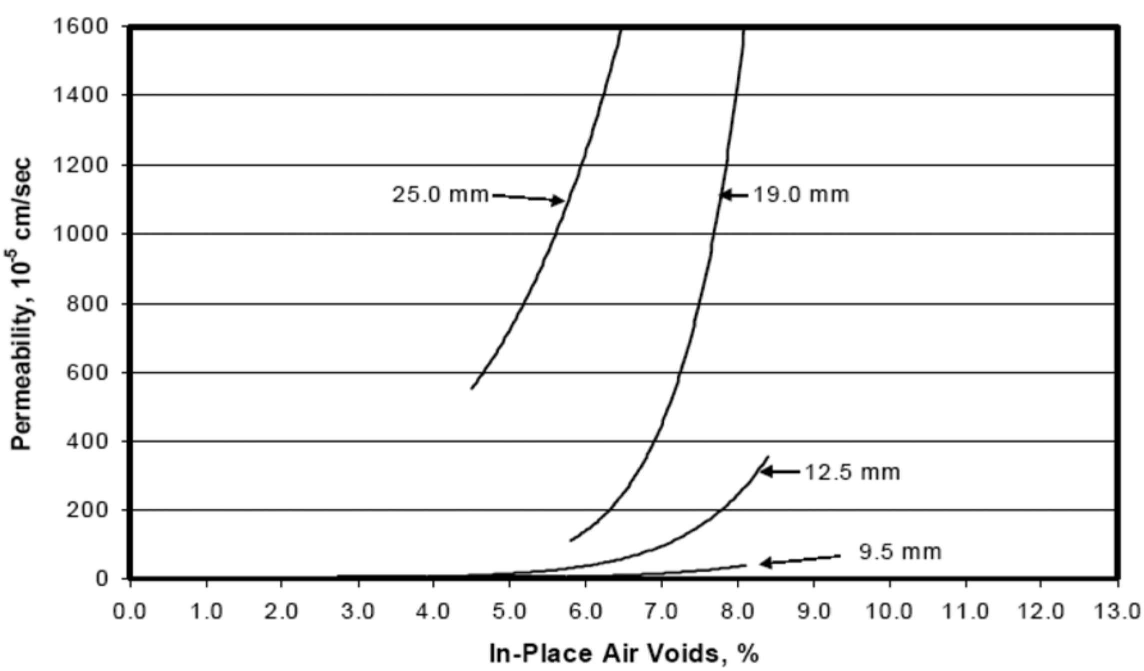
One of the chief concerns of thin lift overlay performance is the bond between the old pavement and the new overlay, and this means that special attention needs to be paid to the surface preparation of the old surface and the application of the tack coat. Beyond this, paving and compaction operations can proceed normally, although the screed control is critical to ensuring the proper mat thickness on layers this thin.

Where it can be done, milling of the old surface will help to remove defects that could reflect through the new overlay and provide the opportunity to achieve better ride quality by paving on a smoother surface. It will help roughen the surface which will provide a greater degree of shear resistance to the pavement surface so it will not be as likely to shove and debond. In fact, research is showing that placing an overlay directly on a milled surface is more beneficial to overlay bond strength than placing a tack coat on an unmilled surface. Using automated grade controls and operating the milling machine at the correct speed will improve the smoothness. Milling will also provide material that can be recycled into new asphalt mixtures. The milling machine should be sized appropriately for the project. Large milling machines traveling over light pavement structures may actually harm the pavement structure by overloading it. Once the milling is complete, the old pavement surface should be swept clean of all debris and dust in order to facilitate bonding.

