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SYNTHESIS 464

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Thin Asphalt Concrete Overlays

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Thin Asphalt Concrete Overlays

A Synthesis of Highway Practice

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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The project that is the subject of this report was a part of the National Cooperative Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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Cover photo: Construction project in Tifton, Ga. Photo by Don Watson.

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Donna L. Vlasak
Senior Program Officer
Transportation Research Board

This report documents the current state of the practice and research efforts on the use of thin asphalt concrete overlays for pavement maintenance, rehabilitation, and preservation.

This synthesis was performed by conducting a literature review, including both U.S. and international technologies, as well as a survey of state departments of transportation (DOTs) and selected local agencies. Information was also gathered from selected individuals and private industry representatives.

Responses to the survey were received from 47 of 52 states (90%), as well as eight companies from the private industry, 55 of 60 (92%). Case examples from agencies that have had successful experiences with thin overlays are also included. State and local DOTs, as well as industry representatives, will find this synthesis useful.

Donald E. Watson and Michael Heitzman, National Center for Asphalt Technology, Auburn University, Auburn, Alabama, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable with the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

THIN ASPHALT CONCRETE OVERLAYS

SUMMARY

Thin asphalt overlays are extremely useful as a routine maintenance/pavement preservation tool. One of the appealing factors for thin overlays is that they generally are more economical than thicker dense-graded layers. The thin layers allow pavement managers to overlay more lane-miles with the same tonnage. Thin overlays are often shown to have lower life-cycle costs than do other types of pavement preservation treatments. The use of thin overlays has been standard practice for many years for some agencies. In some states, for example, placement of surface courses less than 1.5 in. (38 mm) thick has been performed routinely for more than 40 years, even on high-traffic-volume and heavy-truck routes, such as interstates.

The degree to which thin asphalt overlays are successful depends in large part on the project selection and amount of distress in the existing pavement. Pavements that are failing or have failed cannot be successfully treated with a thin overlay alone; they must be repaired so that a stable foundation is provided before the thin overlay is placed.

The objective of this synthesis is to review the current state of the practice and research efforts on the use of thin asphalt concrete overlays for pavement maintenance, rehabilitation, and preservation. This was accomplished by conducting a literature review of thin overlay use and through a survey distributed to all state transportation agencies; agencies in the District of Columbia, Puerto Rico, and selected Canadian provinces; and selected consultants and contractors. The survey had a 90% response rate from U.S. agencies (47 of 52 agencies) and received eight responses from private industry, for a total of 55 of 60 responses (92%).

Agencies surveyed reported the service life of thin overlays is generally between 7 and 11 years. The reasons most often expressed for the variability are differences in traffic, weather, existing pavement condition (and level of distress) at the time of the overlay, and the use of different quality standards when thin overlays are placed on interstate projects versus secondary and local roads. The variability in service life may also be the result of the wide variety of situations in which thin overlays are used. Twenty-two (40%) survey responses indicated that thin overlays are used on interstate projects; 38 (69%) responses indicated that the overlays are used on primary and secondary routes; and 29 (53%) reported thin overlays are used on low-traffic-volume routes.

Agencies reported several practices that have been observed to improve performance. One practice reported by several survey respondents is selecting the right candidate. Sometimes thin overlays have been used in mill-and-fill operations to surface badly cracked pavements simply because funding was not available to add additional structure or perform the rehabilitation needed. In such cases, the thin overlay is fulfilling a purpose, but it is not expected to have a substantial service life. To give thin overlays a chance for success, agencies reported that such overlays should be applied before structural failure begins. Indeed, much of the success of several agencies is the result of resurfacing with thin overlays early in the deterioration cycle, before extensive rehabilitation is needed. Others reported that it is important

the existing roadway not be rutted or structurally unsound. In addition, the existing surface should not be rough because a thin overlay alone may not be able to correct the distress to the desired smoothness. The proper amount and application of tack coat are needed to create adequate bond with the existing pavement to prevent raveling and slipping, and provide for a long service life. When these practices are followed, thin overlays can be expected to perform well for many years.

CHAPTER ONE

INTRODUCTION

PURPOSE AND SCOPE OF SYNTHESIS

Thin asphalt concrete overlays have become so common for pavement preservation and rehabilitation that their use has become standard practice by many agencies. These thin overlays are accepted practice owing to their numerous advantages (Newcomb 2009). The overlays

- Provide long service life when placed on structurally sound pavements,
- Provide a good riding surface,
- Reduce noise at the tire-pavement interface when fine-graded mixtures are used,
- Maintain grade and slope geometry with little environmental impact,
- Are recyclable, and
- Are easily maintained.

Thin overlays are well established in some states, but other states are just beginning to develop practices and procedures for their use. Little consensus exists on exactly what constitutes a thin asphalt concrete overlay. What some agencies may specify as a minimum layer thickness, other agencies refer to as a maximum layer thickness for surface courses. Likewise, there is disagreement as to when thin overlays should be employed, the materials and mix design to be used, and effective construction practices. With the advent of innovative pavement technologies and greater use of recycled, reclaimed, and alternative materials, it is important to document current experience and practices.

The objective of this synthesis is to review the current state of the practice and research efforts on the use of thin asphalt concrete overlays for pavement maintenance, rehabilitation, and preservation. This synthesis includes a literature review, including both U.S. and international technologies, such as the ultrathin bonded wearing course (UTBWC) process developed in France, as well as a survey of state departments of transportation (DOTs) and selected agencies to determine the current use of thin asphalt concrete overlays. In addition, information has been gathered from selected individuals and private industry representatives who have experience with thin asphalt concrete overlay. The information gathered includes the following:

- Typical agency definitions, thicknesses, design service life, and selection criteria;
- Effect of pavement condition and preparation on performance;
- Current mixtures and mix designs used by agencies;
- Uses as a function of traffic levels and speed;
- Specifications for materials and construction;
- Construction techniques;
- Quality control/quality assurance procedures;
- Performance;
- Agency typical annual lane miles paved and cost information;
- Innovative technologies and reclaimed and recycled (resource responsible) material use; and
- Ongoing research and needs.

SURVEY RESPONSE

A survey was conducted to determine how thin asphalt overlays were used as a pavement preservation tool and for general highway system upgrades. The web-based survey was distributed to all 50 states, the District of Columbia, Puerto Rico, several Canadian provinces, and selected consultants and contractors. Forty-seven of 52 U.S. jurisdictions (90%) responded to the survey, as well as eight companies from private industry, for a total of 55 of 60 (92%).

DEFINITION

Little consensus exists regarding the point at which the thickness of a pavement overlay classifies it as a thin lift overlay because most agencies do not define mixes as "thin" or "non-thin." For example, in Alaska the minimum thickness for an asphalt overlay is 2 in. (50 mm), and four other responses to the synthesis survey indicated thicknesses to 2 in. (50 mm) would be considered a thin overlay. However, in many states a thin overlay is considered to be no more than 1 in. (25 mm). Twenty-four (38%) of the survey responses (Figure 1) stated that a thin overlay was considered to be no more than 1 in. (25 mm) in thickness, with six agencies (11% of the responses) indicating a thin overlay was considered to be less than 0.75 in. (19 mm) thick. Some agencies consider overlays of 1.0 to 1.5 in. (25–38 mm) to be "normal" instead of thin, and practically all surface courses for the agency are within that thickness range. A few agencies responded to multiple categories because the thickness allowed depends on the mix type being used for surfacing. For example, an agency may use an UTBWC at less than 0.75 in. (19 mm) or a 4.75-mm nominal

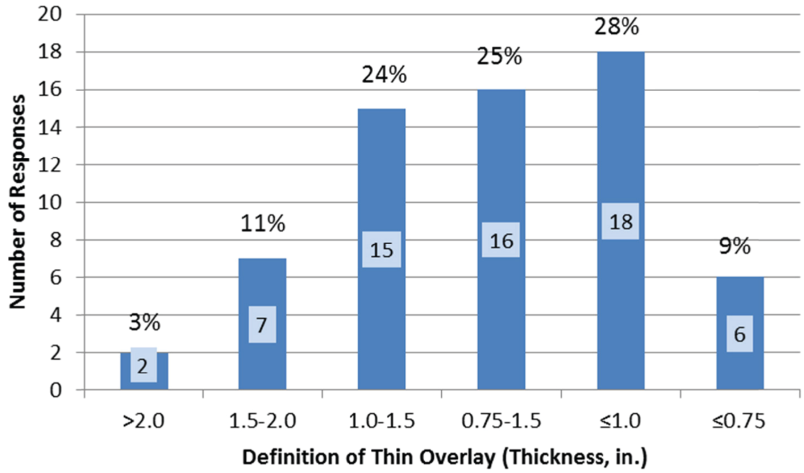


FIGURE 1 Responses to definition of thin overlay. (*Source*: Survey responses.)

maximum aggregate size (NMAS) mix of less than 1 in. (25 mm) thick. For purposes of this synthesis, thin overlays are defined as surface courses typically placed no more than 1.5 in. (38 mm) thick. Based on the survey, 86% (55 of 64) of the responses will fit this definition; however, some agencies responded to more than one category.

BACKGROUND

"As road and highway agencies struggle to do more work with less money, thin overlays are increasingly answering the need" (Anderson 2011).

Many who are responsible for pavement management at the state and local levels have renewed interest in the successful use of thin asphalt overlays to preserve pavement structure and as a form of pavement maintenance. As a result, numerous projects and test sections have been used to experiment with assorted variations in materials and construction methods to find economical solutions for pavement preservation.

Developments in technologies, such as warm mix asphalt (WMA) and use of spray-paver equipment, have also introduced alternative construction methods and materials for evaluation. Although many reports have been written on these trial projects, there is no single report that contains the results of these test projects. Therefore, this synthesis provides valuable information for those who currently use thin asphalt overlays and those who are exploring for the first time the possibility of using thin overlays to meet their pavement needs.

The use of thin asphalt overlays is a relatively new concept in some areas but a well-established practice in others. For that reason, typical experiences in the United States are provided and experiences of agencies in other nations are considered.

PREVIOUS RESEARCH OR RELATED SYNTHESES

The National Asphalt Pavement Association (Newcomb 2009) Information Series 135 is the most recent summary of thin asphalt overlay construction found in the literature search. The report discusses how the character of pavement construction has changed over the years from that of building new roads to maintaining and preserving existing infrastructure. Thus, there is much interest in using thin overlays as a method of extending the available funds for maintenance and preservation so that a greater number of lane-miles can be resurfaced annually. During this same transitional period, new technologies and improved materials have helped extend the service life of asphalt pavements. A 2012 survey on pavement preservation treatments in cold regions (Zubeck et al. 2012) found that in conditions of heavy studded-tire usage, crack-sealing, patching, and thin overlays are the most commonly used treatments. Those treatments are used almost exclusively in moist climate conditions. The average service life of thin overlays and UTBWC mixtures in that environment is 6 years or more.

A synthesis performed for the Montana DOT by Cuelho et al. (2006) summarized survey responses for expected service life and cost per lane-mile for several types of preventive maintenance treatments. Table 1 shows that thin overlays are comparable in cost to chip seals and microsurfacing when the additional service life is considered.

NCHRP Synthesis 260 (Geoffroy 1998) specifically focused on surface treatments and a single layer of hot mix asphalt (HMA) less than 50 mm (2 in.) over an unbound base. The predominant topics examined in the report were pavement type selection and structural design. The questionnaire was distributed to federal, state, and local agencies. More than half of the 286 respondents used thin-surfaced pavements, and more than half of the user agencies were counties. These

TABLE 1
SUMMARY OF EXPECTED LIVES AND COSTS FOR PREVENTIVE MAINTENANCE TREATMENTS

Preventive Maintenance Treatment	Average Service Life (Years)	Cost per Lane-Mile (12 ft wide)
Thin overlay	8.4	$14,600
Double chip seal	7.3	$12,600
Microsurfacing	7.4	$12,600
Slurry seal	4.8	$6,600

Source: Cuelho et al. (2006).

local agencies have limited technical resources and rely on their expertise for pavement type selection and design. The primary factors in the selection and design are traffic volume, funds available, route classification, and truck volume. However, the study focused on new construction and did not evaluate the use of asphalt mixtures in a thin overlay.

NCHRP Synthesis 222 (Zimmerman and ERES Consultants 1995) presented descriptions of the various methodologies used to determine project selection and pavement preservation treatment recommendations. Some of the processes used were found to be highly automated to remove as much subjectivity as possible. The synthesis survey found three predominant strategies for project and treatment selection:

- Pavement Condition Analysis—was based on ratings of current pavement condition;
- Priority Assessment Models—used prediction models to forecast pavement condition, thereby making the method useful for "what if" scenarios with alternative treatments; and
- Network Optimization Models—used prediction models to evaluate the entire network and establish funding needs so agencies could set priorities and decide on treatment selection.

Responses to *NCHRP Synthesis 222* indicated that the most important basis for treatment selection was finding the treatment that most effectively addressed the deficiencies of the existing pavement. Therefore, the benefits of each treatment type are used for selecting the treatment. Those benefits generally relate to total cost, typical service life of the treatment, and life-cycle cost. Other factors, such as pavement condition, functional classification, and type of pavement being overlaid, also were used to evaluate the different treatment options. In some cases, local policies and mandates were important factors.

ORGANIZATION OF SYNTHESIS

A discussion of the various mix types used for thin overlays and their selection criteria is included in chapter two. Chapter three provides information on the design and construction of thin overlays. Chapter four provides findings on how agencies assess performance of thin overlays and how those surfaces are maintained and rehabilitated. Case examples of a few agencies that provided supplemental information are included in chapter five, and conclusions are provided in chapter six. The survey questionnaire is provided in Appendix A, and responding agencies and private industry participants are listed in Appendix B. Appendix C provides questionnaire responses, and Appendix D gives an example of a decision tree matrix provided by the Ohio DOT for the agency's general system flexible pavements. (The decision tree matrix has been reformatted to fit the constraints of page size.)

CHAPTER TWO

USE OF THIN LIFT OVERLAYS

Based on comments by responding agencies, various types of thin overlays are used, and the criteria used for treatment selection is varied. Based on survey responses and supplemental information, it was found that Ohio and California have an extensive evaluation process to aid in selecting the right treatment based on pavement condition.

TYPES OF THIN OVERLAYS

There are several types of mixes that have been used successfully in thin overlay construction. Superpave®-type dense-graded mixes, such as 9.5- and 12.5-mm NMAS mixtures, are common fixtures in most highway applications. Even 9.5- and 12.5-mm NMAS stone matrix asphalt (SMA) mixtures are widely viewed as the premium asphalt mixes for asphalt construction and resurfacing projects. These mixes are designed for stone-on-stone contact to resist rutting and have a rich mortar to provide long-term durability and resist cracking. They cost more than typical dense mixtures but are very cost-effective because the mixes may last more than 20 years without resurfacing (Newcomb 2009).

Another mixture that has gained acceptance within several agencies is the UTBWC, which was originally developed in France. Arkansas uses this mixture exclusively for thin overlays. The UTBWC is a gap-graded mixture with polymer-modified asphalt binder that is typically placed with a spray paver that applies a polymer-modified emulsion tack coat immediately ahead of the paver auger chamber. Arkansas, Illinois, Kansas, Louisiana, Minnesota, and Vermont indicated that UTBWC mixtures are used routinely as an option for thin overlays.

A study at the University of Illinois considered the fracture energy test (ASTM D7313-07b) as a means of evaluating cracking resistance of UTBWC mixes (Sarfraz et al. 2010). Variables such as tack application rate, air void level, and overlay thickness were accounted for in the experiment, and results from roadway cores were compared with those of plant-compacted samples during construction. The results showed UTBWC mixes had greater resistance to cracking than did typical wearing course mixtures.

A dense 4.75-mm NMAS mixture is gaining popularity with many agencies. The fine-graded 4.75-mm mix originally was eliminated from the gradation bands of the Superpave mixture specifications. It was added to the AASHTO specifications in 2002 because of the need for small aggregate size mixtures (West et al. 2006). Yet it is being considered for use so widely in thin asphalt overlays that numerous research projects have been conducted to improve the performance of the mixture. The mixture has continued to gain acceptance after a couple of research studies by the National Center for Asphalt Technology (NCAT). In 2002, a comparison of coarse and fine-graded Superpave mixtures (Kandhal and Cooley 2002) that included 14 mixes with 9.5- and 19-mm NMAS showed no significant difference in rutting resistance between the coarse and fine-graded mixes. If the coarser mixes are not more rut resistant, the use of finer mixes becomes more desirable owing to their being more workable, less permeable, less likely to segregate, and their potential to be more economical because they can be placed in thinner layers.

