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Best Practices for the Use of RAS in HMA: Workshop Student Handbook

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BEST PRACTICES FOR THE USE OF RAS IN HMA

Workshop Student Handbook

by

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CHAPTER 1: INTRODUCTION

The asphalt paving industry has always advocated recycling, including reclaimed asphalt pavement (RAP), recycled asphalt shingles (RAS), tires, etc. The earliest recycling asphalt pavement dates back to 1915. In addition to conserving energy and protecting the environment, the use of RAP/RAS can significantly reduce the cost of hot-mix asphalt (HMA) paving. RAP has been the most extensively recycled material in the history of the asphalt paving industry. With recent increases in the price of asphalt cement and subsequent price fluctuations, the industry has further amplified its recycling efforts (Hansen, 2009). Most recently, the use of RAS in HMA has become another black gold to the asphalt paving industry since RAS contains a significant amount of asphalt binder (see Table 1). There are two basic types of roofing shingle scraps: 1) post-consumer asphalt shingles or tear-off asphalt shingles (TOAS), and 2) manufacture waste asphalt shingles (MWAS) including roofing shingle tab punch-outs and out-of-spec shingles. MWAS is called prompt roofing shingle scrap in some publications. In February 2009, the Texas Commission on Environmental Quality (TCEQ) issued an Authorization Memo to allow HMA plants to include either MWAS or TOAS under the TCEQ air quality standard permit for permanent HMA plants. Since then, RAS has been used in various pavement constructions.

Table 1. Typical Compositions of New Residential Asphalt Shingles.

(modified after Krivit, 2007)

Component	**Organic Shingles, % by wt.**	**Fiberglass Shingles, % by wt.**
Asphalt Cement	30–36	19–22
Reinforcing Mat	2–15	2–5
Mineral Granules/aggregate	20–38	20–38
Mineral Filler/stabilizer	8–40	8–40
Adhesives (modified asphalt based)	0.2–2	0.2–2

More than 30 years ago, some of the original pioneers established the first shingle recycling plants, investigated HMA mix designs incorporating RAS, and then published the first technical literature in the late 1980s (Epps and Paulsen, 1986; Paulsen et al., 1986; Shepherd et al., 1989). More recently, several additional HMA producers and departments of transportation have developed substantial in-house expertise in shingle recycling in HMA (Grzybowski, 1993; Newcomb et al., 1993; Button et al., 1996; Janisch and Turgeon, 1996; NAHB, 1999; Dykes, 2002; Lum, 2006; Brock 2007; Schroer, 2007). Within the last two or three years, a few contractors and state departments of transportation have begun using or studying the use of recycled shingles in warm mix asphalt (WMA) (Robinette and Epps, 2010; Maupin, 2010; Middleton and Forfylow, 2009).

With the recent increased use of asphalt shingles in asphalt mixtures, there is a need to further study this issue. The main objective of this workshop is to present best practices for RAS collection, processing, screening, and stockpile management of processed shingles and RAS mix design, production, construction, and performance evaluation.

This handbook is organized in four chapters. Chapter 1 provides an introduction, and Chapter 2 presents the best practices for the RAS processing and stockpile management in Texas. Chapter 3 discusses the balanced mix design for RAS/RAP/rejuvenators, and the production and field construction of RAS mixes. Finally, this report concludes with a summary described in Chapter 4.

CHAPTER 2: BEST PRACTICES FOR RAS PROCESSING AND STOCKPILE MANAGEMENT

RAS processing is one of the critical steps for using the RAS in HMA and producing high quality RAS mixes. As noted previously, two types of RAS are available for processing: MWAS and TOAS. For use in HMA, MWAS has traditionally been preferred over TOAS, primarily because MWAS contains fewer contaminants (Hansen, 2009; Maupin, 2008), plus the asphalt in MWAS is less oxidized (Button et al., 1996). MWAS only requires grinding with little or no sorting, inspection, testing, or separation of undesirable materials. Specifically, there is no need for asbestos testing for MWAS. However, MWAS is geographically significantly more restricted than TOAS, as shingle manufacturing facilities are typically located only in densely populated areas (see Figure 1). In contrast, TOAS are more readily available to contractors and recyclers. The main concerns with TOAS are potential asbestos, deleterious materials (including metal, wood, plastic, paper, etc.), and very hard highly oxidized asphalt. Consequently, it becomes more difficult to process the TOAS, and asbestos testing is required in Texas.

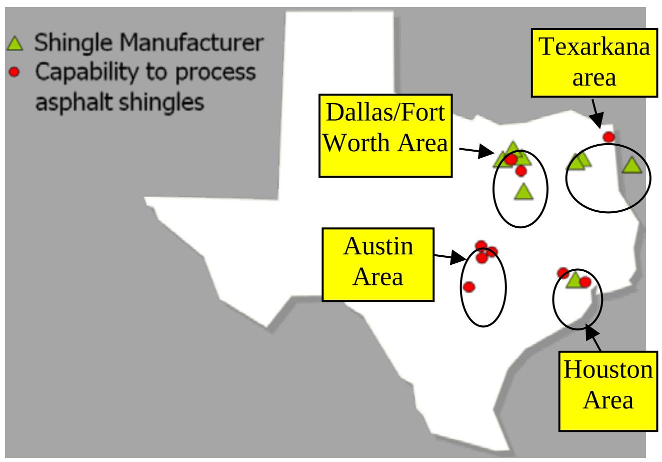

Figure 1. Shingle Manufacturers and Processors in Texas.