The tack coat is crucial to bonding the new overlay to the old pavement, especially on unmilled surfaces. Because the overlay is thin, the interface between the old and new pavement is in close proximity to the shear forces created by vehicles during braking and turning movements. Figure 8 shows the effect of a lack of bond on a thin overlay at a residential street intersection. Most specifications require a heavier-than-normal application of tack coat, and in the instance of California (Caltrans, 2007), the tack applicator is specified as being a part of the paver. Some locations such as California (Caltrans, 2007) and Austria (Litzka, et al. 1994) require the use of polymer modified emulsions, while others such as Minnesota use non-modified emulsions. The application rate range varies according to individual states from as low as 0.04 to 0.08 gal/yd^2 for North Carolina to as high as an average of 0.20 gal/yd^2 for California (Caltrans, 2007). Most states have a range closer to 0.10 to 0.15 gal/yd^2. There is no agreement among state specifications on whether the emulsion used in the tack coat needs to have broken before paving. On one hand, not paving until the emulsion had broken will help ensure that moisture does not become trapped in the pavement; whereas it would be impossible for an emulsion to break if it is applied directly ahead of the asphalt mixture as part of the paver. Georgia requires the use of a PG 67-22 hot asphalt for tack applications which avoids issues with breaking.

When paving, it is best to move the paver continuously in order to match the delivery of material from the plant. This prevents starting and stopping which can lead to an uneven surface and result in poor ride quality. If starting and stopping the paver is necessary, then it is best to stop and start rapidly in order to minimize the mat roughness. A material transfer device can act as a material surge chamber to keep up with the material demands of paving as well as providing access to areas where trucks may have difficulty maneuvering. As mentioned above, thin-lift asphalt mixes are usually produced and placed at a higher temperature than larger NMAS mixes. This is because the thin-lift cools much quicker and the material can lose its workability and compactability. A one-inch mat will cool from 300 to 175oF twice as fast as a 1.5 inch mat, substantially reducing the time available to achieve compaction. This is a situation where warm mix asphalt technology can be a definite benefit. Because the mix starts out cooler, it takes longer for the material temperature to drop a comparable amount allowing additional compaction time.

FIGURE 9
Relationship between Air Voids, NMAS, and Permeability
(Brown et al., 2004)



The goal for compaction of a thin lift asphalt surface should be to increase the stability of the mat and to seal the voids in the material to make it as impermeable as possible. With a small NMAS mix, this can be achieved at a lower density than with a larger stone mixture as shown in Figure 9 taken from Brown et al (2004). Although a 4.75 mm asphalt mix is not shown in this graph, the clear trend is for permeability to dramatically decrease with smaller aggregate size. As will be seen below, measurements of density can be elusive with thin lifts. That being said, mat density is best achieved in thin lifts using a static, steel wheel compactor, and many specifications call for these only. In Austria (Litzka et al, 1994), a rubber tired compactor is used with a static steel wheel finish roller. Vibratory rollers should not be used on thin lifts that are less than about one inch because they may cause roughness or tearing of the mat.

Quality Control

Quality control should take place at three points: before materials enter the plant, the mix after production, and the final pavement. It is important to identify potential material problems early so that timely corrective action can take place.

Quality control at the plant for producing small NMAS mixtures is the same as any other asphalt mixture. Aggregate gradation and moisture content should be monitored throughout production at normal rates. Aggregate gradation from single stockpile sources will be more difficult to control than those coming from two or more stockpiles. Moisture content measurements will have a direct impact on asphalt content in drum plants. As such, frequent monitoring of moisture content for fine aggregate stockpiles is advisable, and the asphalt content should be adjusted as necessary to compensate for moisture changes.

During production, the mixture should be sampled and volumetric properties should be checked. The sampling may take place at the plant from the back of the truck or at the paving site either from the paver hopper or behind the paver. Volumetric properties may be checked by compacting the field samples at the same level as used in mix design and measuring the bulk specific gravity of the sample. The maximum specific gravity can be measured on the loose mix. Using combinations of the measurements along with the bulk specific gravity of aggregate, the air voids and VMA can be checked. A portion of the loose sample should be used to determine the asphalt content of the mix and the gradation through the plant. The asphalt content, VMA, and air voids should be tracked with time and a control chart should be developed showing warning limits and action limits.