The same year, research results were made available that helped establish initial criteria for a Superpave 4.75-mm NMAS mixture (Cooley et al. 2002). The research established parameters for design air void level, voids in mineral aggregate (VMA), and voids filled with asphalt for 50 and 75 gyrations.

When SMA technology was introduced to the United States in 1990, many agencies quickly placed experimental projects with 12.5- and 19-mm NMAS mixtures. However, European SMA specifications also included finer graded mixes. In 2003, NCAT conducted research using 4.75- and 9.5-mm NMAS SMA mixtures (Cooley and Brown 2003) and measured rutting potential with the asphalt pavement analyzer (APA) rut testing machine. Rut depths were measured after 8,000 load cycles at two test temperatures. The finer mixes were found to be rut resistant (Table 2), could be placed in thinner layers, and were less permeable than coarser mixes, thus making them good candidates for use in thin overlays.

Thin overlays are not a new idea to Europe; they have been used in Spain for more than 40 years (Luelmo et al. 1971) as routine road maintenance. Luelmo and colleagues cautioned against placing thin layers during cold weather. Sound advice is also given in a Canadian report that recommended using thin overlays only when the existing pavement and base layers are structurally sound (Cewe 1966). Pavements that are failing or have failed cannot be successfully treated with a thin overlay alone; they must be repaired so that a stable foundation is provided before the thin overlay is placed.

TABLE 2
RESULTS OF RUT TESTING ON DESIGNED SMA MIXTURES

SMA Mix Type	Average Rut Depth (mm) at 50°C	Average Rut Depth (mm) at 64°C
4.75/2.36	4.2	5.3
4.75/1.18	2.7	5.4
9.5/4.75	2.8	4.4
9.5/2.36	3.5	5.4
12.5/9.5	3.7	4.5
12.5/4.75	4.1	5.4
19/4.75[a]	1.7	2.6
19/4.75[b]	1.4	2.2

Source: Cooley and Brown (2003).
[a]Design gradation—Phase 1.
[b]Design gradation—Phase 2.

Open-graded friction course (OGFC) mixtures are also used in thin layer construction. The open structure of the mix causes the OGFC layer to remain cooler than dense-graded mixes. A comparison of the effects of mix type on pavement temperature (Watson et al. 2004) showed that the layer immediately underneath OGFC mix was about 4°F (2°C) cooler than where dense-graded mixes were used. This insulation effect was found to extend the life of jointed concrete pavements in Arizona by reducing the curling stress in concrete slabs (Belshe et al. 2007). The OGFC layer effectively reduces the temperature differential between the top and bottom of the slab.

OGFC mixtures have also proven to be useful for reducing roadway noise at the tire-pavement interface. In 1998, Caltrans placed an OGFC layer for the purpose of monitoring noise abatement and started developing a database of various pavement types and noise levels (Rymer and Donavan 2005). Open and dense-graded asphalt mixtures and portland cement concrete (PCC) pavements in both California and Arizona have since been added to the database. The analysis showed that the quietest one-third of the pavements were either OGFC pavements or pavements with crumb rubber included in the mixture. The middle one-third was dense graded with some overlap of OGFC mixtures and some tined PCC pavements. The loudest pavements typically were PCC and large, angular aggregate asphalt mixtures.

TREATMENT SELECTION CRITERIA

Survey respondents from Pennsylvania provided one of the most descriptive criteria used for selecting thin overlays. The agency recommends that thin overlays be used or limited based on the following conditions: "Low to moderate raveling, low to medium longitudinal cracking not in wheel path, temporary short term fix for longitudinal cracking in wheel path (fatigue), low severity transverse cracks (milling is recommended), low severity rutting ≤ 0.50 inches, increase in skid resistance needed, existing pavement in fair to good condition. Not for alligator cracking, not for severe raveling where pavement deterioration exists, and not for rutting > 0.50 inches without correcting rutting first." In Pennsylvania, a fine-graded 9.5-in. NMAS mix is used for overlay thicknesses of 1.0 to 1.5 in. (25–38 mm) and a 6.3-mm NMAS mix is being used in a pilot program for thicknesses between 0.75 and 1.25 in. (19–32 mm).

Most agencies determine when to apply a thin overlay by conducting condition surveys of the existing pavement. As is done in Pennsylvania, the condition surveys generally are performed annually, at least for high traffic or high project classification, or possibly biannually for lower classification roadways. For example, in Illinois thin overlays are allowed only when the existing condition rating is within a certain range. This appears to be a practical approach because if the rating is too low, the structural damage done may not be remedied with a thin overlay. On the other hand, if the condition rating is too high, it may not be cost-effective to place a treatment. Similarly, the Kentucky respondents indicated their agency uses a pavement management system to generate a list of potential candidates and rehabilitation options.

When asked what investigation was done to determine when to use thin overlays, a number of agencies responded that no investigation was made (Figure 2). One reason for this response may be that some agencies have decided as a matter of policy what treatments would be used under certain conditions. However, other agencies said they use more than one approach. For example, an agency may take cores from the existing roadway to determine thickness for a structural analysis and may also schedule milling to remove cracking based on observation of the cores. One agency responded that milling was often planned to restore geometric profile and increase surface texture to improve adhesion of the overlay.

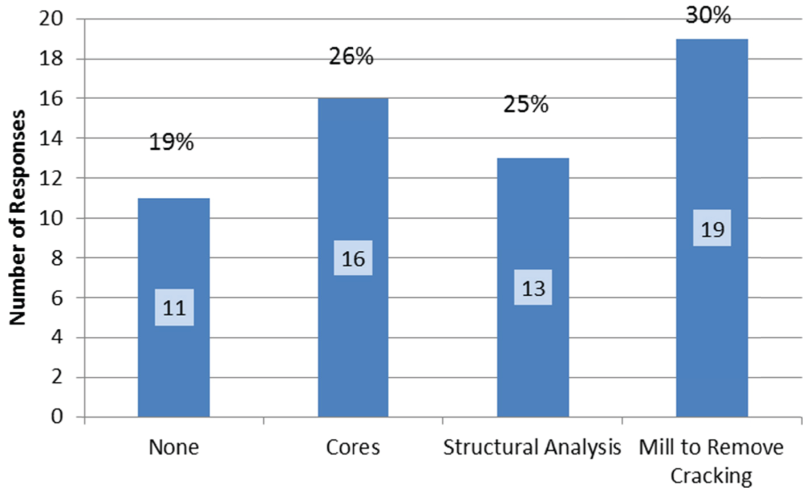


FIGURE 2 Investigation done to determine when to use thin overlays. (*Source*: Survey responses.)

In supplemental information provided during the survey, Ohio respondents described using a decision tree to determine if a project is a candidate for a thin overlay. The decision matrix uses a combination of traffic, pavement condition ratings, and structural deducts to determine if an overlay or other treatment is needed. There is a decision tree for use with primary routes (more than four lanes), and another for use with the general system (two lanes) of roadways. Thin overlays are considered to be cost-effective if the existing pavement condition rating (PCR) score is between 70 and 90 for Ohio's Priority System, and between 65 and 80 for its General System pavements (Chou et al. 2008). An example based on a portion of Ohio's General System decision tree for flexible pavements is given in Appendix D.

A web-based training course (No. 131110) available through the National Highway Institute discusses pavement preservation and in Module 11 describes how to choose various treatments depending on the type of distress being addressed (FHWA-National Highway Institute). The guidelines for the course were based on a Technical Advisory Guide published by the Caltrans Office of Pavement Preservation.

A research project being conducted by NCAT in cooperation with several sponsors will evaluate 25 test sections of a variety of preservation treatment options. The project, which was constructed in 2012, is unique in that all of the test sections are on the same roadway with the same traffic and structural conditions. Control sections with no treatment are also included, so the project can compare the cost-benefit of each treatment to the option of doing nothing (Hunley 2013). Performance curves may also be developed based on the time it takes for each section to deteriorate to the same condition level that existed before the treatment.

One of the sections is a UTBWC mixture placed with a spray paver at 0.75 in. (19 mm) thick. The same thickness is used for comparison on seven test sections with various 4.75-mm NMAS mixes. The 4.75-mm mix sections (Figure 3) include variations in surface preparation, asphalt binder grade (including a highly modified binder), and use of reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS).

New Jersey has compared several mixes used in thin lift surface courses and found that OGFC mixes provide the most benefit for the least cost (Bennert et al. 2005). OGFC mixes performed extremely well at noise reduction, wet friction numbers, ride quality, and cost-effectiveness. The 12.5-mm Superpave mix, which is the standard mix used for overlays, is typically placed a minimum of 2 in. (50 mm) thick, resulting in a construction cost twice as expensive as the OGFC.

Survey respondents were also asked when they would *not* recommend using thin overlays. Not surprisingly, the largest area of response was that such overlays should not be used when there is existing cracking, especially at a medium to high severity level (Figure 4). As a general rule, underlying

Section	18	19	20	21	22	23	24	25
Surface	4.75/PG 67-22	4.75/PG 67-22	4.75/PG 76-22	4.75/PG 76-22	UTBWC	4.75 50% RAP	4.75 5% Shingles	4.75 PG 88-22
Subsurface	Fibermat	Existing	Full-Depth Reclamation	Existing	Existing	Existing	Existing	Existing

FIGURE 3 The 4.75 mm test sections on Alabama Road 159 in Lee County. (*Source*: Cooley et al. 2002.)

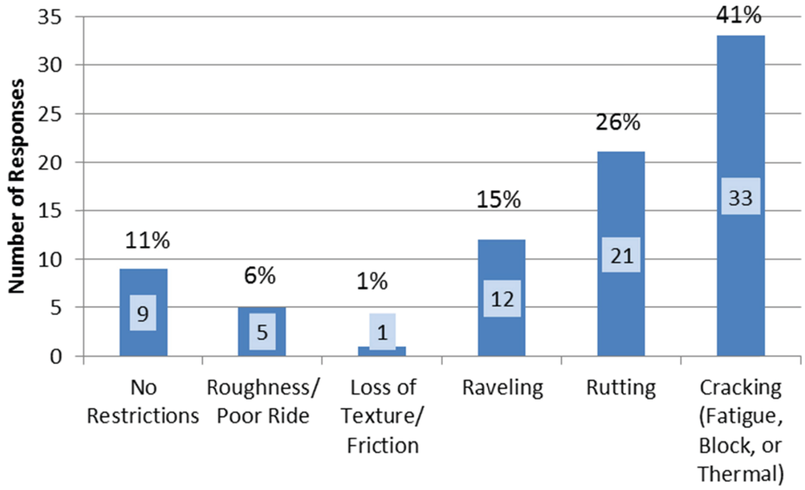


FIGURE 4 Conditions where thin overlays would *not* be recommended. (*Source*: Survey responses.)

cracks propagate upward at a rate of about 1 in. (25 mm) per year. Thus, if asphalt layers are being placed in thin lifts, the cracking can be expected to reflect through to the surface in a short time.

Both rutting and cracking distresses may not be resolved easily with a thin overlay. Rutting, for example, may extend to about 4 in. (100 mm) into the structure. This occurs as the asphalt binder in the pavement begins to soften near the surface from exposure to high ambient temperatures and radiation from the sun. In some cases rutting may be a reflection of unstable base or subgrade underneath the structure. In those cases, a more serious (and costly) approach, including rehabilitation, may be needed. Some current research, such as the high polymer modified asphalt section (Section 25) on Lee County Road 159 may provide useful information about how such a mix can help withstand reflective cracking even in thin layers. Georgia has placed two test sections on the current (2012) research cycle of the NCAT Test Track that will evaluate the effectiveness of different methods for trying to retard reflective cracking. Saw cuts were made to simulate structural block cracking (Figure 5) and covered with surface treatment (chip seal) variations before a thin overlay was placed.

FIGURE 5 Saw-cut sections at NCAT Test Track to simulate structural cracking. (*Source*: Buzz Powell, NCAT.)

CHAPTER THREE

DESIGN AND CONSTRUCTION OF THIN OVERLAYS

Materials, mix design requirements, and construction procedures may have a significant effect on the longevity of thin overlays. Agency specification requirements and construction practices provided through the questionnaire and survey responses were used to identify some of the practices considered to be most useful for successful construction of thin overlays.

MIX DESIGN

The majority of state agencies (72%) use Superpave mix design procedures for designing thin overlays. Of the remaining agencies, the Marshall Mix design method described in Asphalt Institute MS-2 or an agency-specific design procedure is used (such as for UTBWC mix design). In keeping with Superpave criteria, most agencies design thin overlay mixtures in which the optimum asphalt binder content is based on 4.0% air voids.

One of the early concerns with the Superpave mix design system is that implementation was encouraged based on mixture volumetric properties alone. Some agencies (Arkansas, Georgia, Idaho, Illinois, Massachusetts, Montana, New Jersey, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Texas, Vermont, and Washington) have added other performance criteria, such as a rutting test using either the APA or Hamburg Wheel-Tracking Device as a safeguard against possible rutting. A Texas study (Walubita and Scullion 2008) promotes the idea of a "balanced" mix design procedure in which maximum asphalt binder content is determined for which the mixture will be rut resistant, and a minimum asphalt content is needed to ensure resistance to cracking. The range of acceptable optimum asphalt content is within the range that the two parameters have in common. In the research, a Hamburg Wheel-Tracking Test is used to assess rutting potential and the Texas Overlay Tester (OT) is used to evaluate resistance to reflective cracking. The performance tests are conducted on samples at 7.0% ± 0.5% air voids to simulate typical in-place air void levels after construction.

Since the implementation of Superpave in the 1990s, most agencies have found that rutting is no longer the major distress to be dealt with but that cracking is of increasing concern. Numerous research studies are being conducted in an effort to find a reliable test to predict resistance to cracking. Although several tests appear to be promising, currently there is no consensus on one test that appears to adequately and accurately relate laboratory performance to field performance.

Transportation agencies, including those of Alabama, Georgia, Maryland, and others, have found that SMA can be expected to deliver superior performance to conventional dense-graded mixes even on high-traffic, heavy-load conditions. A 12.5-mm SMA mix has been the standard surface mix since the technology was brought to the United States from Europe in 1990. However, the German SMA surface mix is closer to a 9.5-mm NMAS. As agencies consider ways to improve performance with thinner layers of asphalt mix, it is only natural that interest in 9.5- and 4.75-mm SMA mixes has increased. The use of 9.5-mm SMA is routine in Alabama for high-traffic routes (Table 3). NCAT research (Cooley and Brown 2003) has recommended a gradation range for both 9.5- and 4.75-mm NMAS SMA mixes.

MATERIAL REQUIREMENTS

In general, agencies responded that they use the same material specification requirements for thin overlay asphalt mixtures as would be used for thicker layers. For example, if a Superpave mixture would normally be used, the Superpave specifications still apply, and if an SMA mixture is to be used, the same materials specifications that apply for a thicker SMA layer would be used. The only difference may be that a smaller NMAS mixture may be used.

A Kansas study (Rahman et al. 2011) found that aggregate type also may affect performance. The study evaluated 4.75-mm mix placed between 0.6 and 0.75 in. (15–19 mm) thick; after 3 years, the mix composed of crushed gravel aggregates appeared to perform better than did the mixture with crushed limestone.

Most agencies reported they would use the same asphalt binder grade for a project regardless of whether a thin or thick overlay was used. However, Kansas, New Jersey, Rhode Island, and Texas responded that they typically would use a different asphalt binder grade for thin overlays than if a thicker overlay were used on the same project. Most agencies responded that the decision to use modified asphalt usually was tied to traffic volume. For example, Kentucky uses modified binder in surface courses for all interstate routes and roads with more than 30 million equivalent single axle loads

TABLE 3
RECOMMENDED SMA GRADATION RANGES, PERCENT PASSING

Sieve (mm)	9.5-mm NMAS	4.75-mm NMAS
12.5	100	
9.5	90–100	100
4.75	26–60	90–100
2.36	20–28	28–65
1.18	13–21	22–36
0.6	12–18	18–28
0.3	12–15	15–22
0.075	8–10	12–15

Source: Cooley and Brown (2003).