Processing RAS basically includes five steps: collecting, sorting, grinding, screening, and storing the processed RAS plus asbestos testing for the TOAS. The research team visited different recyclers and contractors in Texas and reviewed published literature to identify the best practices for each of the steps. Figure 2 shows the best practices identified; detailed explanations and associated guidelines follow.

Figure 2. Proposed RAS Processing Steps.

STEP 1. COLLECTING

Quality (cleanness) of RAS and a sustainable supply are two major issues related to collecting RAS. MWAS is relatively clean, but its supply is limited. In contrast, TOAS has relatively more supplies, but its cleanness (or contamination) is a bigger problem. According to Krivit (2007), the two basic types of strategies to develop a clean, secure supply are:

- *Source Separated*—Attracting high quality, separated loads of clean TOAS. The roofing contractor or hauler must first separate the non-shingle debris (e.g., plastic, metal, wood) before tipping at the shingle recycling plant. **S**ource-separated TOAS should be kept separate from other roofing debris at the demolition site before loading and then are loaded separately onto haul units.
- *Mixed Roofing Material*—Attracting mixed loads of TOAS without requiring source separation, such that the shingle recycler conducts most, if not all, of the materials separation. Non-shingle debris is sorted from the tear-off shingles at a recycling facility. TOAS recyclers might instruct their suppliers to load the shingles first, at the bottom of the haul unit. Then, the non-shingle debris, which are placed on top of the shingles layer, can be easily separated when the load is tipped at the recycling plant.

Under either strategy, Krivit (2007) continues, TOAS recyclers must work proactively with suppliers to ensure that no asbestos containing material (ACM) is delivered to the recycling plant. After the TOAS are tipped at the recycling plant, a second stage of quality inspection and sorting occurs. Most facilities use both manual separation (e.g., dump and pick, sorting conveyors) and mechanical equipment (e.g., screens, air classifiers). Shingle recyclers have demonstrated a wide variety of techniques to cost-effectively meet and exceed the minimum waste sampling and asbestos testing requirements. They have recently developed innovations, such as establishing in-house laboratories that use standard detection methods and certified personnel. Such internal laboratories minimize the turnaround time for test results. Together with other in-house personnel training and supplier technical assistance, TOAS recyclers are proactively managing their supplies through upstream quality control and quality assurance.

Hanson (2009) points out that as part of the quality control and acceptance program, shingle recycling operations need an inspection and testing plan for waste shingles delivered to the site, which should include:

- Type and quality of material that is acceptable.
- Criteria for rejecting loads.
- An asbestos management plan.

A list of prohibited materials for TOAS recyclers should include (Krivit, 2007):

- Cementitious shingles, shake shingles, and transite siding that may contain ACM.
- Any type of hazardous waste (e.g., mercury-containing devices such as thermostats, paint, solvents, or other volatile liquids).
- Significant amounts of other debris that are not asphalt shingles (e.g., plastic, paper glass, or metal).
- Significant amounts of trash.

STEP 2. ASBESTOS TESTING FOR TOAS

According to Hansen (2009), the main issue that impedes recycling of TOAS is concern over potential asbestos content. In the past, asbestos was sometimes used in manufacturing asphalt shingles and other shingle installation materials. Asphalt shingle manufacturers generally acknowledged that, between 1963 and the mid-1970s, some manufacturers did use asbestos in the fiber mat in some of their shingle products, but the total asbestos content of those shingles was always less than 1 percent. Other materials used in shingles, such as some tarpapers and some types of asphalt cement, also reportedly contained asbestos. In reality, while asbestos was used in some asphalt roofing materials, asbestos was rarely used in the shingles themselves.

Since TOAS may contain asbestos, the Texas Department of State Health Service (TDSHS) regulates asbestos-containing materials including TOAS. More detailed information on asbestos program can be found at TDSHS' website: http://www.dshs.state.tx.us/asbestos/pubs.shtm. Generally, asbestos testing (Figure 3) involves sampling each layer of roofing material. Details of asbestos testing are described in *Test Method for the Determination of Asbestos in Building Materials* (Perkins and Harvey, 1993). The complete test method is available at: http://www.rti.org/pubs/Test-Method-for-Determination.pdf. Representative samples must be properly selected, labeled, recorded in a sample log book, and then sent to an accredited asbestos testing laboratory for assay of asbestos content. TOAS recyclers should contact the appropriate state environmental and/or health agency to determine specific requirements for sample collection, analytical procedures, data reporting, and records preservation.

Figure 3. Setup for Asbestos Testing (after Krivit, 2007).