Although density in the final mat is important, it is difficult to measure, particularly for mats that are one-inch or less in thickness. For thicknesses greater than one inch, thin lift density gauges can be used to obtain in-situ density so long as the devices are properly calibrated for the material on a daily basis. It is often best to use density gauges on this type of pavement construction to monitor the consistency of density. It is difficult to drill and trim cores and obtain an accurate in-situ density measurement in the laboratory. It can be hard to trim a core with the surface layer less than one inch thick. Even if that is possible, there is a likelihood that the test will have a great deal of variability associated with it. It may be best to specify thin lift asphalt construction using a set rolling pattern as is done in New York. As shown in Figure 9, it is not likely that a small NMAS mixture will be permeable, even at a relatively high level of air voids. It is also important to maintain a lift thickness to NMAS ratio of between 3 and 5 to 1 in order to achieve the desired level of compaction (Brown et al., 2004).

One of the objectives of thin lift asphalt construction is to improve the pavement smoothness. The degree to which this can be accomplished will depend upon: 1) the condition of the old pavement surface, 2) the amount of surface preparation prior to overlay, and 3) the thickness of the thin overlay. It is generally thought that a 40 to 60 percent improvement in ride quality can be achieved with subsequent lifts of asphalt mixtures. Thus, the best solution for maximizing smoothness in a thin overlay is to mill the existing pavement to the extent that the effects of cracks and ruts can be removed prior to placement. Any specification for ride quality or roughness should be predicated on the condition of the pavement prior to overlay in order to maintain a realistic expectation of improvement.

Performance

The performance of a thin overlay will depend upon a number of factors including traffic, climate, underlying pavement type, surface preparation, materials, and the construction quality. Higher traffic loads will demand the use of premium materials and construction methods to resist rutting and cracking.

In colder climates, special attention must be paid to resistance to thermal cracking as well as debonding because of the snow plow use. Reflective cracking and debonding are the greatest concerns when overlaying jointed concrete pavements. It is a certainty that reflective cracking will occur in jointed concrete pavements with a thin overlay. For continuously reinforced concrete pavements in good condition with little or no deterioration, reflective cracking would not be as problematic.

The immediate benefits of performance improvement with a thin overlay are the improvement in ride quality, pavement condition, decreased noise level, and, in some cases, friction. Labi et al. (2005) suggest that the immediate benefit to ride quality ranges from an 18 to a 36% decrease in International Roughness Index (IRI), a 5 to 55% reduction in rut depth, and a 1 to 10% improvement in the pavement surface condition rating.

Corley-Lay (2007) stated that noise reduction on overlaid concrete pavements was 6.7 dB on average. The FHWA (2005) reported that thin asphalt rubber overlays in the Phoenix area were successful in reducing noise by about 5 dB. The significance of these noise reduction levels is that every 3 dB decrease is equivalent to doubling the distance from the source of the noise or reducing traffic by half.

Table 3 shows the results of a number of performance studies on thin overlays in a variety of climates, with different levels of traffic and types of underlying pavements. These indicate anywhere from seven to 16 years of performance when thin overlays are placed on asphalt pavements, and from six to 10 years for thin overlays on concrete or composite pavements (concrete pavements previously overlaid with asphalt). In the Ohio study, Chou et al. (2008) considered thin

TABLE 3
Performance Summaries of Thin Overlays

Climate or Location	*Traffic*	*Existing Pavement*	*Expected Performance, yrs.*	*Reference*
Ohio	High and Low	Asphalt	16	Chou et al., 2008
	Low	Composite	11	Chou et al., 2008
	High	Composite	7	Chou et al., 2008
North Carolina	—	Concrete	6 to 10	Corley-Lay and Mastin, 2007
Ontario, Canada	High	Asphalt	8	Uzarowski, et al., 2005
Illinois	Low	Asphalt	7 to 10	Reed, 1994
New York	—	Asphalt	5 to 8	New York Construction Materials Association, undated
Indiana	Low	Asphalt	9 to 11	Labi and Sinha, 2003
Austria	Low or High	Asphalt	≥ 10 years	Litzka, et al., 1994
	High	Concrete	≥ 8 years	Litzka, et al., 1994
Georgia	Low	Asphalt	10 years	Hines, 2009

overlays to be two inches or less, and thus, thicker than the 1.5 inch definition given in this document. The range of expected performance for thin overlays was remarkably consistent from one project to the next, and did not seem dependent upon climate or traffic levels. From these studies, it is apparent that overlays of asphalt pavement tend to last longer than those placed on either concrete or composite pavements.