(ESALs) over a 20-year design life, and Montana uses modified binders on all roads with more than 50 daily ESALs. Louisiana, New Jersey, Rhode Island, Utah, and West Virginia reported using modified asphalt in all thin overlay surface mixes.

One area that tends to be different for thin overlays is the use of recycled materials. Although the use of reclaimed asphalt pavement (RAP) and recycled asphalt shingle (RAS) is widely accepted for Superpave mixtures, many agencies do not allow RAP or RAS to be used in SMA and OGFC mixtures. Alabama is one of the few agencies that allow as much as 15% RAP in SMA mixes. Other agencies are beginning to consider RAP use in those specialty mixes. A 2008 study for Georgia DOT (Watson et al. 2008a) compared laboratory performance of four RAP types with four aggregate sources using four RAP proportions from 0 to 30%. The study found that virgin aggregate had a much greater influence on Los Angeles abrasion loss and percent flat and elongated particles than did the RAP aggregate. Higher RAP proportions increased mixture tensile strength values but reduced the fatigue life based on the bending beam procedure of AASHTO T 321. The study found that as much as 20% RAP could be used without significantly affecting performance. One concern with high RAP proportions is that the potential for low temperature cracking may be increased, but in the Georgia DOT study, as much as 30% RAP had little effect on the low temperature properties of the binder.

Texas agency respondents indicated they are considering the effect of allowing RAP and RAS in SMA and fine-graded OGFC mixtures that may be used for thin overlays to 1 in. (25 mm) thick. Each mix was subjected to Hamburg Wheel-Tracking Test and OT laboratory performance analysis, and the study showed that these mixes perform exceptionally well. Results for rutting resistance increased as expected because of stiffness associated with the addition of RAP, yet the resistance to cracking as measured by the OT was still acceptable (Swaner 2012).

In the past, some agencies have been reluctant to use RAP, particularly in surface mixes. However, the economic advantages for doing so are clear. Missouri DOT reported that for the first 5 years after the agency began incorporating RAP in its asphalt mixes, the department had estimated savings of $34 million (Watson 2009).

LABORATORY COMPACTION LEVEL (N_{DESIGN})

Many agencies responded they use the Superpave-specified gyration level for laboratory compaction as specified in AASHTO M 323. Others have conducted research to evaluate the gyration level at which the aggregate structure begins to lock together. That gyration level then becomes the accepted gyration level for their asphalt mixes, especially for mix used in thin overlays. To achieve increased density beyond that point may fracture aggregate particles and create exposed aggregate faces that are uncoated and susceptible to moisture infiltration and stripping. Both Maryland and Georgia use 50 gyrations for compacting 4.75-mm NMAS mixtures used in thin overlays. Georgia, Maryland, and Virginia use 65 gyrations with a Superpave gyratory compactor as the N_{DESIGN} level for other mixtures (including those placed on higher–traffic-volume projects), whereas Alabama has found the aggregate structure essentially locks at approximately 60 gyrations for the aggregate materials that agency uses. This practice generally allows a higher asphalt binder content.

It is recommended that an agency determine the locking point of the aggregate structure in its mixtures and use that number of gyrations for its N_{DESIGN} level, while keeping the binder type the same, especially for thin asphalt overlays. The locking point is defined as the first occurrence at which the specimen height remains the same for three successive gyrations (Watson et al. 2008b). The Georgia DOT study found that the locking point density correlated well with the ultimate density achieved under field conditions. The study also showed that mixtures designed at 60 gyrations had approximately twice the fatigue life as specimens for mixtures designed at 110 gyrations.

TESTING CONSTRAINTS OWING TO SMALL NORMAL MAXIMUM AGGREGATE SIZE OR THIN LAYERS

One of the concerns with standard laboratory testing for thin overlays is that the procedures and specification parameters were often developed for coarser mixes that are placed in thicker layers. For example, is it reasonable to assume that a 4.75-mm NMAS specimen prepared for AASHTO T 283 moisture susceptibility testing in a 6-in. (150 mm) diameter mold at a thickness of 3.75 in. (95 mm) will perform the same when placed on the roadway at 0.75 in. (19 mm) thick?

A limited study for Georgia DOT compared the effect of Marshall samples with that of Superpave gyratory samples

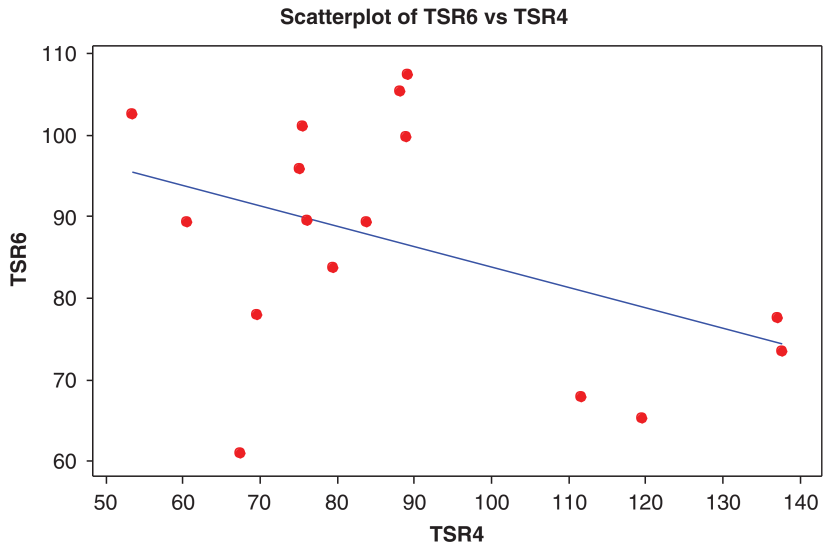


FIGURE 6 Comparison of 4-in. Marshall versus 6-in. gyratory TSR results. (*Source*: Watson et al. 2008b.)

on results for AASHTO T 283 (Watson et al. 2008b). Tensile strength of Marshall samples 4 in. (100 mm) in diameter × 2.5 in. (64 mm) thick were compared with gyratory samples 6 in. (150 mm) in diameter × 3.75 in. (95 mm) thick. A statistical regression showed there was basically no significant relationship between the two results. Increases in tensile strength based on aggregate source with Marshall size specimens had a trend of decreasing strength for gyratory size samples (Figure 6).

These results are of concern particularly because several of the mixture requirements for Superpave mixtures were copied from the mixture requirements developed for Marshall mixtures. Relating current test parameters, and possibly test procedures, to fit the sample sizes actually encountered in the field might be accomplished. For example, laboratory samples for tensile strength prepared according to AASHTO T 283 are 95 mm in thickness. A question arises as to correlation and applicability when those same parameters are used for roadway cores from a pavement layer 1.5 in. (38 mm) thick or less.

PRODUCTION

With fine mixes such as 4.75- and 9.5-mm NMAS mixtures typically used for thin overlays, plant production may be slower because material will need to be kept in the dryer for a longer period to remove moisture. The finer aggregate has more surface area and thus generally has higher moisture content than does coarse aggregate. Private industry respondents have reported that using a storage shelter (Figure 7) for stockpiling fine aggregate, RAP, and RAS will soon pay for the investment with reduced drying costs. Plant diagnostic tools show that a 1% increase in moisture increases drying costs by approximately 10% to 12% while reducing production by approximately 11%. For a plant that produces approximately 150,000 tons of asphalt mix per year, a contractor could save approximately $75,000 annually if sheltered stockpiles reduced moisture content just 1% (Frank 2013).

If RAP is used in production of fine mixes, it may need to be crushed or fractionated so that it meets the maximum size gradation requirements. Although crushing and sizing may not be required, it can be advantageous for a contractor to make the most efficient use of RAP in different NMAS mixtures. RAS material also will need to be shredded to a maximum size for the mix being produced.

Production temperatures may need to be greater for thin overlays because they cool more quickly. When placed, an asphalt mixture begins cooling from both the bottom (existing pavement temperature) and the top (ambient temperature) so that thin layers have reduced time available for the

FIGURE 7 Storage shed for aggregate stockpiles. (*Source*: Randy West, NCAT.)

contractor to obtain density. A 1-in. mat will cool twice as fast as a 1.5-in. mat in the typical compaction range of 300°F to 175°F (149° to 80°C) (Newcomb 2009). For this reason, contractors are finding that warm mix technologies are helpful as a compaction aid, especially in cool weather, because they increase the working window of temperatures at which compaction may be accomplished. However, some agencies have concerns about very low production temperatures with WMA for fear the temperature may not be adequate to completely remove aggregate moisture.

Responding agencies realize that cooler temperatures will limit the capability of the contractor to properly compact thin overlays (Table 4). For that reason, most agencies limit placement based on layer thickness and ambient temperature, and a few also have seasonal limitations. Mississippi, Alabama, and New Jersey allow lower temperatures if an approved warm mix technology is used. Mississippi reported a minimum ambient temperature of 55°F (12°C) is used for placement of thin layers, but for WMA, placement to 40°F (4°C) is allowed. New Jersey and Alabama normally require an ambient temperature of 45°F (7°C) for mix placement but will allow ambient temperatures to 35°F (2°C) when WMA is produced.

CONSTRUCTION

Surface Preparation

For long-term service life with thin overlays, it is essential to resurface a candidate project that has a stable foundation with high severity distresses. Any areas of poor drainage need to be addressed before applying the overlay. The amount of surface preparation needed is dependent on the type and severity of the existing pavement distresses.

Milling has several advantages when used on thin overlay projects. Milling helps to maintain existing grade so that bridge clearances and curb and gutter structures are not adversely affected. Milling equipment may use grade and slope controls to restore geometric shape and improve ride quality. A few states, such as Georgia, Ohio, Oklahoma, South Carolina, and Texas, have smoothness requirements for the milled surface. Those requirements are generally to eliminate isolated high or low spots, and measurements are taken with a straightedge. Georgia was the only state found to use inertial profiler measurements on a milled surface. Agencies need to have realistic expectations about how much improvement in smoothness can be obtained with just a thin overlay. A combination of milling and overlay may be used in such cases to meet smoothness

TABLE 4
MINIMUM TEMPERATURES FOR PLACING THIN OVERLAYS

State	Minimum Ambient Temperature (°F)	Comments	State	Minimum Ambient Temperature (°F)	Comments
AL	>45	>35 for WMA	NC	>40	
AK	>40		ND	>40	
AR	≥55		NE	≥40	
AZ	>70	Surface temp >85	NH	>50	
CA	> Freezing		NJ	>45	>35 for WMA
CO	>55		NM	>60	
DE	>45		NV	>45	
FL		<1 in. = 50; >1 in. = 40; >1 in. = 45 if PG > 76 or ARB-5; WMA = 5°	OH	<1 in. = 60; 1–1.4 in. = 50; 1.5–2.9 in. = 40	
GA	>45	>55 if < 1 in. & for OGFC	OK	>55	
ID	>60	(Surface Temp)	OR	>60	
IL	>45		PA	≥40 for 9.5 mm	Seasonal calendar dates by region
KS	>55		RI	>50	
KY	>45		SC	>45	
LA	>50		TN	>45	
MA	>45		TX	>70	
ME	>50	Seasonal—May 15 to First Saturday after Sept. 15	UT	>45	
MD	>45		VT	≥50	
MO	> Freezing		WA	> Freezing	
MS	>55	>40 for WMA	WV	>50	
MT	> Freezing				

Source: Survey responses.
Agencies listed by postal abbreviations.

expectations. Milling also provides a rough surface texture that improves the bond between the existing pavement and the applied overlay. Another obvious advantage is that milling provides a renewable resource that can be used to reduce production costs and provide a sustainable pavement.

Cleaning the existing surface to remove dirt and silt, and applying a uniform tack coat is essential for helping to create bond between the newly applied surface mix and the existing surface because the interface is so close to the shearing forces caused by traffic braking and turning on it (Hansen 2013). Nine agencies responding to the questionnaire identified the amount of surface preparation as being one of the reasons for large variations in service life.

If the tack coat is inadequate, slippage of the new overlay, particularly in braking areas, may be a significant problem (Figure 8). Based on survey responses, tack application rates vary from 0.02 to 0.2 gal/yd^2 (0.1 to 0.96 L/m^2). The rate varies depending on whether the overlay is dense-graded mix or UTBWC and whether the tack coat is emulsion, asphalt cement, or a special "trackless" type tack coat. The rate may also depend on the type of surface being placed and whether the existing surface has been milled. For example, Tennessee applies 0.08 to 0.12 gal/yd^2 on a milled surface and 0.05 to 0.1 gal/yd^2 on a nonmilled surface; Kansas uses 0.03 gal/yd^2 for 4.75-mm NMAS mix and 0.13 gal/yd^2 for UTBWC; and Louisiana uses 0.12 gal/yd^2 for OGFC. If an emulsion is used for tack coat, the specified rate is usually based on the residual asphalt amount. Georgia found that slippage may be more of a problem when emulsions are used during hot summer paving, and the agency has required asphalt cement for tack coat for the last 30 years.

Placement

With any asphalt mix construction quality is generally improved by maintaining a continuous operation. Most state agencies have some requirement in their specifications to address this issue, and many agencies even require a materials transfer vehicle (MTV) to be used for this specific purpose. An MTV typically has additional storage capacity so that the paving operation can continue even if no truck is present at the construction site. However, there have been projects even with an MTV where the paver was stopped for a significant portion of time because the contractor failed to provide an adequate supply of trucks (Figure 9). The MTV may also contribute to improved smoothness by keeping the delivery truck separated from the paver.

FIGURE 8 Slippage of thin overlay. (*Source*: Don Watson, NCAT.)

FIGURE 9 Paving operation with use of MTV. (*Source*: Don Watson, NCAT.)

For typical dense-graded mixes, responding agencies normally specify a thickness at least three times the NMAS. Most agencies use these same criteria for placement of thin overlays. Florida, Georgia, Indiana, and Louisiana indicated they use 1.5 × NMAS for thin overlays, particularly those less than 1 in. (25 mm) thick. However, layer thickness is often dependent on mix type. For example, respondents of the Florida agency reported they typically use 3 × NMAS as a basis for layer thickness but use 1.5 × NMAS criteria for OGFC mixtures. Alabama, California, Idaho, Maryland, Minnesota, Montana, and Texas responded that 2 × NMAS is typically used for thin overlays. Surfacing with UTBWC may also be in the range of 1.5 to 2 × NMAS. South Carolina's survey response cautioned that using placement rates too low may cause drag marks and other issues. One contractor also responded that placement rates were sometimes too thin for the NMAS being used and that an additional 25 lb/yd^2 would help achieve density and smoothness, thereby providing longer life. Another contractor cautioned against using thin overlays on slow-moving traffic urban roads where such overlays do not perform as well in turning lanes and intersections.

Compaction

Density of the final mat may be difficult to determine, especially for layers less than 1 in. (25 mm) thick owing to the process of coring and sawing the layer. The integrity of such a thin sample may be distorted so that results are not dependable. For that reason, responding agencies report that they generally do not require a certain density level or target value for thin overlays. If the layer is less than 1 in. (25 mm), an agency may specify that the rolling effort must be to the satisfaction of the engineer. Other agencies may even specify the type rollers to be used and the number of passes to make.

It is not uncommon for responding agencies to restrict the use of vibratory rollers in vibratory mode when compacting thin layers because of the potential of fracturing aggregate particles. Steel wheel rollers may be used, or vibratory rollers may be used in static mode. Pneumatic-tired rollers may also be required in an effort to improve density through the kneading action of the roller tires.

For layers greater than 1 in. (25 mm), density is most often controlled by comparing results to the theoretical voidless density. Compaction may also be based on a percent of laboratory density or a percent of a field-established control strip. Some agencies reported specifying more than one method, depending on the mix type and/or layer thickness (Table 5).

Several agencies use nuclear and/or nonnuclear density gauges to evaluate roadway density. Other agencies allow the contractor to use such gauges to monitor compaction during construction but use roadway cores for acceptance testing.