Krivit (2007) advised that shingle recycling operators should attend state-sponsored training courses to become licensed asbestos inspectors. Trained personnel should inspect each load to visually detect possible ACM. This will help increase the awareness of potential asbestos containing materials and allow company personnel to help provide accurate, timely, and state-approved information and related technical assistance to material suppliers and other customers. Shingle recycling operators should contact their state representative for the National Emission Standards for Hazardous Air Pollutants to explore technical assistance resources, including a listing of organizations providing asbestos inspector training. The website www.shinglerecycling.org is an excellent source of EPA and other regulatory information on asbestos, management, and recommended best practices. Specifically, in Texas, TCEQ has several regulations that may impact asphalt shingle processors, which can be found using the following links:

- Recycling: http://www.tceq.state.tx.us/permitting/waste_permits/msw_permits/MSW_amIregulatedrecycling.html.
- Industrial Storm Water: http://www.tceq.texas.gov/permitting/stormwater/TXR05_AIR.html.
- Storm Water from Construction Activities: http://www.tceq.texas.gov/permitting/stormwater/TXR15_AIR.html.

STEP 3. SORTING

Generally, little sorting work is needed for MWAS. However, substantial sorting work is required for TOAS because various debris (e.g., nails, wood, and insulation) contaminate this type of shingle. Any debris must be removed to prevent equipment damage during size reduction and produce high-quality processed RAS. There is no standard processing equipment to accomplish this task; in most cases, the debris has to be sorted out manually (see Figure 4).

Figure 4. Sorting RAS Manually.

Note that most facilities will recover metal and cardboard (perhaps in baled form) as secondary recyclable products. Trash from such sorting consists of plastic, non-recyclable metal, and paper. Recovery rates of TOAS from mixed waste sorting systems range from 15 to over 90 percent, depending on the feedstock and the efficiency of the separation (Krivit, 2007).

STEP 4. GRINDING

The vast majority of RAS used in asphalt paving mixes is ground into pieces smaller than 1/2 in. (13 mm) in size using a shingle grinding or shredding machine consisting of a rotary shredder and/or a high-speed hammer mill. It seems logical that, as shingles are ground finer, more RAS asphalt can be mobilized into the paving mixture.

According to Krivit (2007), each grinder manufacturer uses a unique combination of material handling and size reduction designs. RAS sizing is a key specification and will determine the product's suitability for various applications. For example, the larger particle size (+ 3/4 in.) may be more suitable for aggregate supplement. In general, the grinder will include a loading hopper; a grinding chamber that includes cutting teeth, sizing screens, and exit conveyor; and a feeding drum to present the shingles into the grinding chamber. A pulley head magnet at the end of the exit conveyor is standard equipment for removing nails and other ferrous metal. The final RAS product is stacked using a stacking conveyor and/or front-end loader. During visits to recyclers and contractors, the research team noted that it is important and necessary to pick up some debris left in the sorted, clean pile before feeding to the grinder (see Figure 5).

Figure 5. Preparation for Grinding.

To prevent agglomerating during grinding, the material may be passed through the grinding equipment only once to reduce heating, or it is kept cool with water spray at the hammer mill. However, the application of water is not very desirable, since the processed material becomes quite wet and must be dried (thus incurring additional fuel cost) prior to introduction into the HMA (Chesner et al., 1997).

STEP 5. SCREENING

Ground shingles may contain oversized pieces that do not meet the specification requirement. To remove the oversized pieces, the operators ideally should screen the processed RAS using a trommel screener (Figure 6). This equipment can help customize the size of processed RAS, guaranteeing that the specifications are met. Furthermore, the oversized pieces can be reground to the ideal size. Chesner et al. (1997) contends that scrap shingle greater than 1/2 in. may not readily disperse in HMA and may function much like aggregate particles; too small particles can release short fibers, which act as a filler substitute. Hansen (2009) adds that several HMA producers have found that grinding to less than 3/8 in. improves blending. The Texas Department of Transportation (TxDOT) specifies 100 percent passing the 1/2-in. sieve with 95 percent passing the 3/8-in. sieve.

Figure 6. Screening RAS Using Trommel Screen Machine.

STEP 6. STORING

Storing the processed RAS is typically similar to that of aggregate or RAP. Because the average gradation of RAS is very small, a stockpile can absorb a large amount of water, which can cause problems during HMA mixing (inadequate coating), compaction (mat tenderness), and performance (higher stripping potential) as well as require more fuel for drying. Ideally, a RAS stockpile should be covered (Figure 7). Additionally, it is important to keep loaders off RAS stockpiles and separate high AC RAS (tear-offs) from low AC RAS (manufacture waste).

Button et al. (1996) deduced that, during static storage in a stockpile, shredded roofing shingle material can agglomerate. High temperatures and the stickier manufacturing waste shingles can magnify this issue. Significant agglomeration or consolidation of processed roofing material necessitates reprocessing and rescreening prior to introduction into the hot mix plant. To mitigate this problem, processed roofing shingle scrap may be blended with a small amount of less sticky carrier material, such as sand or RAP, to prevent the RAS particles from clumping together.

Figure 7. Covered RAS Storing Facility.

SUMMARY

This chapter discussed best practices for RAS processing and proposed guidelines for collecting, sorting, grinding, screening, and storing the processed RAS. The asbestos test is required for the TOAS.