When compared to other types of pavement preservation treatments, thin overlays are often shown to have the lowest life cycle costs. Chou et al. (2008) concluded that thin overlays on flexible pavements were nearly always cost effective, and that thin overlays on composite pavements were not as cost effective, but, according to the authors that was probably because of greater deterioration prior to overlay. It is significant to note that the Minnesota Department of Transportation received the Asphalt Pavement Alliance Perpetual Pavement Award three years in a row from 2002 through 2004, and that in each of these pavements, thin overlays played a vital role in ensuring the longevity of the pavement structure.

Belshe et al. (2007) concluded that thin asphalt-rubber open-graded overlays in Arizona hold the potential for extending jointed concrete pavement life by reducing the curling stress in the concrete slabs by reducing the temperature differential in the pavement. Bausano, et al. (2004) noted that thin asphalt overlays maintained a high level of service compared to chip seals and crack sealing. In terms of overall performance improvement and longevity, thin asphalt overlays are clearly effective pavement preservation treatments which explains why they are the most popular method of preventive maintenance (AASHTO, 1999).

Summary and Recommendations

Summary

Thin asphalt overlays are popular approaches to pavement preservation primarily because of their ability to 1) provide improved ride quality, 2) reduce pavement distresses, 3) maintain surface geometrics, 4) reduce noise levels, 5) reduce life cycle costs, and 6) provide long-lasting service. As with any preservation technique, thin overlays should be placed before the pavement deterioration has reached a critical stage where more extensive rehabilitation is required. Thin overlays can be expected to provide 10 years or more performance on asphalt surfaces and six to 10 years on concrete or composite surfaces. This document has provided guidance on when to choose thin overlays, how to select materials and design the mixes, construction and quality control, and what type of performance benefits to expect.

Recommendations

Pavement Evaluation and Project Selection

A complete and thorough project evaluation should be conducted to ensure that a thin overlay is the proper approach to fix the pavement. Generally, for thin overlays to be effective, the distress should be confined to the pavement surface and should extend over more than 10 percent of the project. Surface preparation should be dictated by the particular distresses present.

Materials and Mix Design

Binder

The binder should be selected according to the climate and expected traffic. It is recommended that a polymer modified binder be considered for high levels of traffic. Asphalt-rubber has also successfully been used in gap-graded and open-graded applications.

Aggregate

Local availability of materials and traffic levels should be reviewed in selecting aggregates for thin overlays. For high-volume roads where rutting may be a concern, angular aggregate should be used. In all cases, a skid-resistant aggregate should be used.

RAP

Any RAP used in thin asphalt overlay mixes should be processed to a maximum size equal to or smaller than the maximum aggregates size for the mix being used, and it should be used in a proportion that does not impact the gradation requirement.

Mix Design

The mix design parameters should reflect whether the mix is to be a dense-graded Superpave, an SMA, or an OGFC. All three have been successfully used in the design and construction of thin lift overlays.

Construction and Quality Control

Production

Moisture and gradation control of small NMAS mixtures are important issues. Best practices for stockpiling aggregates should be followed. Plant operations are usually slower in producing these types of mixes and production temperatures may be higher. This is an opportunity to explore the use of Warm Mix Asphalt in order to avoid higher temperatures and obtain advantages in placing and compacting thin lift asphalt.

Paving

Preparation of the pavement surface is important to the ultimate performance of the thin overlay. Milling should be considered if roughness or cracking are present. The tack coat is important in providing a good bonding with the old pavement surface, and this will help in resisting shear due to braking or acceleration of vehicles. Paving operations should be as continuous as possible, and compaction, in most cases, should be done in the static mode.

Quality Control

Aggregate quality should be monitored in the typical fashion by testing gradation and moisture content during production. Post production testing should include sampling the loose mix, compacting it in the laboratory to verify volumetric properties and testing for asphalt content. In-situ density testing of thin lift overlays can be problematic although nondestructive devices exist for monitoring the density. These must be calibrated daily. It may be simpler to establish a set rolling pattern for the project.

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