TABLE 5
METHOD OF SPECIFYING DENSITY BY AGENCY

% of Control Strip	% of Lab Density	% of Theoretical	Not Measured-Satisfy Engineer	Not Measured-Rollers and/or Passes Specified
GA	DE	AK	AL	AR
ID	MN	CO	KS	AZ
OH	NH	FL	LA	IN
VT	WA	GA	MS	KS
		IL	NC	ME
		KY	RI	OK
		MA	TN	OR
		MD	TX	TN
		MO		VT
		MT		
		NC		
		ND		
		NJ		
		NM		
		NV		
		OH		
		PA		
		VT		
		WV		

Source: Survey responses.
Agencies listed by postal abbreviations.

Acceptance Criteria

Responding agencies routinely use the same acceptance criteria for thin overlays as for thicker layers with the exception of density for layers less than 1 in. (25 mm) thick. Gradation, asphalt content, plant lab air voids, roadway density, and smoothness are commonly used criteria (see Table 6). Idaho, Illinois, and Mississippi also mentioned voids in mineral aggregate as an acceptance parameter.

Because smoothness is an acceptance parameter for many responding agencies, milling, leveling, or both may be needed to help meet the requirements when thin overlays are specified. As a general rule, only 40% to 60% improvement in ride quality can be expected with a single layer of asphalt mix (Newcomb 2009).

TABLE 6
ACCEPTANCE CRITERIA FOR DENSE-GRADED THIN ASPHALT OVERLAYS

Asphalt Content		Gradation		Plant Lab Air Voids		Roadway Density		Smoothness	
AK	MO	AK	NC	AL	NC	AK	MT	AK	MO
AR	MS	AR	ND	CO	NE	CA	NC	AR	MS
AZ	NC	AZ	NH	DE	NH	CO	ND	CA	MT
CA	NE	CA	NM	FL	NJ	DE	NH	CO	NE
CO	NH	CO	NV	ID	NM	FL	NJ	DE	NH
DE	NM	DE	OH	IL	OR	GA	NM	FL	NJ
FL	NV	FL	OR	IN	PA	IL	NV	GA	NM
GA	OH	GA	PA	KY	RI	KY	OH	KY	NV
IN	PA	IN	RI	MA	TX	MA	PA	IL	OH
KY	RI	LA	SC	ME	VT	MD	WA	IN	OR
LA	SC	MA	TN	MN	WA	MN	WV	LA	PA
MA	TN	ME	VT	MS	WV	MO		MA	WA
ME	WA	MN	WA	MT				MN	WV
MN		MO							
		MS							

Source: Survey responses.
Agencies listed by postal abbreviations.

CHAPTER FOUR

PERFORMANCE, MAINTENANCE, AND REHABILITATION OF THIN OVERLAYS

This chapter provides detailed findings on how transportation agencies assess performance of thin overlays, expectations for service life, and factors used to determine whether thin overlays are considered successful. Some diversity in the DOT responses was expected because the definition of thin asphalt overlay is applied differently from state to state. A thin asphalt surface can range from a simple small NMAS dense-graded mix to a specially formulated OGFC for high traffic (Shatnawi and Toepfer 2003). As such, the expectation of the DOT may vary with the type of application. For example, North Carolina DOT evaluated the use of ultrathin wearing course for jointed plain concrete pavements and used reflective cracking as the measure of performance (Corley-Lay and Mastin 2007). This summary of the performance of thin overlays does not attempt to separate the range of mixes and applications because some of the responses are not specific and could not be classified by mix type.

This section of the report divides the agency responses into the four basic AASHTO climate regions to see if there are any patterns related to climate. The four climate regions were developed during the Strategic Highway Research Program in the early 1990s based on weather station data. The climate regions define the relative degree of precipitation (dry or wet) and low temperature (freeze or no freeze). States that experience more than one climate type were placed in the predominant category. Other reports noted that climate is a factor in the selection of a thin asphalt surface (Irfan et al. 2009; Wang et al. 2012a; Liu and Gharaibeh 2013).

The analysis of the survey data by climate region is limited by the lower number of responses from the agencies in three climate regions. At the same time, an analysis of all the data in a single group would be dominated by the large response from the wet-freeze climate region. The analysis is based on the percent of responses within each climate zone.

The responders were asked how they monitored or verified the service life of thin asphalt overlays. Half of the responses indicated they used a single method, mostly manual condition surveys. The other half responded with multiple methods. Figure 10 combines all responses and expresses the tally based on the percent of responses in each category for each climate region. The use of video records was noted in all four climate regions. The use of deterioration curves to monitor pavement service life had the lowest response. The responses of the industry group expressed a large emphasis on manual condition surveys and no use of deterioration curves or threshold values.

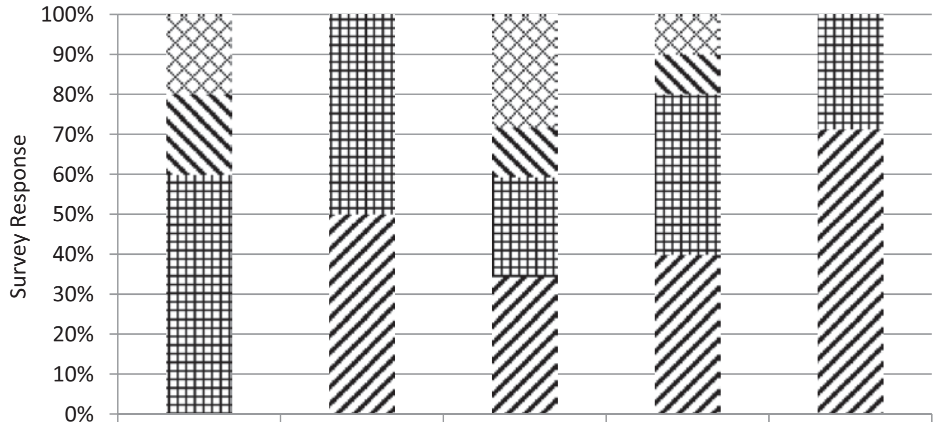
Just as the definition of a thin overlay varies, an agency's measure of service life will depend on the various types of surface (Brewer and Williams 2005). Liu and Gharaibeh (2013) compiled 341 thin overlay test sections from the LTPP GPS and SPS data representing 40 states and eight Canadian provinces. The data were divided into subsets according to the four climate zones based on precipitation and a freezing index. Liu and Gharaibeh observed that climate was a factor in the performance of thin asphalt overlays. Dry-freeze and wet-freeze climates achieved shorter performance life. Moisture had a lesser impact on service life. The analysis determined that the median life expectancy for the four climate groups was 7 years (wet-freeze) to 9.5 years (wet-no freeze). The responses from agencies that participated in this synthesis survey give a similar time frame (Figure 11).

PERFORMANCE STANDARDS AND THRESHOLD VALUES

In Indiana, a Purdue University study (Irfan et al. 2009) discussed three performance measures used to determine overlay treatment life—International Roughness Index (IRI), PCR, and rut depth. It was found that overlay treatments have different service lives depending on the criteria used for the evaluation. The thresholds used and expected service life for thin asphalt overlays is given in Table 7.

MAINTENANCE

One of the options for extending the life of thin overlays is to apply a fog seal. This may be helpful to retard raveling as the pavement ages. The responders were asked how the optimal rate for fog seals was determined. Figure 12 displays the distribution of the responses. The predominant response was no fog seals or rejuvenators are used. There were slightly more responses for the agency standard rate over an application rate based on level of distress.

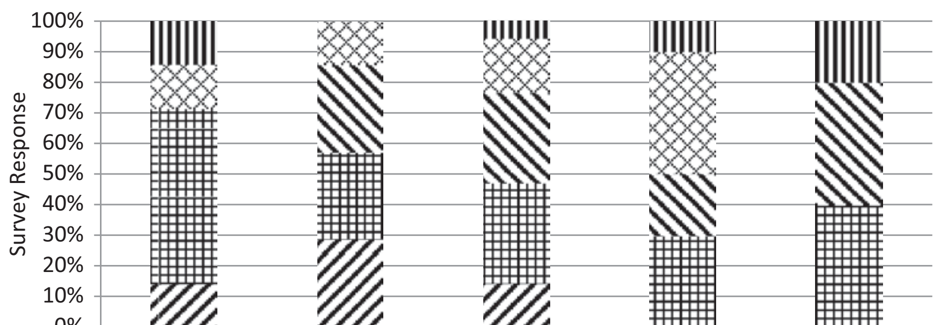


	Dry-Freeze Climate	Dry-No Freeze Climate	Wet-Freeze Climate	Wet-No Freeze Climate	Industry
Threshold	1	0	9	1	0
Curves	1	0	4	1	0
Video	3	3	8	4	2
Manual	0	3	11	4	5

(Chart shows percent of responses from each climatic zone; table shows number of responses.)

Legend Key: Threshold, Curves, Video, Manual

FIGURE 10 How pavement service life is monitored/verified and number of responses for each category. (*Source:* Survey responses.)



	Dry-Freeze Climate	Dry-No Freeze Climate	Wet-Freeze Climate	Wet-No Freeze Climate	Industry
> 12 yrs	1	0	2	1	1
10-12 yrs	1	1	6	4	0
8-10 yrs	0	2	10	2	2
5-8 yrs	4	2	11	3	2
< 5 yrs	1	2	5	0	0

(Chart shows percent of responses from each climatic zone; table shows number of responses.)

Legend Key

>12 yrs. 10-12 yrs. 8-10 yrs. 5-8 yrs. <5 yrs.

FIGURE 11 Reported service life of thin asphalt concrete overlays. (*Source*: Survey responses.)

TABLE 7
EXPECTED SERVICE LIFE OF THIN ASPHALT OVERLAYS

Performance Indicator	Roughness (IRI)	Condition (PCR)	Rut Depth
Threshold used	110 in./mi (1.74 m/km)	85	0.25 in. (6 mm)
Expected life (years)	7–10	7–11	8–11

Source: Irfan et al. (2009).

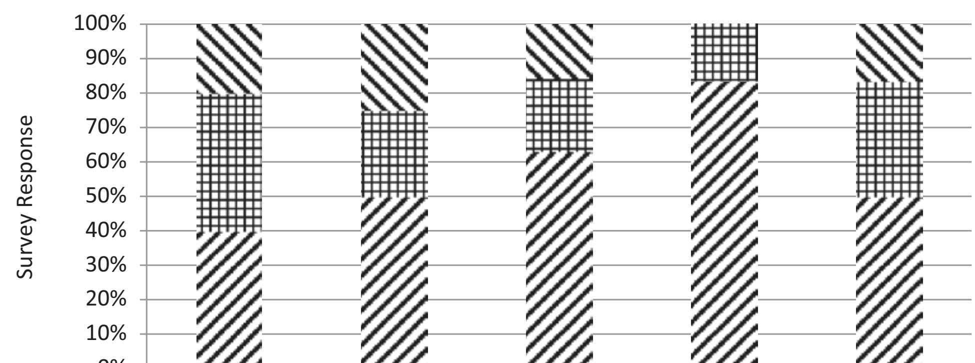
The responders were asked how they determine when special procedures are used to maintain surface condition (Figure 13). As examples, special procedures could include texturing, grinding, or fog seals. The key part of this survey question is "when" the special procedure was needed, not what special procedure was needed. Using the response categories provided in the survey, the results show two categories split a majority of the response. Approximately 35% of the responses indicated no special activities are used, and 35% stated the special activity was based on type and level of distress. Pavement condition rating and smoothness split the remaining 30% of responses. There were only two responses that indicated the agency automatically scheduled intervals. The "no activity" response (35%) for this survey question was noticeably smaller than the response for fog seals (more than 50%). One could conclude that most agencies are monitoring surface condition of their thin asphalt overlays, but aging of the surface (need for a fog seal) is not a priority or that agencies question the effectiveness of fog seals.

COST/BENEFIT OF THIN OVERLAYS

A 2012 study (Wang et al. 2012b) based on survey results from 29 state DOTs compared the extension of pavement life for several preservation treatments for flexible pavements. The study found that thin asphalt overlays were the most expensive initially, but they also extended pavement life the longest. Based on the survey responses, thin overlays extended pavement life an average of 5.4 years; chip seal, 1.9 years; crack seal, 1.7 years; and slurry seal, 1.1 years.

An Oregon study evaluated 87 sites in the state that were treated with different types of materials for preservation treatment (Parker 1993). The study concluded that thin, dense-graded asphalt overlays appeared to be the more cost-effective treatment on a life-cycle basis, particularly in heavy traffic conditions.

Based on the variability in service life reported by agencies, as shown in Figure 14, responders were asked to explain



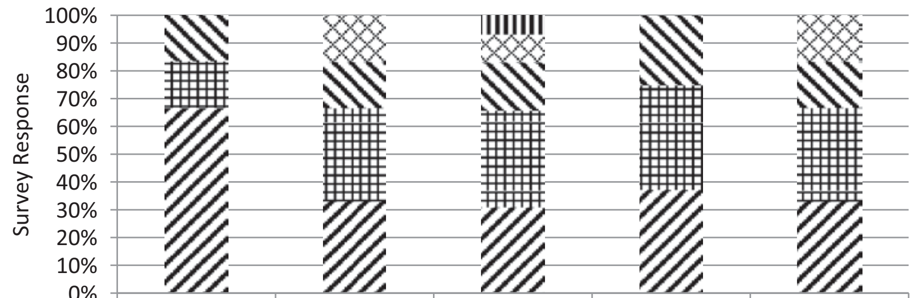
	Dry-Freeze Climate	Dry-No Freeze Climate	Wet-Freeze Climate	Wet-No Freeze Climate	Industry
Distress based	1	1	3	0	1
Standard rate	2	1	4	1	2
Not used	2	2	12	5	3

(Chart shows percent of responses from each climatic zone; table shows number of responses.)

Legend Key

Distress based Standard rate Not used

FIGURE 12 Method used to determine fog seal or rejuvenator application rate. (*Source*: Survey responses.)



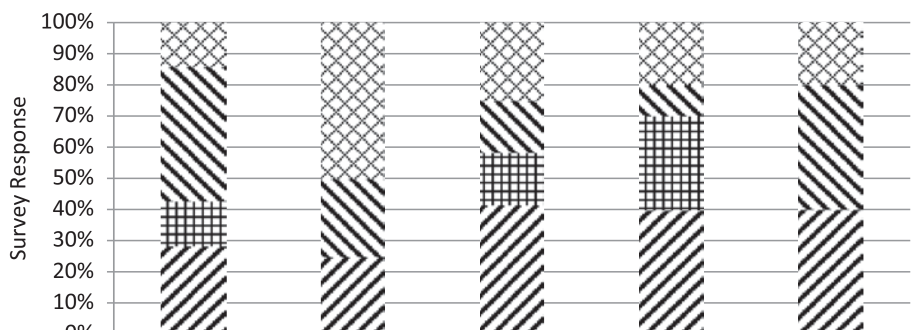
	Dry-Freeze Climate	Dry-No Freeze Climate	Wet-Freeze Climate	Wet-No Freeze Climate	Industry
Automatic	0	0	2	0	0
Smoothness	0	1	3	0	1
Rating	1	1	5	2	1
Distress	1	2	10	3	2
No special	4	2	9	3	2

(Chart shows percent of responses from each climatic zone; table shows number of responses.)

Legend Key

Automatic Smoothness Rating Distress No special

FIGURE 13 Basis for using special procedures to maintain surface condition. (*Source*: Survey responses.)



	Dry-Freeze Climate	Dry-No Freeze Climate	Wet-Freeze Climate	Wet-No Freeze Climate	Industry
Construct. Quality	1	2	6	2	1
Traffic Volume	3	1	4	1	2
Surface Prep.	1	0	4	3	0
Existing Surf.	2	1	10	4	2

(Chart shows percent of responses from each climatic zone; table shows number of responses.)

Legend Key

Construction Quality Traffic Volume Surface Preparation Existing Surface

FIGURE 14 Possible explanations for large range in service life. (*Source*: Survey responses.)