CHAPTER 3: BALANCED RAS/RAP MIX DESIGN, PRODUCTION, AND CONSTRUCTION

INTRODUCTION

Although there is no significant difference between RAS mixes and virgin mixes in terms of production in the plant, designing RAS mixes is more complicated than that for virgin asphalt mixes. Not only must the virgin aggregate and virgin binder information be obtained, but RAS binder content and RAS aggregate gradation must be determined through the ignition oven. Asphalt binder recovery tests may be needed to grade the RAS binder in order to use the asphalt blending chart. Additionally, there are at least five more challenges when designing RAS mixes in Texas.

Cracking Resistance of HMA Mixes with RAS

Virgin HMA mixes designed using the Texas gyratory compactor (TGC) are generally dry and have good rutting resistance but relatively poor fatigue and reflection cracking resistance. Poor cracking resistance may become even worse when mixes containing stiff, hard RAS binders are placed. It is critical for HMA mix designs with RAS to have acceptable cracking resistance through increasing the density requirement for TGC designed mixes or reducing N_{design} for Superpave Gyratory Compactor (SGC) designed mixes so that enough virgin binder is included in the mix. Alternatively, a balanced mix design approach Zhou et al. (2007) proposed can be used to design mixes with RAS, whereby the optimum asphalt content (OAC) is selected based on target air voids (or density), rutting/moisture, and cracking resistances determined using the Hamburg wheel tracking test (HWTT) and the Overlay test (OT), respectively.

Virgin and RAS Binder Blending

The virgin and RAS binder blending issue has not been well investigated. The actual blending between virgin and RAS binder during production is unknown. Although some approaches (e.g., dynamic modulus-based approaches) have been proposed for RAP/virgin binder blending, how much of the RAS binder actually blends with the virgin binder is very difficult, if not impossible, to determine accurately. Apparently, more work is needed in this area.

RAS Heating

RAS needs heating to make it workable and activate RAS binder. Many methods are available for handling RAS in the lab during the mix design process, but none of them can truly simulate the plant production process.

It is important to heat RAS materials to ensure the RAS binder becomes an active part of the HMA binder. Basically, there are two issues with RAS heating in the laboratory: time and temperature. Different methods are available. Some designers preheat RAS materials at the target mixing temperature for a certain period of time before mixing with virgin aggregates. Others superheat the virgin aggregate to ensure heat transfer to the RAS, which is added at room temperature. There is no specific information on RAS heating in the literature. Based on the research team's experience with RAP mix design and limited data on RAS mix design, a two-step preheating process is recommended: (1) warm the RAS overnight (12–15 hours) at 140°F

(60°C), which is a common temperature to dry materials, and 2) preheating the RAS at the mixing target temperature for two hours, which is a common time for preheating virgin binder. This two-step preheating process needs further verification.

Mixing and Compaction Temperatures

Mixing and compaction temperatures are important and influence compaction, volumetrics (e.g., air voids, VMA), and consequently OAC. For any virgin asphalt mix, the mixing and compaction temperatures are selected based on virgin binder properties (i.e., viscosity). When RAS is added, one has to consider both virgin binder and RAS binder properties. Guidelines are needed for selecting suitable mixing and compaction temperatures, especially when designing HMA mixes with high RAS content.

Mixing and compaction temperatures for high RAS mixes have not been well addressed in the literature. For RAS mixes, there are at least three options for selecting laboratory mixing and compaction temperatures:

- Those corresponding to the virgin binder.
- Those corresponding to the blended virgin/RAS binder.
- Those corresponding to the RAS binder.

Generally RAS binder is stiffer than virgin binder. The virgin binder will be overheated and, consequently significantly aged if Option 3 (those corresponding to the RAS binder) is chosen. Increasing the mixing and compaction temperatures lowers the OAC and consequently, cracking resistance of RAS mixes, since the higher mixing and compaction temperatures lead to lower OAC. From the conservative point of view, researchers propose to use Option 1: the mixing and compaction temperatures corresponding to virgin binder. This potentially provides RAS mixes adequate OAC, so better cracking resistance.

RAS in Warm Mix Asphalt

A few researchers (Robinette and Epps, 2010; Middleton and Forfylow, 2009) recently reported that RAS had been used in WMA, but no lab testing has been done to make conclusive findings on RAS/WMA. The only one report (Maupin, 2010) was found in which testing of WMA containing RAS was performed. However, after carefully reviewing the work done by Maupin (2010), researchers found that neither additives nor a forming system was used to produce the WMA. Instead, he simply lowered the mixing temperature to 250°F from the regular HMA temperature of 300°F, so more work is definitely needed in this area.

BALANCED RAS/RAP MIX DESIGN

Rutting has not been a significant problem with TxDOT's current RAP/RAS mixes, since it is well controlled through the HWTT (or other tests) and associated criteria. The cracking issue widely observed in the field should be the main focus when designing mixes containing RAP/RAS. Therefore, the philosophy of developing a mix design system was to focus on meeting both volumetric and cracking requirements, while ensuring that acceptable rutting and moisture damage resistance is also achieved. Table 2 lists potential cracking distresses when mixtures containing RAP/RAS are used for different applications.

Table 2. Potential Major Cracking Distresses for Different Applications.

Applications		Main concerns
Asphalt overlay	AC/existing AC/granular base	Reflective cracking, fatigue cracking, or thermal cracking
	AC/existing AC/cement stabilized base	Reflective cracking, thermal cracking
	AC/Jointed PCC	Reflective cracking , thermal cracking
	AC/CRCP	Thermal cracking, reflective cracking
New construction pavement	Surface layer	Thermal cracking, fatigue cracking (top-down)
	Intermediate layer(s)	
	Bottom layer	Fatigue cracking

Currently, asphalt mix design in Texas is based on volumetric properties of asphalt mixes plus checking potential rutting and moisture damage. Texas and other states have already established the rutting/moisture damage requirements for mixes with different types of binders. For example in Texas, the rut depth of a mix with PG76-22 binder should be less than 1/2 in. (12.5 mm) after 20,000 passes. However, there is no cracking requirement on most Texas mixes. As clearly observed in the field, it is very difficult (if not impossible) to establish a single cracking requirement for all scenarios, because cracking performance of asphalt mixes depends on traffic, climate, pavement structure, and existing pavement conditions for asphalt overlays. A balanced RAP/RAS mix design system for project-specific conditions, rather than a single cracking requirement, should be developed and then implemented to ensure the mixes designed with acceptable field performance.

This system is a two-step process. In Step 1, the site conditions will be evaluated and the performance model will be run to predict pavement performance for a range of different materials properties (different OT cycles), and the designer then selects the OT requirement to meet the design performance goal (for example less than 50 percent reflective cracking after 5 years). In Step 2, a lab mix design is run to develop a mix with the required OT cycles. If this does not work, the mix will be redesigned, this time changing overlay thicknesses or virgin binder (or others).

In the last 10 years, TTI researchers have made significant progress toward that goal—the balanced RAP/RAS mix design system for project-specific conditions, as shown in Figure 8. This system integrates both mix design and pavement structure design, which has been pursued for long time. Basically, the proposed system is an expanded balanced mix design procedure in which cracking performance is evaluated through a simplified asphalt overlay performance analysis system, S-TxACOL, with OT cycles as an input, as shown in Figure 9. The same reflective cracking model as that in TxACOL (Zhou et al., 2010) is used in the S-TxACOL.

Three mechanisms (shearing, bending, and daily thermal movement) of reflective cracking are all modeled through fracture mechanics.

In summary, this section described the balanced RAP/RAS mix design system for project-specific conditions. In this system, the HWTT and associated criteria are used to control rutting/moisture damage. The S-TxACOL prediction model with the input of the OT cycles computes the amount of reflective cracking development with time with consideration of climate, traffic, pavement structure, and existing pavement conditions. The next section includes cases studies presented to demonstrate this approach.

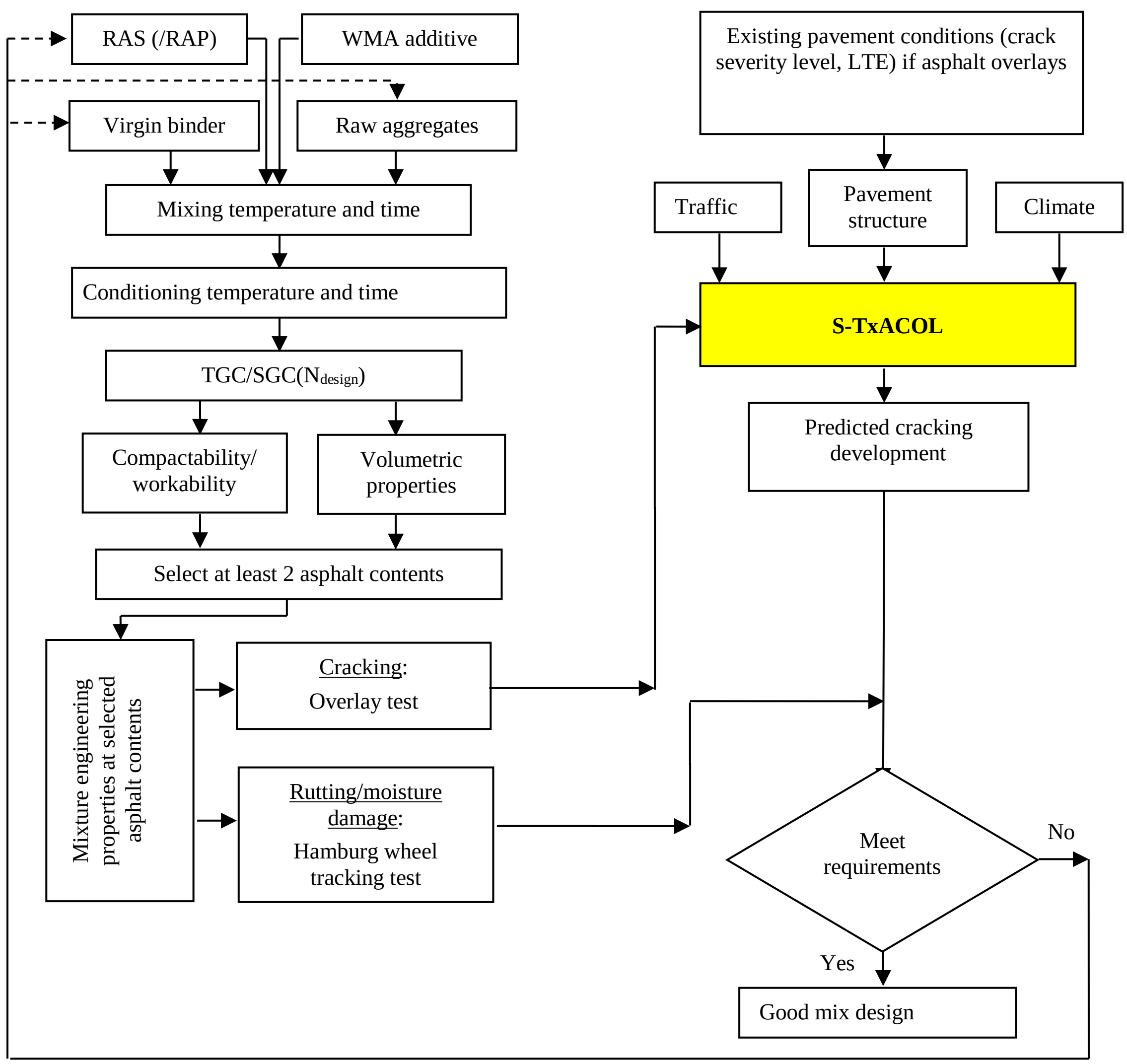

Figure 8. Balanced RAP/RAS Mix Design for Project-Specific Service Conditions.

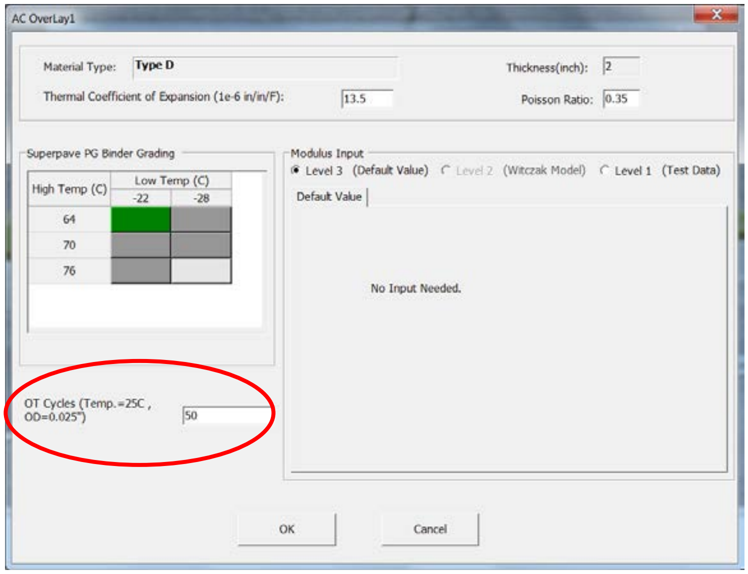

Figure 9. OT Cycles Input Interface for S-TxACOL.

DEMONSTRATION OF VARIOUS CRACKING REQUIREMENTS FOR PROJECT-SPECIFIC CONDITIONS

Two series of case studies were performed using the simplified TxACOL to demonstrate the importance of varying cracking requirements for different applications. Detailed information is described below.

Case 1: Impact of Different Existing Pavement Conditions on Cracking Requirements

A 2 in. (50 mm) asphalt overlay with PG 70-22 binder is applied to the following existing pavements with different load transfer efficiency (LTE) in Bastrop County, Austin District. The traffic level is 3 million Equivalent Single Axle Load (ESAL) within 20 years. The relationship between OT cycles and cracking development for each application predicted from S-TxACOL is shown in Figures 10 and 11:

- 10 in. (250 mm) jointed portland concrete pavement (JPCP) over 6 in. (150 mm) base with LTE=70 percent.
- 3 in. (75 mm) asphalt pavement over 10 in. (250 mm) cement stabilized base (CTB) with LTE=70 percent.
- 5 in. (125 mm) asphalt layer over 12 in. (300 mm) granular base with medium severity cracking (LTE=70 percent).
- 10 in. (250 mm) continuous reinforced concrete pavement (CRCP) over 6 in. (150 mm) base with LTE=90 percent.
- 8 in. (200 mm) asphalt layer over 10 in. (250 mm) very stiff base with low severity level (LTE=50 percent).

The results shown in Figure 10 and Figure 11 clearly indicate that varying OT cycles (or cracking requirement) are necessary for different applications. In order to have the same overlay life, the mix being used for asphalt overlay over JPCP should have higher OT cycles, when compared to asphalt overlay over CRCP. Clearly, it is much safer to use RAP/RAS mixes for asphalt overlay over CRCP.

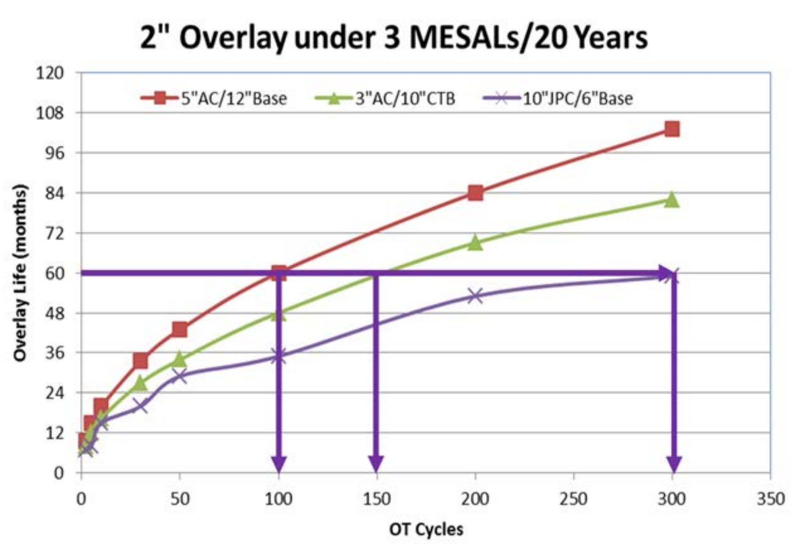

Figure 10. Relationships between OT Cycles and Cracking Development for Three Applications with Medium Cracking Severity.

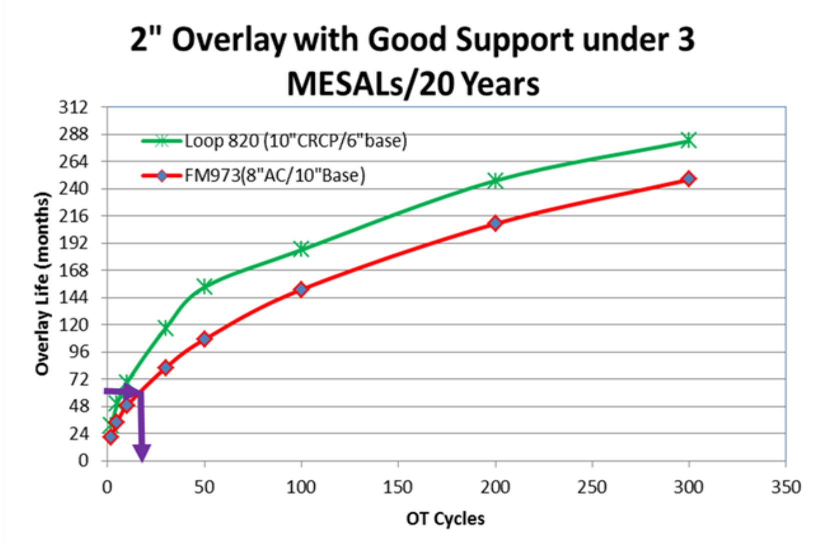

Figure 11. Relationships between OT Cycles and Cracking Development for Two Applications with Very Good LTE.

Case 2: Impact of Climate on Cracking Requirements

Again, the same 2 in. (50 mm) asphalt overlay with PG 70-22 binder is assumed to apply to the following existing pavements at three climatic zones: Amarillo, Austin, and McAllen. Amarillo has severe winter conditions with lots of freeze-thaw cycling, and McAllen has a very mild winter with no freeze-thaw cycle. The same traffic level of 3 million ESALs within 20 years is assumed. Figure 12, Figure 13, and Figure 14 show the relationship between OT cycles and cracking development for each application predicted from S-TxACOL. The overlay life is defined as time until 50 percent return of reflective cracking. It is obvious that climate has significant influence on cracking development and consequently on cracking requirement:

- 10 in. (250 mm) JPCP over 6 in. (150 mm) base with LTE=70 percent.
- 3 in. (75 mm) asphalt pavement over 10 in. (250 mm) CTB with LTE=70 percent.

In summary, all things else being equal to get equivalent life until reflective cracking returns different OT requirements are needed for these three zones. For the flexible pavement design, the OT requirement would changes from 65 to 300 cycles with a change from mild to cold climates. This section further demonstrates that a single cracking requirement does not apply to all asphalt overlay applications and the necessity of performing S-TxACOL analysis for project-specific conditions.

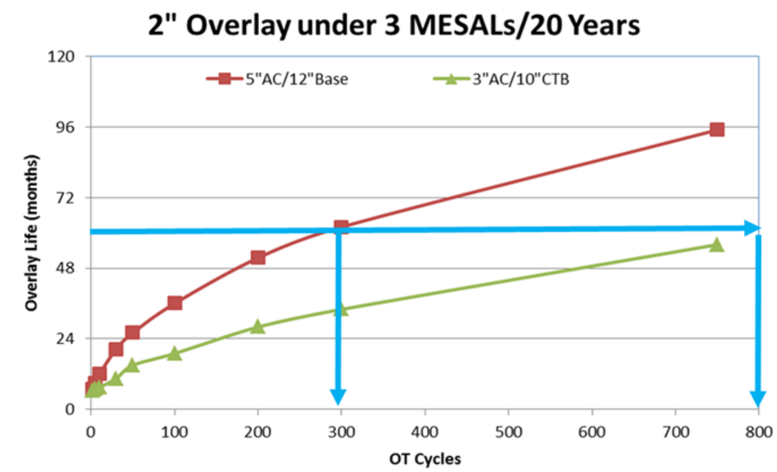

Figure 12. Amarillo: Relationships between OT Cycles and Cracking Development.

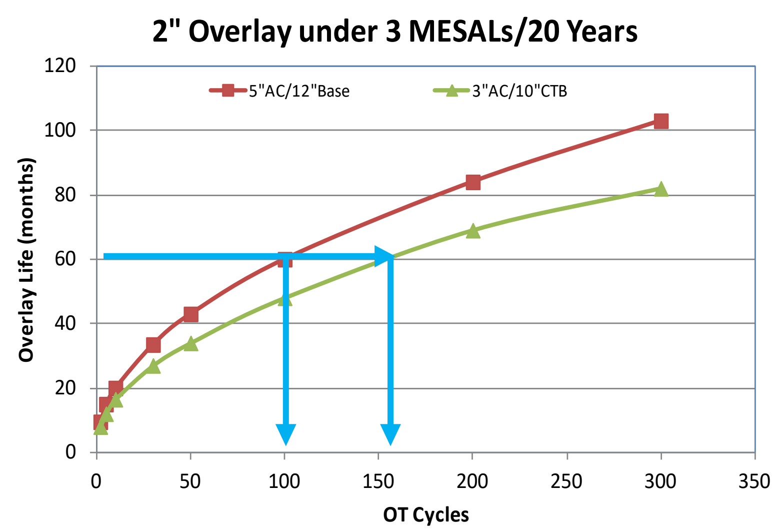

Figure 13. Austin: Relationships between OT Cycles and Cracking Development.

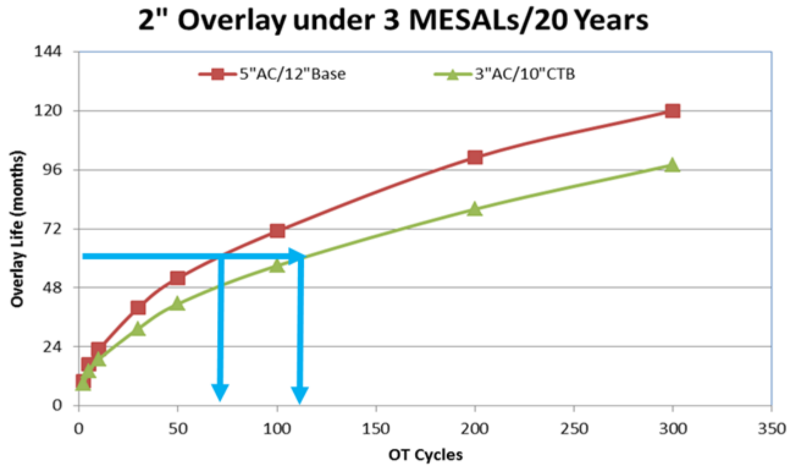

Figure 14. McAllen: Relationships between OT Cycles and Cracking Development.

RAS MIX PRODUCTION

Producing RAS mixes is similar to that for RAP mixes. Normally RAS is treated like RAP with a cold bin and is fed into the plant. As Morton (2011) noted, there are at least four specific issues that are worth watching when producing RAS mixes:

- Keep RAS bin empty when not in use.
- Use a vibratory scalping screen (Figure 15) to help break down or remove clumps that may be in the RAS material before entering the drum.

Figure 15. Vibratory Scalping Screen (after Morton, 2011).

- Do not superheat the mix; it makes the RAS mix stiffer and more difficult to work with in the field.
- Avoid holding RAS mix in silo overnight.

RAS MIX CONSTRUCTION

Construction of RAS mixtures is similar to that for RAP mixes. Again there are several specific issues to consider during RAS mix construction, as Morton (2011) pointed out:

- Consider the weather.
- Consider the haul distance.
- Consider the trucks that haul the mix.
- Do not let mix sit in trucks too long on job site.
- Check RAS mix temperature when unloading trucks.
- Stiffen quicker in trucks than standard hot mix.
- Be more difficult to hand work.
- Be more sensitive to temperature segregation.

SUMMARY

This chapter discussed issues related to balanced RAS/RAP mix design, production, and field construction.

CHAPTER 4:
SUMMARY AND RECOMMENDATION

This handbook presented the best practices for using RAS in asphalt mixes in terms of RAS processing and stockpile management, balanced RAS/RAP mix design, production, and field construction. Based on the information presented, the following findings and conclusions are offered:

- A six-step RAS processing guideline is proposed in this study, which includes: collecting, sorting, grinding, screening, and storing the processed RAS plus asbestos testing for TOAS.
- RAS binders are very stiff. It is critical to investigate blending between virgin binders and RAS binders. Note that the low temperature PG of RAS binder is **above** 0°C.
- Issues related to RAS mix design, production, and construction were identified and discussed. Specifically, the balanced RAS/RAP mix design is proposed for project specific conditions.

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