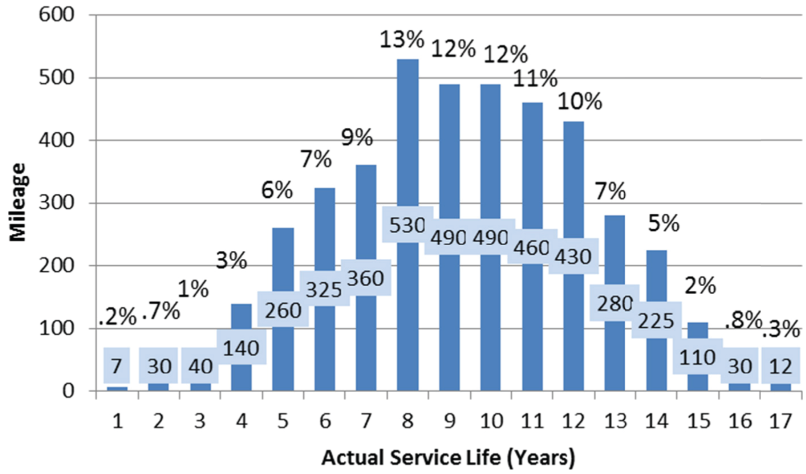


FIGURE 15 Mileage versus service life distribution of thin overlay projects on the general system in Ohio. (*Source*: Chou et al. 2008.)

why there is a large range in service life. Figure 15 summarizes the responses. This question did not attempt to classify types of thin asphalt overlays. It does provide four categorical responses that are common for most paving sections. Most responders identified multiple categories. Similar to the survey response for service life, the response to "why" differs by climate region. Traffic volume and condition of the existing surface are the predominant response in the dry-freeze climate. Construction quality is half of the dry-no freeze response but is based on only two responses. The wet-freeze response noted that condition of the existing surface was important and the other categories were generally equally weighed. The responses in the wet-no freeze climate were similar to the wet-freeze climate, but more concern was expressed about the amount of surface preparation (including selection of the right treatment for the right project). The industry response is similar to that of the DOTs in that variation in construction quality is only 20% of the total.

Other comments given by respondents as to why there may be a large variation in service life were as follows:

- Environmental conditions
- Variations in construction quality standards (interstate versus secondary roads)
- Regional variations in material and construction quality
- Roads needing rehabilitation were only mill and fill because of cost or other factors.

Seven DOTs responded that they had thin asphalt overlay projects that exceeded their expectations. Those agencies were Texas, Kansas, Ohio, Rhode Island, Minnesota, Georgia, and Louisiana. Three DOTs added a comment relative to their response that included the type of thin asphalt overlay. Texas referred to the performance of permeable friction course, whereas Minnesota and Louisiana described an ultrathin bonded wearing course.

Several agencies reported that they had thin asphalt overlay projects that significantly failed to perform as expected. Similar to the answers for the previous question, none of the DOTs in the dry-freeze climate region stated they had experienced a significant failure. In the two wet climate regions and in the dry-no freeze climate region agencies stated they had a significant failure. In all, seven DOTS responded that they had experienced a failure: Arizona, Kansas, Missouri, Ohio, Rhode Island, Georgia, and Massachusetts. Three of these DOTs provided insight to the reason for early failure. Ohio attributed the failures to pavement rehabilitation selection, construction, or traffic load. Massachusetts also identified pavement rehabilitation selection as a critical factor along with surface preparation and adequate tack coat. Georgia's comment implies that reflective cracking was a significant problem.

Tennessee has recently made comparisons in bid prices based on cost per square yard for both microsurfacing and thin lift 4.75-mm NMAS asphalt mixtures in their pavement preservation treatments. A bid comparison (Table 8) shows that thin overlays are competitive in price with the microsurfacing preservation alternative.

TABLE 8
COMPARISON OF TENNESSEE DOT BID PRICES FOR PRESERVATION TREATMENTS

Year	Microsurfacing ($/yd^2)	4.75-mm NMAS ($/yd^2)
2013	2.02	2.24
2011	2.41	1.88
2009	2.15	2.09

Source: Woods (2010).

CHAPTER FIVE

CASE EXAMPLES

Several state transportation agencies indicated in the survey that they had successful experiences with the use of thin overlays. Some of those same states also had experiences in which the thin overlays did not perform as well. NCAT has also placed several thin asphalt sections 0.75 in. (19 mm) thick as part of a pavement preservation experiment. This chapter discusses some of those experiences to determine under what conditions thin overlays are most successful.

OHIO

Ohio DOT has been using thin overlays for maintenance and preservation of its highway system for many years. The agency has found that one of the most significant factors for achieving successful performance with thin overlays is project selection criteria. It is not cost-effective to place thin overlays on existing surfaces that have high levels and high severity of distress. The level of distress is reflected in the pavement condition rating used by most agencies to assist in planning and prioritizing resurfacing and rehabilitation needs. Eltahan (1999, in Chou et al. 2008) found that when the existing pavement was structurally sound and in good condition, pavement life expectancy of a thin overlay was 7.5 years as opposed to only 2.5 years when the existing pavement was in poor condition. The study also concluded that applying thin overlays on surfaces that are in poor condition increases the risk of failure by two to four times. The amount of annual snowfall in cold geographical areas is also partially responsible for lower life expectancy in those areas.

Ohio DOT has developed a decision tree that helps ensure the right treatment is used on the right project depending on the current pavement condition rating. Thin overlays are considered as an alternative for any project with a condition rating less than 80, depending on traffic level and whether structural deductions are noted. In doing so, Ohio DOT has been able to obtain 10 to 12 years of service from their thin overlays. It was also found that comparing service life of a pavement can be misleading because some projects may be resurfaced when the pavement is in better condition. Thus, deciding not to resurface a thin overlay project until it is in poor condition may artificially indicate a long service life (Chou et al. 2008). The terminal threshold for resurfacing with thin overlays is 65 for primary routes and 60 for general system routes. Figure 15 shows actual service life of two-lane general system Ohio projects at the time they were terminated or resurfaced.

Ohio DOT also verified the importance of thin overlays on improvement in smoothness. For flexible pavements, it takes nearly 16 years for the smoothness level of a thin overlay to return to the same International Roughness Index of the existing pavement prior to the overlay (Chou et al. 2008).

The cost of a thin overlay is only about 40% of the cost of a minor rehabilitation project on a primary route and about 60% of minor rehabilitation cost on general system routes. Not only are considerable funding and natural resources saved, but the time required for disrupting traffic flow is greatly reduced.

TEXAS

Texas DOT has had considerable success in using thin overlays and has worked with the Texas Transportation Institute (TTI) to develop fine-graded dense and open-graded mixtures as well as a fine-graded SMA. These mixes may be placed at 1 in., or less, in thickness and can result in savings of 30% compared with the cost of traditional mixes (Dennis 2013).

The thin (¾ in.) porous friction course (PFC) was recently applied on US-183 in Stephens County, Texas (Figure 16) to combat a problem with a “bleeding” surface from a prior chip seal application and reduce road noise. The dense-graded mix was recently placed at 0.5 in. thick on a project near Austin. Such a thin layer makes an overlay cost competitive with chip seals and microsurfacing options. The SMA was placed on a busy intersection project on State Route 6 in the Bryan District. Texas DOT is expecting 10 to 12 years of service life from this thin SMA layer. All three mix types passed Texas DOT requirements for Hamburg testing for moisture and rutting resistance, and the Texas OT, which indicates resistance to reflective cracking.

Specifications for these mixes can be found at www.dot.state.tx.us/business/specifications.htm.

LOUISIANA

Louisiana placed its first UTBWC in 1997. The process, also known as Novachip and Paver-Laid Surface Treatment, uses a special paver that applies a polymer-modified emulsion

FIGURE 16 Thin PFC overlay on US-183 in the Brownwood District of Texas. (*Source*: Cindy Estakhri, TTI.)

tack coat immediately ahead of the mixture. In doing so, the tack coat is applied at a higher rate than conventional tack applications so it can seal the surface and ensure adequate bond to the existing surface. The typical application range is 0.23 ± 0.07 gal/yd^2. The project is just more than 5 miles in length on State Route 308 north of Raceland and compared the UTBWC with conventional hot mix asphalt. The UTBWC layer was placed at 0.75 in. thick, whereas the conventional layers were 3.5 in. thick.

A life-cycle cost analysis was performed that assumed the UTBWC would need to be overlaid a second time in the same 20-year period that the conventional mixes were expected to perform (Cooper and Mohammad 2004). Even so, it was determined that the Louisiana DOT would save approximately \$3.34/yd^2 using the UTBWC. After more than 6 years, the UTBWC was still performing well. As a result, it was recommended that UTBWC be considered on all new or surface rehabilitation projects as an alternative surface for concrete overlays and as an alternate to mill-and-fill operations so long as there is a stable base foundation.

MINNESOTA

Minnesota DOT placed UTBWC on US-169 in Princeton in 1999/2000 at an average of 3/8 in. thick and compared performance to a control section on the same project that consisted of the existing pavement with crack seal and annual maintenance. The project has average annual daily traffic of 15,900 vehicles, including 4% trucks. Cracks in the existing surface were sealed before the overlay. After 6 years, the ride quality of the UTBWC layer was still in good condition, whereas the control section had deteriorated five times faster to the point the section needed rehabilitation or reconstruction (Ruranika and Geib 2007). After 7 years, the UTBWC had some transverse reflective cracking but the cracks were still tight.

GEORGIA

For years, Georgia DOT has made efficient use of thin overlays. A long-time goal of resurfacing 10% of its paved roads each year has allowed Georgia DOT to keep its highway system in good condition by applying thin overlays relatively early in the pavement deterioration cycle. In the 1990s, Georgia DOT also implemented the use of SMA surface courses on interstate projects. During that time, the agency learned that the use of polymer modified asphalt binder and fiber stabilizers to improve durability and eliminate drain-down in SMA mixtures could improve OGFC mixtures as well. This combination of dense SMA surface course with an OGFC overlay to provide water drainage that reduces the potential for hydroplaning and back-spray has proven to be a successful combination. This SMA/OGFC combination was used on a major resurfacing project on I-75 and I-85 in Atlanta just before the 1996 summer Olympic Games. A portion of the project through the heart of downtown Atlanta carries approximately 300,000 vehicles/day and was resurfaced after 16 years (Figure 17). Another portion of the project is being scheduled for resurfacing after 18 years.

During the mid-1990s, Georgia DOT began to use a coarser-graded OGFC mixture (referred to as porous European mix, or PEM) based on European specifications, and increased the

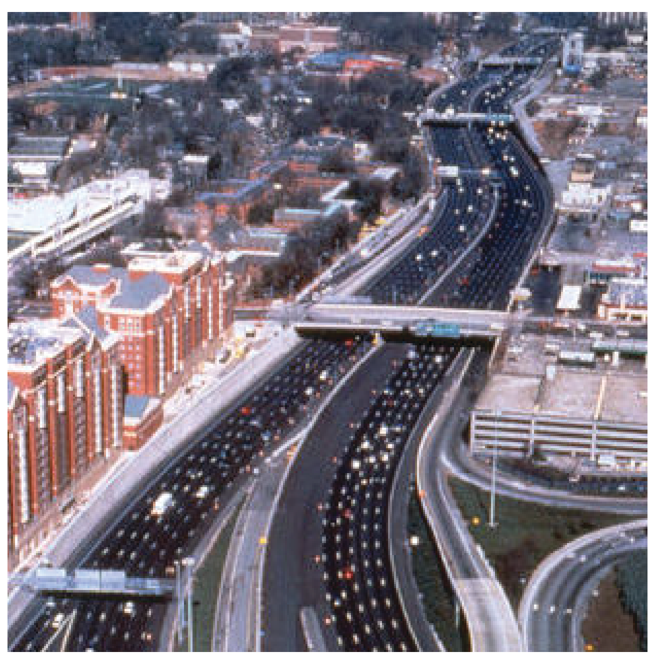


FIGURE 17 I-75/85 Connector in downtown Atlanta with OGFC. (*Source*: Georgia DOT.)

layer thickness from 0.8 in. to 1.25 in. The changes were made to further increase the drainage capacity of the porous surface course across multiple lanes.

NATIONAL CENTER FOR ASPHALT TECHNOLOGY

NCAT, with significant support from several sponsors, has constructed special test sections for 4.75-mm mix on a local county road near Auburn, Alabama. Trucks from a rock quarry and an asphalt plant use the road, so the heavy loading will be a challenging test for each of the sections. Control sections with no treatment are also included, so there will be the capability to compare the cost-benefit of each treatment to the option of doing nothing (Hunley 2013). Performance curves may also be developed based on the time it takes for each section to deteriorate to the same condition level it was at before the treatment. One of the sections is a UTBWC mixture placed with a spray paver at 0.75 in. (19 mm) thick. The same thickness is used for comparison on seven test sections with various 4.75-mm NMAS mixes. The 4.75-mm mix sections include variations in surface preparation, asphalt binder grade (including a highly modified binder), and use of RAP and RAS. One of those sections has as much as 50% RAP, and another has a high polymer concentration (PG 88-22). This research project will continue to be monitored for several years to document service life of various treatments and determine cost-benefit scenarios.

CHAPTER SIX

CONCLUSIONS

The objective of this synthesis is to review the current state of the practice and research efforts on the use of thin asphalt concrete overlays for pavement maintenance, rehabilitation, and preservation. This synthesis was performed by conducting a literature review and a survey of state departments of transportation (DOTs) and selected agencies to determine the current usage of thin asphalt concrete overlays. Information has also been gathered from selected individuals and private industry representatives who have experience with thin asphalt concrete overlay. Responses to the survey were received from 47 of 52 U.S. agencies (90%) and eight companies from the private industry (total, 55 of 60 or 92%). Case examples from agencies that have had successful experiences with thin overlays are also included.

SUMMARY OF FINDINGS

From information gathered during this synthesis, it is evident that thin asphalt overlays are being used more frequently as a routine maintenance/pavement preservation tool. Thin overlays have several benefits that make them attractive for most agencies, and in numerous cases it was found that thin overlays have been standard practice for many years. For example, in Georgia and Alabama, placement of surface courses no more than 1.5 in. (38 mm) thick has been performed routinely for more than 40 years, even on high–traffic-volume and heavy-truck routes, such as interstates. Alabama has successfully used 9.5-mm stone matrix asphalt (SMA) mixes on high-traffic facilities to enhance performance of thin overlays. The revision of AASHTO specifications in 2002 to include gradation parameters for a 4.75-mm mix has also expanded the use of such overlays.

Respondents report that one of the appealing factors for thin overlays is that these overlays are more economical than thicker dense-graded layers. The thin layers allow pavement managers to overlay more lane-miles with the same tonnage. As a result, thin overlays are often shown to have lower life-cycle costs than do other types of pavement preservation treatments (Newcomb 2009). It was also shown that the benefit of thin overlays in improving ride quality is highly significant because ride quality is the most noted factor by the traveling public for evaluating quality of performance. Ohio DOT determined that thin overlays perform as long as 16 years before smoothness levels digress to the point they were at before the overlay (Chou et al. 2008).

Thin open-graded friction course (OGFC) overlays can also extend the life of concrete pavements. By acting as an insulation layer, OGFC reduces the curling stress in concrete pavements caused by large temperature differentials from the top to the bottom of the pavement structure.

The degree to which thin asphalt overlays are successful depends in large part on the project selection and amount of distress in the existing pavement. Pavements that are failing, or have failed, cannot be treated successfully with a thin overlay alone; they must be repaired so that a stable foundation is provided before the thin overlay is placed. When agencies were asked where they would *not* recommend placing thin overlays, the largest response was not to use thin overlays on projects that have moderate to severe cracking.

As with thicker layers and coarser mixtures, the decision to use modified asphalt binders for thin overlays is generally based on traffic volume or axle loading. Many of the parameters used for Superpave, SMA, and OGFC in the past are also applicable to mixtures for thin overlays. Although increasing proportions of reclaimed asphalt pavement (RAP) are being researched and implemented in Superpave mixtures, there are only a few instances in which RAP is allowed in SMA and OGFC courses.

The finer aggregate also has a potential to have higher moisture content as a result of the increased surface area of fine particles. Contractors have found that substantial savings can be realized by placing stockpiles of fine aggregate and RAP under shelters to minimize the amount of moisture absorbed during rainfall.

Contractors have also discovered the thin overlays cool much faster than do thicker layers. For that reason, and to help with drying issues, the contractor may need to produce the mix at a higher temperature to maintain workability until it can be adequately compacted. The use of warm mix asphalt technology may allow the contractor to lower production temperatures and still maintain workability.

An adequate and uniformly applied tack coat is essential to the success of thin overlays. Raveling and slipping of the surface course at the interface with the existing pavement are common problems when tack coats are insufficient or when they are applied in streaks.

It is difficult to determine accurate density on thin layers, especially those less than 1 in. thick. Normally, a core would be taken and the layer in question would be sawed off, but for such thin layers this process may distort the sample and make the test results unreliable. Therefore, several agencies have provisions designating that the degree of compaction is not measured, but rolling is left up to the satisfaction of the project engineer. In other cases, the type of roller and number of roller passes are specified.

Agencies reported the service life of thin overlays is generally within 7 to 11 years, although some states reported service life beyond 12 years. The reasons most often expressed for the variability are differences in traffic, weather, existing pavement condition (and level of distress) at the time of the overlay, and the use of different quality standards when thin overlays are placed on interstate projects versus secondary and local roads.

An Ohio study (Chou et al. 2008) determined that thin overlays cost only 40% of the expense of a minor rehabilitation on primary system projects and 60% of the minor rehabilitation expense on general system routes. Not only do thin overlays save on materials costs, but there also is a significant reduction in time delays for motorists and disruption to traffic flow.

SUGGESTIONS FOR FUTURE RESEARCH

Although modified asphalt has been used in thicker courses placed on more severe traffic and load conditions, the use of modified asphalt with thin overlays was inconsistent from state to state. It was noted during the survey that several agencies do not use modified asphalt in thin overlays in an effort to minimize the cost of the mixes. Meanwhile, other agencies use modified asphalt as a way of extending the life and improving performance of the mixes. Research could evaluate the use of modified asphalt binder in thin asphalt overlays to determine the cost-benefit in terms of initial construction cost and in relation to improvements in performance. Any improvements in performance or service life from the use of modified asphalt in thin overlays could be validated for various geographical and climatic areas.

One of the main concerns with the use of thin overlays is the potential for reduced performance as a result of reflective cracking from underlying layers. Research might compare the various laboratory crack prediction tests under a variety of simulated field conditions. In this manner, one crack initiation test may be found to better correlate laboratory performance to field performance. A cracking test might be developed for thin overlays that can assess the potential for a mix to resist cracking at the mix design stage so crack susceptible mixtures can be identified before the mixture is placed on the roadway.

Some of the laboratory test procedures used for mixtures placed in thick layers are not reliable for mixtures placed in thin layers. A research investigation might be conducted that relates test results for specimen size and thickness used in the laboratory to the specimen thickness that would be encountered on field projects. In many cases, results of density and tensile strength tests performed on thin layers are not reliable.

To further reduce the cost of thin overlays, research might investigate the use of RAP and/or recycled asphalt shingle (RAS) material in SMA and OGFC mix designs. Because the asphalt binder is the most expensive component of the mix, the binder contribution from RAP and RAS may reduce the cost of thin overlays considerably. Although the use of RAP and RAS is common in typical dense-graded mixtures, it is not as common in SMA and OGFC mixtures. Additional research might address durability concerns regarding the use of high RAP proportions in thin layers.

ACRONYMS

APA	Asphalt pavement analyzer
DOT	Department of transportation
ESAL	Equivalent single axle load
IRI	International Roughness Index
HWTT	Hamburg Wheel Tracking Test
MTV	Materials transfer vehicle
NCAT	National Center for Asphalt Technology
NMAS	Nominal maximum aggregate size
OGFC	Open-graded friction course
OT	Overlay tester
PCC	Portland cement concrete
PCR	Pavement condition rating
PFC	Porous friction course
RAP	Reclaimed asphalt pavement
RAS	Recycled asphalt shingles
SMA	Stone matrix asphalt
TTI	Texas Transportation Institute
UTBWC	Ultra-thin bonded wearing course
VMA	Voids in mineral aggregate
WMA	Warm mix asphalt

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APPENDIX A

Survey Questionnaire

1. What is your agency's definition of "thin" asphalt concrete overlay? Check all that apply.

- [ ] May be greater than 1.5 inches
- [ ] 1 inch to 1.5 inches
- [ ] 0.75 to 1.5 inches
- [ ] Less than 1 inch
- [ ] Less than 0.75 inches

Other (please specify):

2. What investigation is done to determine when to use thin asphalt concrete overlays ? (If you check more than one item, please provide a comment indicating where the different criteria are used.)

- [ ] No investigation is done
- [ ] Cores are taken to determine what rehab may be needed
- [ ] A structural analysis is done to determine adequate structure is provided
- [ ] The surface is typically milled to remove top-down cracking

Other (Please specify):

3. Where are thin overlays used?

- [ ] Interstate
- [ ] Primary & secondary routes

- [ ] Local routes
- [ ] Low traffic volume routes

Only for certain types of pavement distress (please specify):

4. How does your agency determine what mix type will be used [based on Nominal Maximum Aggregate Size (NMAS)] for thin overlay applications? (If you check more than one item, please provide a comment indicating what criteria are used.)

- [ ] Based on traffic volume or functional classification
- [ ] Based on thickness/NMAS ratio of 2:1
- [ ] Based on thickness/NMAS ratio of 3:1
- [ ] Based on economic conditions/budget constraints

Other (please specify):

5. Is this mix typically used even when there are sufficient funds to place a thicker layer?

- [ ] Yes
- [ ] No

6. Under what pavement conditions would you NOT use thin asphalt concrete overlays? (Describe severity level at which thin overlays would not be used.)

- [ ] No restrictions
- [ ] Roughness/poor ride

☐ Loss of surface texture/low friction

☐ Raveling

☐ Rutting

☐ Cracking (fatigue, block, or thermal)

7. What requirements are used for aggregates used in thin asphalt concrete overlays? (Attach specification if you prefer.)

☐ Superpave Criteria (AASHTO M323)

☐ SMA Criteria (AASHTO M325)

☐ Agency specific

Other (please specify):

8. Is the same asphalt binder grade used for thin asphalt overlays as would be used on the same project for thicker overlays?

○ Yes

○ No

9. Are modified asphalt binders used? If so, under what conditions?

☐ Modified binders are not used

☐ Based on classification/function (Interstate, primary route, etc.)

- [ ] Based on traffic volume or ESAL; specify criteria
- [ ] Based on condition of existing pavement

Other (please specify):

10. Are Recycled Asphalt Pavement (RAP) and/or Reclaimed Asphalt Shingles (RAS) allowed in thin asphalt concrete overlays? If so, what amounts (or under what conditions) may RAP and RAS be used?

- [ ] RAP/RAS not allowed in thin overlays
- [ ] RAP limited to 15% in thin overlays
- [ ] RAP limited to 25% in thin overlays
- [ ] RAP limited to 50% in thin overlays
- [ ] RAS limited to 5% in thin overlays
- [ ] RAS limited to <10% in thin overlays
- [ ] RAP/RAS limited based on recovered binder properties

Other (please specify):

11. If RAP/RAS are used, how is the amount of binder contribution determined?

- [ ] Solvent extraction
- [ ] Ignition oven
- [ ] Based on a percentage of the recovered binder
- [ ] Back-calculated using the *G*mm value

Other (please specify):

12. What mix design method is used?

- ☐ Superpave (AASHTO R 35/T 312)
- ☐ SMA (AASHTO R46)
- ☐ Marshall (AASHTO T245)
- ☐ Hveem (AASHTO T 246)
- ☐ California Kneading Compactor (AASHTO T 247)

Other (please specify): ______

13. What air void level, or range of air void levels, is used to determine optimum asphalt content?

- ☐ <3.5%
- ☐ 3.5–4.5%
- ☐ 4%
- ☐ 4%–5%
- ☐ 4%–6%

Other (please specify): ______

14. What laboratory performance tests are typically required? (If different from AASHTO, please provide a copy.)

- ☐ Moisture Susceptibility (AASHTO T 283)
- ☐ Rutting Susceptibility (AASHTO T 340—Asphalt Pavement Analyzer)
- ☐ Rutting Susceptibility (AASHTO T 324—Hamburg)

☐ Flow Number (AASHTO TP 79)

☐ Dynamic Modulus (AASHTO TP 79)

Other (please specify):

15. Are there restrictions on placing thin layers during cold weather? If the restrictions are different for "hot" and "warm" mix, explain.

☐ No restrictions

☐ Must be above freezing

☐ >45 degrees F

☐ >55 degrees F

Other (please specify):

16. What tack application rates (based on residual) are used for thin lifts?

☐ 0.02–0.06 gal/sq yd

☐ 0.02–0.08 gal/sq yd

☐ 0.04–0.08 gal/sq yd

Other (please specify):

17. Is there a minimum thickness based on NMAS?

☐ 1.5 × NMAS

☐ 2 × NMAS

- [ ] 3 × NMAS
- [ ] 4 × NMAS

18. How is density specified?

- [ ] % of control strip
- [ ] % of laboratory density
- [ ] % of theoretical
- [ ] Density not measured—compact to satisfaction of engineer
- [ ] Density not measured—type rollers and number of passes specified

19. What mixture/pavement properties are used for acceptance?

- [ ] Asphalt content
- [ ] Gradation
- [ ] Plant lab air voids
- [ ] Roadway density
- [ ] Smoothness
- [ ] Spread rate

Other (please specify): ____________________

20. Approximately how many tons of thin overlay mixes do you place each year?

- [ ] Less than 100,000
- [ ] 100,000–500,000

- [ ] 500,000–less than 1 million
- [ ] >1 million

21. If special procedures are used to maintain surface condition (texturing, grinding, fog seal, etc.), how is it determined when those activities should be applied?

- [ ] No special activities are used
- [ ] Based on type and level of distress
- [ ] Based on condition rating
- [ ] Based on smoothness
- [ ] Automatically scheduled at periodic intervals

Other (please specify): ______

22. How is the optimal application rate for fog seals or rejuvenating agents determined?

- [ ] No fog seals or rejuvenators are used
- [ ] Agency standard rate is used
- [ ] Based on type and level of distress

Other (please specify): ______

23. What is the actual service life of thin asphalt concrete overlays?

- [ ] <5 years
- [ ] 5–8 years
- [ ] 8–10 years

☐ 10–12 years

☐ >12 years

24. If there is a large range in service life (more than one answer checked in previous question), is there an explanation for the large range?

☐ Condition of existing surface at time of overlay

☐ Amount of surface preparation

☐ Large fluctuations in traffic volume from project to project

☐ Variation in construction quality

Other (please specify): ____________________

25. How is pavement service life monitored/verified?

☐ Manual condition surveys

☐ Video records of condition

☐ Deterioration curves based on condition/serviceability are updated annually

☐ Threshold values are used to determine when action is needed

Other (please specify): ____________________

26. Are annualized cost comparisons per mile available for thin asphalt overlays versus other pavement maintenance/preservation treatments?

○ Yes. (If so, please provide the basis for those comparisons.)

○ No

27. Are warranties required for thin asphalt concrete overlays?

- Yes. (If so, attach specification.)
- No

28. Do you have example projects of thin asphalt overlays that have far exceeded expectations?

- Yes
- No

Comments/Explanation:

29. Do you have example projects of thin asphalt overlays that have significantly failed to meet expectations?

- Yes
- No

Comments/Explanation:

30. List any suggestions/recommendations for "successful practices" you have observed during project selection, mix design, construction, and maintenance/preservation that have been helpful in extending the service life or overall performance of thin asphalt overlays.

APPENDIX B

Responding Agencies and Private Industry

Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Florida
Georgia
Idaho
Illinois
Indiana
Iowa
Kansas
Kentucky
Louisiana
Maine
Maryland
Massachusetts
Michigan
Minnesota
Mississippi
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New Mexico
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
Tennessee
Texas
Utah
Vermont
Virginia
Washington
West Virginia
Wisconsin
E & B Paving
Granite Construction
Heritage Research
Old Castle
Paving Contractor
Prairie Construction
Silver Star Construction
Wiregrass Construction

APPENDIX C

Survey Responses

Response of agencies is listed by their postal abbreviation. Private industry responses are listed as follows:

EB = E & B Paving GC = Granite Construction HE = Heritage Research

OC = Old Castle PC = Paving Contractor PRC = Prairie Construction

SS = Silver Star Constr. WG = Wiregrass Construction

1. **What is your agency's definition of "thin" asphalt concrete overlay? Check all that apply.**

   May be greater than 1.5 inches AK, IL, MT, ND, NM, OH, UT

   1 inch to 1.5 inches CA, ID, KY, MN, MO, ND, NE, NH, NV, OR, RI, VT, WI, GC, OC

   0.75 to 1.5 inches CO, ID, IL, IN, LA, MA, MD, NJ, PA, RI, TX, VT, OC, HE, PRC, SS

   Less than 1 inch AL, AZ, DE, GA, ID, ME, MS, NC, OK, SC, TN, VA, VT, WA, WV, HE, OC, PC

   Less than 0.75 inches AR (UTBWC), KS, MD, MN, TN, VT

   Other (please specify): AK—2" min.; FL—Not defined; GA—1.0–1.5" is normal, not thin; KY—1.25–1.5"; MN—HMA = 1.5", UTBWC = <0.75"; MT—1.8–2.4"; OH—<2"; PA—0.75–1.25; UT—<2"; WI—<1.5"

2. **What investigation is done to determine when to use thin asphalt concrete overlays?**

   No investigation is done ID, IL, KS, ND, NH, OH, OK, PA, TN, WV, PRC

   Cores are taken to determine what rehab may be needed AL, AZ, CA, FL, GA, IN, MA, MD, MO, MS, NE, NJ, NM, NV, RI, UT

   A structural analysis is done to determine adequate structure is provided AL, AK, CA, CO, GA, MA, MD, MS, NE, NM, NV, TX, GC

   The surface is typically milled to remove top-down cracking AL, FL, GA, IL, KY, LA, MA, MN, NE, NV, OH, OK, PA, RI, SC, HE, OC, SS

   Other (Please specify): DE—Visual; GA—Roads visually rated each year; KY—Pavement Management System generates list of candidates; OH—Use decision tree; VA—Visual survey and maintenance history

3. **Where are thin overlays used?**

   Interstate AK, AZ, GA, ID, IL, KS, KY, LA, MA, MN, MT, NH, NJ, NM, OH, OK, TX, VA, VT, GC, OC, PRC

   Primary & secondary routes AK, AZ, DE, FL, GA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MN, MO, MS, MT, NC, ND, NE, NH, NM, OH, OK, PA, RI, TN, TX, UT, VA, WV, EB, GC, HE, OC, PC, SS

   Local routes AL, CA, GA, ID, IL, IN, KY, LA, MD, ME, MN, MS, MT, NC, NE, NH, NM, NV, RI, SC, TX, UT, VA, HE, OC

   Low traffic volume routes AL, CA, CO, DE, GA, ID, IL, IN, LA, MD, ME, MN, MS, MT, NC, ND, NE, NH, NV, OH, RI, SC, TN, TX, UT, VT, WA, PC, SS

   Only for certain types of pavement distress (please specify): PA—Low to moderate raveling; NJ—Used for minimal distress, 7–10 years old

   Comments GA—1.25–1.5" has been standard overlay for years; IL—2" mill & fill & UTBWC used on interstates; IN—Discontinued use on interstates due to low friction/macrotexture; OR—Only being used experimentally

4. **How does your agency determine what mix type will be used (based on Nominal Maximum Aggregate Size (NMAS) for thin overlay applications?**

   Based on traffic volume or functional classification AL, AK, CA, GA, LA, MA, MO, MS, NC, OH, TN, WV

   Based on thickness/NMAS ratio of 2:1 ID, ME, NV

   Based on thickness/NMAS ratio of 3:1 CO, DE, IL, KY, MA, MD, MO, MS, NE, NH, NJ, NM, OK, OR, SC, UT, VA,WA, WI, GC, PC, SS

   Based on economic conditions/budget constraints CA, IN, MA, MS, NC, ND, NJ, RI, TX, VT, OC

Other (please specify): AR—Use UTBWC; AZ—≤1" use rubberized OGFC; FL—Use 3 × NMAS for dense-graded & 1.5 × NMAS for OGFC; IL—UTBWC does not follow NMAS ratio; KS—Use UTBWC; LA—12.5 mm used for OGFC and coarse graded > 700 ADT; MA—Function of many factors—OGFC for limited access, 9.5 at 1.25" thick for low volume, 1.25" gap graded rubber mix for high volume; MO—Traffic & function determine treatment type, but thickness based on NMAS; MT—0.75" used for most overlays; PA—9.5 mm mix for 1.0–1.5" thickness, 6.3 mm experimented with for 0.75–1.25"; WI—12.5 mm NMAS is smallest size used; GC—minimum of 3:1 NMAS ratio

5. **Is this mix typically used even when there are sufficient funds to place a thicker layer?**

Yes AK, AR, CA, DE, FL, GA, IN, KS, KY, LA, MA, MS, MT, ND, NE, NH, NJ, OH, OK, RI, SC, TN, VT, WV, HE, OC, PC, PRC

No CO, ID, IL, MD, ME, MN, MO, NC, NV, OR, PA, UT, WA, GC, SS

6. **Under what pavement conditions would you NOT use thin asphalt concrete overlays?**

No restrictions DE, GA, KY, ND, NE, RI, TX, VT, PC

Roughness/poor ride AK, KS, RI, WA, WV

Loss of surface texture/low friction NC

Raveling AZ, MA, NC, PA, RI, SC, TN, UT, VA, WA, WI, GC

Rutting AZ, CA, ID, IL, IN, KS, MA, ME, MS, NC, NM, NV, PA, RI, SC, TN, VA, WA, HE, OC, PRC

Cracking (fatigue, block, thermal) AL, AK, CA, CO, ID, MA, MD, ME, MO, MS, MT, NC, NH, NJ, NM, NV, OH, OK, OR, PA, RI, SC, TN, UT, VA, WA, WI, EB, GC, HE, OC, PRC, SS

(Comment: FL does not place an overlay without milling to remove distresses.)

7. **What requirements are used for aggregates used in thin asphalt concrete overlays?**

Superpave Criteria (AASHTO M323) AL, AR, CO, DE, FL, GA, ID, KY, MA, MD, ME, MN, MO, MS, MT, NC, ND, NE, NH, NM, OR, PA, VT, WA, WV, EB, HE, OC, PRC, WG

SMA Criteria (AASHTO M325) GA, LA

Agency specific AK, AZ, CA, GA, IL, IN, KY, LA, MD, MN, NJ, NV, OH, RI, SC, TN, UT, VT, GC, PC, SS

Other IL—Aggregate requirements based on polish resistance; KS—Superpave specs for 4.74-mm mix, agency specific for UTBWC; LA—Micro Deval of 18

8. **Is the same asphalt binder grade used for thin asphalt overlays as would be used on the same project for thicker overlays?**

Yes (All agencies/private industry except for the "No" agencies/industry below)

No KS, NJ, RI, TX, PRC

9. **Are modified asphalt binders used? If so, under what conditions?**

Modified binders are not used AL, IN, MD, ME, NC, WG

Based on classification/function (Interstate, primary route, etc.) AZ, CO, DE, GA, KY, MA, MO, MT, RI, TN, HE, OC, SS

Based on traffic volume or ESAL; specify criteria CA, DE, FL, GA, ID, IL, KY, MO, MS, MT, ND, NE, OR, SC, TN, VT, OC, PC, PRC

Based on condition of existing pavement MA, RI, TN, VT

Other (please specify): AR—For UTBWC; CA—Climate; FL—Also used in areas with history of rutting problems; ID—Based on LTPPBind program for ESAL & climate; KY—All interstates and routes > 30 million ESALs; LA—all surface mixes; MT—All roads > 50 daily ESALs; NH—Application specific (ramps, intersections, high traffic volume); NJ—Always required for thin overlays; NV—Based on climate, location; OR—High traffic volume > 10 million ESALs; PA—Same as for thicker layers; RI—All thin overlays; TX—Use modified asphalt for optimum performance; UT—All thin overlays; WA—Based on climate zone; WV—All thin overlays

10. **Are Recycled Asphalt Pavement (RAP) and/or Reclaimed Asphalt Shingles (RAS) allowed in thin asphalt concrete overlays? If so, what amounts (or under what conditions) may RAP and RAS be used?**

RAP/RAS not allowed in thin overlays AK, AZ, LA, NJ, OK, PA, RI, TX, PRC, SS

RAP limited to 15% in thin overlays CA, MA, MT, NV, OH, TN, WV

RAP limited to 25% in thin overlays AL ≤ 20%, DE, FL ≤ 20%, KY, MS, ND ≤ 20%, NE, OH, OR, SC, UT, VT, WA ≤ 20%, HE, OC, PC

RAP limited to 50% in thin overlays GA ≤ 40%, NC, NM ≤ 35%

RAS limited to 5% in thin overlays AL, GA, KY, OH, PA, SC, HE, OC, PC

RAS limited to < 10% in thin overlays (No responses)

RAP/RAS limited based on recovered binder properties CO, MD, NC, NH, PA, WA

Other (please specify): ID—No RAS: RAP not limited except for aggregate angularity; IN—RAS ≤ 25% binder replacement: RAP ≤ 40% binder replacement; MA—≤10% for gap graded rubber mixes; ME—Up to 30% based on RAP properties; MN—Based on binder replacement; MS—No RAP in 4.75-mm mix; NH—RAS ≤ 0.6 binder replacement: RAP/RAS ≤ 1.5% total binder contribution; SC—≤30% aged binder of total binder from RAP/RAS; VT—No RAP in UTBWC; HE—RAP not allowed in >10 million ESAL due to limestone in RAP; WG—Total RAP/RAS ≤ 20%, RAS ≤ 5%

11. If RAP/RAS are used, how is the amount of binder contribution determined?

Solvent extraction CA, IL, IN, KY, MA, ME, MN, MO, MS, NV, OH, TN, WA, GC, HE, OC, PC

Ignition oven AL, DE, FL, IN, KY, KS, MA, MN, MT, NC, NE, NM, OR, SC, TN, UT, WV, GC, OC, PRC

Based on a percentage of the recovered binder AL, CO, GA, MA, MD, ND, VT, WI

Back-calculated using the Gmm value AL

Other (please specify): GA—gives partial credit (75%); ID—Ignition oven correction factor correlated to solvent extraction; MA—RAS not given 100% credit; MN—Solvent extraction for mix design, ignition oven for production; OH—RAS binder set at 18%; PA—If ≤15% RAP or ≤5% RAS use solvent or ignition: If >15% RAP or both RAP and RAS used, use solvent

12. What mix design method is used?

Superpave (AASHTO R 35/T 312) AL, CO, FL, GA, ID, IL, IN, KS, KY, LA,MA, MD, ME, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, OH, PA, SC, UT, VT, WA, WI, GC, HE, OC, PRC, SS, WG

SMA (AASHTO R46) GA, OH

Marshall (AASHTO T245) AK, MO, OH, RI, TN, WV, PC

Hveem (AASHTO T 246) CA, NV

California Kneading Compactor (AASHTO T 247) CA

Other (please specify) AZ—Agency specific; RI—Added 150 mm stability requirements; TX—Agency specific; VT—Agency specific for UTBWC

13. What air void level, or range of air void levels, is used to determine optimum asphalt content?

<3.5% (No responses)

3.5–4.5% CO, MD, MT, NE, NJ (3.5), SC, UT, VT, PC

4% AL, CA, DE, FL, GA, ID, IL, KS, KY, MA, ME, MN, MO, MS, ND, NM, NV, OH, OK, OR, PA, TN, WA, WI, HE, SS, WG

4%–5% (No responses)

4%–6% MS (not for 4.75 mm), NC, RI, WV, OC, PRC

Other (please specify) AR—≥10% for UTBWC; AK—3–5%; GA—4–7% for 4.75 mm; IN—5%; MN—4% for surface, 3% for non-surface; NH—3–5.5%; OH—4% for high truck volume, 3.5% for low truck volume; TX—20% for OGFC (PFC)

14. What laboratory performance tests are typically required? (If different from AASHTO, please provide a copy.)

Moisture Susceptibility (AASHTO T 283) AL, AR, CA, CO, GA, IL, IN, KY, LA, MA, MN (Modified), MO, MT, NC, NE, NH, NJ, NM, NV, OH, OK, OR, PA, SC, VT, HE, OC, PRC, SS, WG

Rutting Susceptibility (AASHTO T 340—Asphalt Pavement Analyzer) AK, GA, ID, NC, NJ, OH, OR, PA

Rutting Susceptibility (AASHTO T 324—Hamburg) IL, LA, MA, MT, OK, PA, TX, VT, WA, OC, PRC, SS

Flow Number (AASHTO TP 79) (No responses)

Dynamic Modulus (AASHTO TP 79) (No responses)

Other (please specify): FL—Some areas of state use APA during mix design; GA—Hamburg, FN, E* for research info; ID—Use ASTM D 1075 instead of AASHTO T 283; MS—APA typical, but not required; ND—None; RI—None; TN—TSR by ASTM D 4867; TX—Overlay Test (TX 248-F)

15. Are there restrictions on placing thin layers during cold weather? If the restrictions are different for "hot" and "warm" mix, explain.

No restrictions (No responses)

Must be above freezing CA, MO, MT, WA,

>45 degrees F DE, GA, IL, KY, MA, MD, NJ, NV, SC, TN, UT, HE, OC, PC,

>55 degrees F AR, CO, KS, MS, OK, SS

Other (please specify) AZ->70; FL->50 if <1", >40 if >1", >45 if PG > 64 or ARB; GA->55 ≤1" or OGFC; ID->60 for surface; IN->60; LA->50; ME-Seasonal (May 15–Sat after Sept. 15) and >50; MS->40 for WMA; NC->40; ND->40; NE-≥40; NH->50; NJ->35 for WMA; NM->60; OH-1.5"–2.9" = 40, 1.0"–1.4" = 50, <1" = 60; OR->60; PA-Calendar Dates by Region ≥ 40 for 9.5 mm, 50 for 6.3 mm; RI->50; TX->70; VT-≥50; WV->50; PCR->60

16. What tack application rates (based on residual) are used for thin lifts?

0.02–0.06 gal/sq yd CA, FL, IL, MD, ME, MN, MS, MT, NV, WV

0.02–0.08 gal/sq yd CO, ID, ND, NE, NJ, NM, PA (0.02–0.07), WG

0.04–0.08 gal/sq yd AK, GA, KY, LA, MA, MO, NC, NE, OR, UT, VT, HE, OC, PC, PRC, SS

Other AZ-PG = 0.06–0.08, Emulsion = 0.08; DE-0.08–0.17; GA-0.06–0.08 for OGFC, 0.04–0.06 for others; KS-0.03 for 4.75 mm, 0.13 for UTBWC; LA->0.12 for OGFC; MN-0.2 for UTBWC; NH-0.02–0.05; RI-0.08; SC-0.05–0.15; TN-0.05–0.1 for non-milled surface, 0.08–0.12 for milled surface; TX-0.04–0.16

17. Is there a minimum thickness based on NMAS?

1.5 × NMAS FL (OGFC), GA, IN, LA, PRC

2 × NMAS AL, CA, ID, MD, MN, MT, TX, OC, SS

3 × NMAS AK, CO, DE, FL, IL, KY, MA, MN, MO, MS, ND, NE, NJ, NM, NV, OR, SC, UT, VT, WA, GC

4 × NMAS HE

18. How is density specified?

% of control strip GA, ID, OH, VT

% of laboratory density DE, MN, NH, WA

% of theoretical AK, CA, CO, FL, GA, IL, KY, MA, MD, MO, MT, NC, ND, NE, NJ, NM, NV, OH, PA, UT, WV, OC, PRC, WG

Density not measured—compact to satisfaction of engineer AL, KS, LA, MS, NC, RI, SC, TN, TX, SS

Density not measured—type rollers and number of passes specified AR, AZ, IN, KS, ME, OK, OR, TN, VT

19. What mixture/pavement properties are used for acceptance?

Asphalt content AK, AR, AZ, CA, CO, DE, FL, GA, IN, KY, LA, MA, ME, MN, MO, MS, MT, NC, NE, NH, NM, NV, OH, OR, PA, RI, SC, TN, VT, WA, WV, HE, OC, PR, PRC, SS, WG

Gradation AK, AR, AZ, CA, CO, DE, FL, GA, IN, LA, MA, ME, MN, MO, MS, MT, NC, ND, NH, NM, NV, OH, OR, PA, RI, SC, TN, VT, WA, OC, PR, PRC

Plant lab air voids AL, CO, DE, FL, ID, IL, IN, KY, MA, ME, MN, MS, MT, NC, NE, NH, NJ, NM, OR, PA, RI, TX, VT, WA, WV, HE, OC, PR, PRC, SS, WG

Roadway density AK, CA, CO, DE, FL, GA, IL, KY, MA, MD, MN, MO, MT, NC, ND, NH, NJ, NM, NV, OH, PA, WA, WV, OC, PR, WG

Smoothness AK, AR, CA, CO, DE, FL, GA, IL, IN, KY, LA, MA, MD, MN, MO, MS, MT, NE, NH, NJ, NM, NV, OH, OR, WA, WV, OC, PR

Spread Rate AL, FL, RI, SC, PRC, WG

Other ID—VMA; IL—VMA; KS—Varies by mix type; LA—Gmm variation; MS—VMA; HE—VMA

20. Approximately how many tons of thin overlay mixes do you place each year?

Less than 100,000 AK, CA, CO, DE, IN, MD, MS, NC, NE, NJ, NV, OR, PA, RI, UT, WA, WI, WV, HE, PR, PRC, SS, WG

100,000–500,000 AL, AZ, ID, IL, KS, MA, MN, MT, ND, NH, NM, SC, TN, TX, VT

500,000–Less than 1 million ME

>1 million FL, GA, KY, OH, MO, OC

21. If special procedures are used to maintain surface condition (texturing, grinding, fog seal, etc.), how is it determined when those activities should be applied?

No special activities are used AL, CO, FL, GA, ID, IL, KS, KY, LA, MT, ND, NJ, RI, TN, TX, VT, WA, WV, SS

Based on type and level of distress AK, AZ, DE, IN, MN, MO, MS, NC, NE, NH, NM, NV, OR, PA, SC, UT, OR, PR, PRC

Based on condition rating CA, IN, MN, MO, MS, NC, NM, NV, PA, SC, UT, OC

Based on smoothness CA, IN, MN, MO, NM, NV, HE

Automatically scheduled at periodic intervals CA, IN, MO

Other OH—Decision Tree; MN—Determined by District; HE—Micromilling

22. How is the optimal application rate for fog seals or rejuvenating agents determined?

No fog seals or rejuvenators are used AK, AL, FL, GA, ID, IL, KS, KY, LA, MA, MD, MN, MT, ND, NH, OH, OR, PA, RI, SC, TN, TX, HE, PC

Agency standard rate is used CA, MO, MS, NC, NE, NM, NV, OK, UT, VT, WA

Based on type and level of distress AZ, CA, CO, IN, NV, WV

Other GA—Testing on one project; SC—Concerns due to loss of friction initially; VT—Only on FDR with cement stabilizer

23. What is the actual service life of thin asphalt concrete overlays?

<5 years AK, CO, MD, MN, NC, NE, NM, TX

5–8 years AL, CA, GA, ID, IL, KS, MA, MD, MN, MO, ND, NE, NH, OK, PA, SC, TN, TX, UT, VT, WA, WV, PC

8–10 years AL, AZ, CA, DE, GA, IL, IN, KS, KY, MA, MN, MO, NJ, NV, OH, TX, OC

10–12 years AL, CA, GA, IL, KY, MN, MS, MT, NH, NV, OH, RI, TX

>12 years FL, GA, KY, MN, MT

24. If there is a large range in service life (more than one answer checked in previous question), is there an explanation for the large range?

Condition of existing surface at time of overlay AL, AZ, CA, CO, GA, IL, KS, KY, MA, MN, MO, MS, NE, NV, PA, SC, VT, WA, WV, OC

Amount of surface preparation AL, GA, IL, MN, MO, NV, SC, VT, WA

Large fluctuations in traffic volume from project to project AZ, CA, CO, GA, KY, MN, MT, NH, OK, WA, WV, OC

Variation in construction quality AZ, GA, KY, MD, MN, MO, NV, SC, TX, VT, WA, WV

Other CA—Weather; FL—Geographic location; GA—Roads needing rehab were only mill/fill due to cost or other factors; NH—Variation in construction standard (Interstate vs. secondary roads); NV—Environment; OH—Regional materials and construction quality

25. How is pavement service life monitored/verified?

Manual condition surveys AL, AZ, CA, FL, GA, IN, KS, KY, MA, MO, MS, NC, NE, NH, NM, OH, OR, RI, TX, VT, OC, PRC

Video records of condition AK, AL, CA, ID, IL, KS, MA, MD, MN, MO, MS, ND, NE, NM, OR, PA, VT, WA, HE, OC

Deterioration curves based on condition/serviceability are updated annually KS, LA, MA, MN, NJ, TN, WA

Threshold values are used to determine when action is needed AK, CA, GA, IN, KS, MA, NC, NE, NJ, OH, TN, UT

Other MT—Automated vehicles; PA—video logs annually on high-class project, every 2 years on lower-class projects

26. Are annualized cost comparisons per mile available for thin asphalt overlays versus other pavement maintenance/preservation treatments?

Yes GA, MT, TN

No All agencies responded no except for yes responses.

27. Are warranties required for thin asphalt concrete overlays?

Yes FL (3 years), WV

No All agencies responded no except for FL and WV.

28. Do you have example projects of thin asphalt overlays that have far exceeded expectations?

Yes GA, KS, LA, MN, OH, RI, TX, PC, PRC

No All agencies responded no except for the yes responses listed above.

29. Do you have example projects of thin asphalt overlays that have significantly failed to meet expectations?

Yes AZ, GA, KS, MO, OH, RI, PC

No All agencies responded no except for the yes responses listed above.

Comments GA—Led to placing two test sections at NCAT test track to try to retard reflective cracking; OH—Poor construction, not following decision tree, unforeseen loading

30. List any suggestions/recommendations for "successful practices" you have observed during project selection, mix design, construction, and maintenance/preservation that have been helpful in extending the service life or overall performance of thin asphalt overlays.

CA—Select the right candidate.

GA—Make sure the correct maintenance treatment is applied to balance cost and manpower.

KY—Avoid overly coarse mix designs with low AC-less durable, proper construction of longitudinal joint.

MA—Surface prep and adequate tack coat are critical, improper project selection can be catastrophic.

MD—Struggled with friction for 4.75 mm, changed from 4% to 5% VA for design and added fineness modulus of 3.30 to build more macrotexture.

MO—Need adequate tack coat, limit visual segregation.

MS—Condition of existing pavement structure and surface conditions are critical to success.

MT—Must level adequately to fill ruts and improve smoothness before thin overlay, increased leveling quantities resulted in better smoothness and performance; where there is crack sealant place 0.8 in. layer to isolate crack sealant before thin overlay (eliminates the bumps).

NJ—Thin overlays used successfully for pavement preservation, select road in good to fair condition; there is little improvement in smoothness because of thin layer. Can pave later in the season with WMA.

NV—Material selection and construction quality control.

OH—Target resurfacing after life of most recent activity is exhausted, but before structural failure occurs. Resurfacing too early is not cost-effective.

PA—Sound structure and good density.

RI—1.5–2.0 in. in mill-and-fill operations works well; modified binders (rubber or polymer) provide more service life; using AASHTO M19, specify E grade for preservation and V grade for 2 in. mill and fill.

SC—Ensure road is not rutted and is sound structurally before paving (this may be different than when project was set up), placement rates too low may cause drag marks and other issues.

TN—Never place over sections with cracks > $\frac{3}{16}$ in. or areas significantly raveled or rough.

TX—Use appropriate amount of tack coat for adequate bonding; may need tandem rollers for thin overlays.

VT—Need well-trained construction inspectors and continual spec. improvement based on experience.

OC—Proper tack coat is essential for long life; placement rate is too thin in many cases, an additional 25 LB/y^2 would help achieve density and smoothness for longer life.

WG—Avoid < 1 in. on slow moving urban roads; turn lanes and intersections do not perform as well.

APPENDIX D

Example of Ohio's Flexible Pavement System Decision Tree

(Source: Ohio DOT)

Note: The Decision Tree for General System refers to 2-lane routes, while the Priority System refers to 4+ lanes with divided median. For the Priority System, activities 30–38 are thin overlays. For General System activities, 50 and 60 are thin overlays (½ inch scratch layer plus 1.25 inch surface) especially for lower volume routes.

Ohio General System Decision Tree

Office of Pavement Engineering **Version E 05-02-12**

LEGEND

Severity Levels

L Low

M Medium

H High

Extent Levels

O Occasional

F Frequent

E Extensive

Activity Codes

20 - Crack Sealing

25 - Chip Seal

30 - Microsurfacing

31 - Double Micro

35 - Ultrathin Bonded AC

38 - Fine-graded Polymer AC

40 - CPR

45 - Intermediate Course Recycled AC

50 - AC Overlay w/o Repairs

52 - AC Inlay

55 - Double Chip Seal

60 - AC Overlay w/Repairs

70 - Crack and Seat

73 - Break and Seat

77 - Rubblize and Roll

80 - Whitetopping

90 - Unbonded Concrete Overlay

95 - Unbonded Composite Overlay

100 - New Flexible Pavement

110 - New Rigid Pavement

120 - New Composite Pavement

Ohio General System Decision Tree

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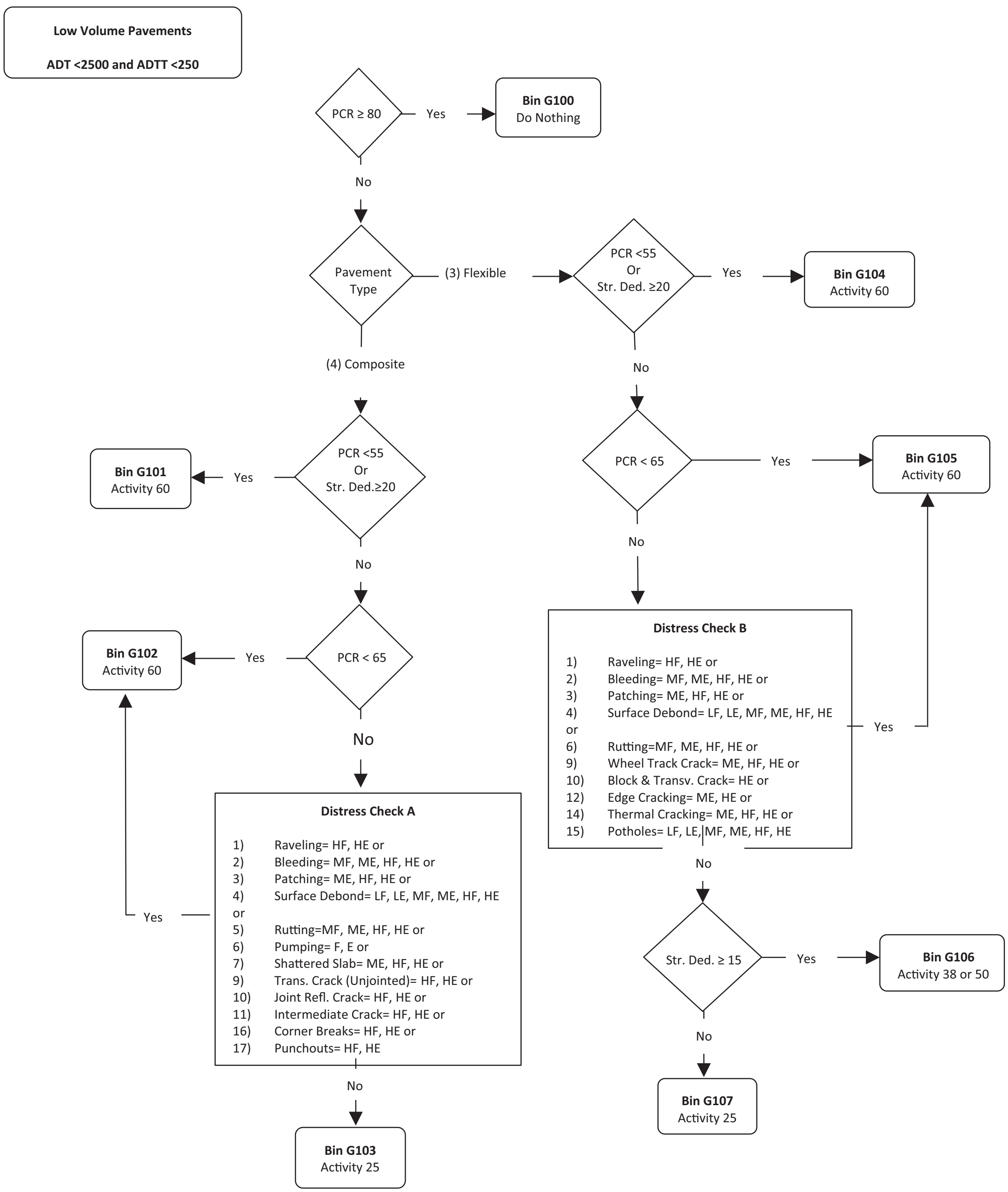

Ohio General System Decision T7ree

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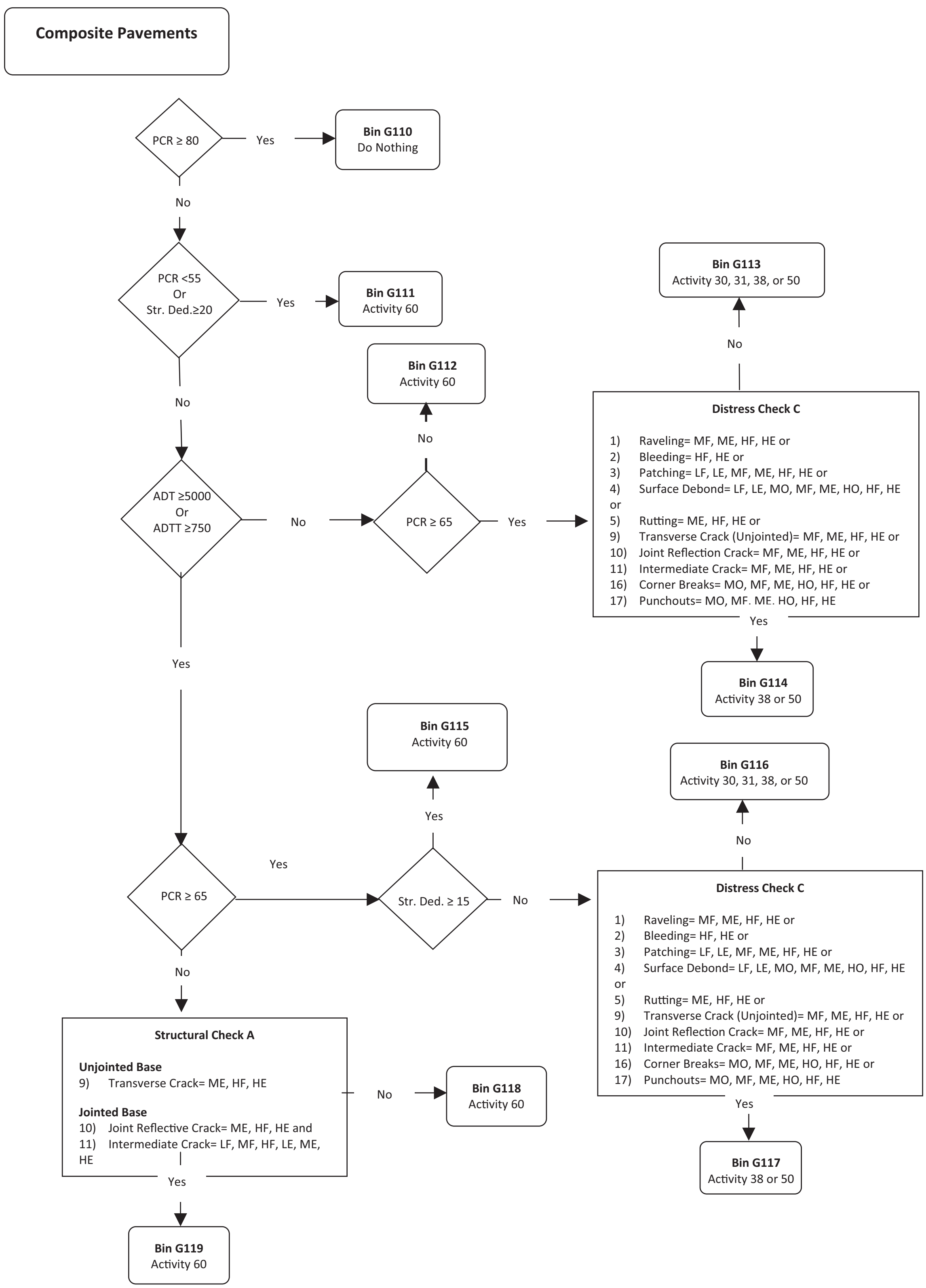

Ohio General System Decision Tree

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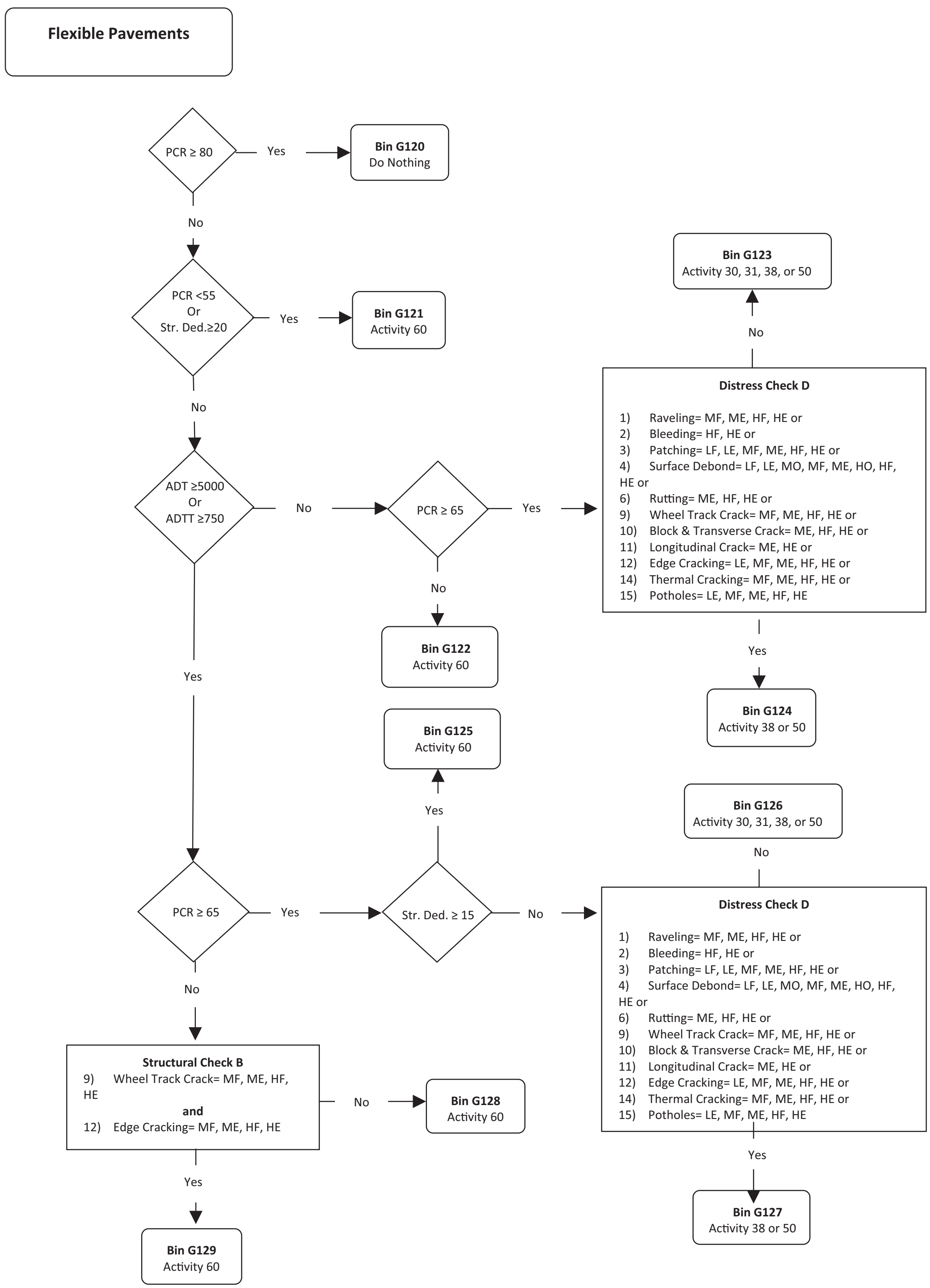

Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation