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16. Abstract

The Texas Department of Transportation (TxDOT) instituted a change in their seal coat binder specification in 2010 which allowed districts to select multiple binders within specified traffic levels or tiers for the purposes of allowing contractors to bid the work with the most economical binder available to them. Known as the tier system, it is estimated that this approach has saved TxDOT over $33 million in the 2.5 years that it has been used. While this savings is substantial, it was recognized that refinements to the tier system were needed to address specific performance problems. This research project was initiated to poll TxDOT district personnel, contractors, and chip seal binder suppliers to ascertain how the tier system was working, what modifications could be made to improve performance, and what other issues needed to be addressed. Although the tier system is generally working as intended, there are opportunities for improvement. These include an expanded education effort for all levels of TxDOT personnel involved in chip seal construction, changing traffic requirements to reflect cumulative and truck characteristics, keeping the tier system for district wide chip seal programs, updating the current chip seal manual, developing standards for pavement preparation ahead of sealing, allowing more flexibility for selecting binders for individual projects, developing generic chip seal binder specifications, removing aggregate requirements from the current tier system, initiate research into the development of a good winter binder, and initiate research into the development and application of seal coat test methods.

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EVALUATION OF THE TEXAS TIER SYSTEM FOR SEAL COAT BINDER SPECIFICATION

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

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INTRODUCTION

BACKGROUND

In 2012, TxDOT allocated approximately $336.68 million for preventive maintenance (PM) work throughout the state. The allocation was distributed among the 25 TxDOT districts as shown in Table 1.

Table 1. TxDOT District Allocation for Preventive Maintenance and Total Construction.

District	PM Funding Allocation Cat. 1PM (millions of $)	Total Construction Allocation Cat. 1 - Cat. 12 (millions of $)
Abilene	8.76	30.63
Amarillo	11.36	37.00
Atlanta	9.17	36.00
Austin	22.28	154.87
Beaumont	10.64	33.37
Brownwood	7.09	19.20
Bryan	12.65	38.26
Childress	8.35	17.14
Corpus Christi	15.03	53.80
Dallas	17.46	296.18
El Paso	6.69	68.64
Fort Worth	18.65	186.58
Houston	23.16	405.96
Laredo	19.24	33.81
Lubbock	12.80	55.65
Lufkin	11.93	34.46
Odessa	6.71	28.20
Paris	16.71	50.06
Pharr	19.45	87.54
San Angelo	6.55	18.83
San Antonio	23.42	171.01
Tyler	13.30	32.16
Waco	13.77	38.26
Wichita Falls	5.67	21.02
Yoakum	15.84	37.63
TOTAL	336.68	1,986.26

This funding provides for the routine care of highway facilities to extend their life rather than expend rehabilitation funds earlier than necessary. Each year TxDOT districts develop district-wide preventive maintenance contracts to maximize the benefit of the available funding level. These contracts predominantly utilize seal coats to treat roadways selected by district staff. The roadways selected to receive a seal coat treatment are determined by evaluating the

current Pavement Management Information System (PMIS) data along with visual inspections and recommendations of Maintenance Supervisors and Area Engineers. A prioritized list of projects including corresponding project cost estimates is typically developed and compared to the preventive maintenance funding allocated to the district. Projects are selected for the district-wide program based on prioritized need and available funds. The projects unable to be funded in the current funding cycle generally become higher priority projects in the following year.

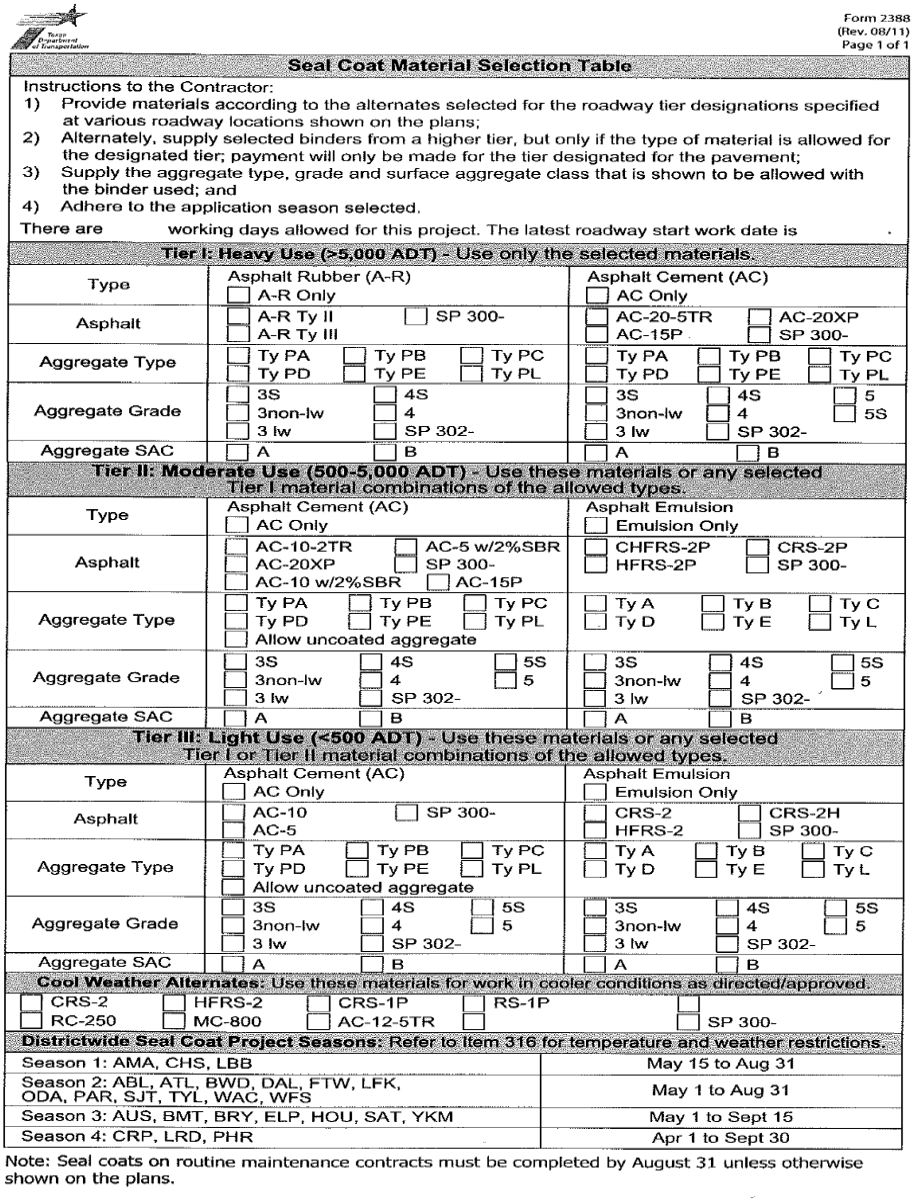
Significant funding constraints have required TxDOT to focus available resources on preventive maintenance activities and to maximize the return on each dollar invested. As shown in the table above, several districts are faced with the fact that the annual district-wide preventive maintenance contract represents a significant portion of the construction funding available. This condition, and method of funding distribution, is expected to continue for each fiscal year for the foreseeable future. Consequently, the preventive maintenance program has become a primary funding source for these districts to provide a safe, reliable, and efficient highway network. In an effort to address the available level of funding, TxDOT began the development of a contracting method to maximize the benefit available from the preventive maintenance funds. This contracting method included the development and implementation of the Seal Coat Material Selection Table. The goal associated with the implementation of the table was to reduce construction costs through increased competition and contract flexibility.

The Seal Coat Material Selection Table, shown in Figure 1, provides a three-tiered approach based on average annual daily traffic (AADT) for the selection of an asphalt binder to be used for the corresponding projects. There are three different traffic tiers: Tier I with greater than 5,000 AADT, Tier II with 500 to 5,000 AADT, and Tier III with less than 500 AADT. In each tier there are multiple types of asphalt available for selection by the designer. Tier I represents high type facilities, Tier II facilities are moderately trafficked and Tier III is comprised of low volume roadways. The binders identified for Tier I are highly modified asphalts (AC) and include asphalt-rubber (A-R), Tier II binders are lightly modified asphalts and include emulsions, and Tier III binders are unmodified asphalts and also include emulsions. Seal coat seasons for the districts were also established and included in the table. Within a given traffic tier of the Seal Coat Material Selection Table, a district can elect to have the contractor choose the binder type and grade from several options that should provide comparable performance. The district does this by selecting one or more binders within a tier. On district-wide seal coat programs, this allows the contractor to minimize the overall cost by balancing the binder selection between the price of the binder grade and the economy of scale through quantity discounts. On individual maintenance and construction contracts, it allows the contractor to select the most economical binder of the choices available.

Several districts successfully piloted the use of a seal coat material selection table in 2009. This success prompted TxDOT to require use of the table in each district for future preventive maintenance projects beginning with the 2010 district-wide programs. The lessons learned from the pilot utilization were integrated into the Seal Coat Material Selection Table used for the 2010 district-wide programs. Similarly, lessons learned from the statewide

implementation of 2010 were incorporated into the table used for the 2011 projects. Modifications made to the table for the 2011 projects included revised traffic (AADT) thresholds for each tier, adjusting the binders available for selection in each tier and allowing the designer to select either A-R only, AC only, or emulsion only. Bid items for tiered aggregates were implemented for the 2012 district-wide programs.

There are several binder designations within the table shown in Figure 1, which fall into three broad binder-type categories: A-R, AC, and emulsions. A brief description of the different binder types and their properties is described below.



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Seal Coat Material Selection Table

Instructions to the Contractor:
1) Provide materials according to the alternates selected for the roadway tier designations specified at various roadway locations shown on the plans;
2) Alternately, supply selected binders from a higher tier, but only if the type of material is allowed for the designated tier; payment will only be made for the tier designated for the pavement;
3) Supply the aggregate type, grade and surface aggregate class that is shown to be allowed with the binder used; and
4) Adhere to the application season selected.

There are working days allowed for this project. The latest roadway start work date is .

Tier I: Heavy Use (>5,000 ADT) - Use only the selected materials.

Type	Asphalt Rubber (A-R) ☐ A-R Only	Asphalt Cement (AC) ☐ AC Only
Asphalt	☐ A-R Ty II ☐ A-R Ty III ☐ SP 300-	☐ AC-20-5TR ☐ AC-15P ☐ AC-20XP ☐ SP 300-
Aggregate Type	☐ Ty PA ☐ Ty PB ☐ Ty PC ☐ Ty PD ☐ Ty PE ☐ Ty PL	☐ Ty PA ☐ Ty PB ☐ Ty PC ☐ Ty PD ☐ Ty PE ☐ Ty PL
Aggregate Grade	☐ 3S ☐ 3non-lw ☐ 3 lw ☐ 4S ☐ 4 ☐ SP 302-	☐ 3S ☐ 3non-lw ☐ 3 lw ☐ 4S ☐ 4 ☐ SP 302- ☐ 5 ☐ 5S
Aggregate SAC	☐ A ☐ B	☐ A ☐ B

Tier II: Moderate Use (500-5,000 ADT) - Use these materials or any selected Tier I material combinations of the allowed types.

Type	Asphalt Cement (AC) ☐ AC Only	Asphalt Emulsion ☐ Emulsion Only
Asphalt	☐ AC-10-2TR ☐ AC-20XP ☐ AC-10 w/2%SBR ☐ AC-5 w/2%SBR ☐ SP 300- ☐ AC-15P	☐ CHFRS-2P ☐ HFRS-2P ☐ CRS-2P ☐ SP 300-
Aggregate Type	☐ Ty PA ☐ Ty PB ☐ Ty PC ☐ Ty PD ☐ Ty PE ☐ Ty PL ☐ Allow uncoated aggregate	☐ Ty A ☐ Ty D ☐ Ty B ☐ Ty E ☐ Ty C ☐ Ty L
Aggregate Grade	☐ 3S ☐ 3non-lw ☐ 3 lw ☐ 4S ☐ 4 ☐ SP 302- ☐ 5S ☐ 5	☐ 3S ☐ 3non-lw ☐ 3 lw ☐ 4S ☐ 4 ☐ SP 302- ☐ 5S ☐ 5
Aggregate SAC	☐ A ☐ B	☐ A ☐ B

Tier III: Light Use (<500 ADT) - Use these materials or any selected Tier I or Tier II material combinations of the allowed types.

Type	Asphalt Cement (AC) ☐ AC Only	Asphalt Emulsion ☐ Emulsion Only
Asphalt	☐ AC-10 ☐ AC-5 ☐ SP 300-	☐ CRS-2 ☐ HFRS-2 ☐ CRS-2H ☐ SP 300-
Aggregate Type	☐ Ty PA ☐ Ty PB ☐ Ty PC ☐ Ty PD ☐ Ty PE ☐ Ty PL ☐ Allow uncoated aggregate	☐ Ty A ☐ Ty D ☐ Ty B ☐ Ty E ☐ Ty C ☐ Ty L
Aggregate Grade	☐ 3S ☐ 3non-lw ☐ 3 lw ☐ 4S ☐ 4 ☐ SP 302- ☐ 5S ☐ 5	☐ 3S ☐ 3non-lw ☐ 3 lw ☐ 4S ☐ 4 ☐ SP 302- ☐ 5S ☐ 5
Aggregate SAC	☐ A ☐ B	☐ A ☐ B

Cool Weather Alternates: Use these materials for work in cooler conditions as directed/approved.

☐ CRS-2 ☐ HFRS-2 ☐ CRS-1P ☐ RS-1P ☐ RC-250 ☐ MC-800 ☐ AC-12-5TR ☐ SP 300-

Districtwide Seal Coat Project Seasons: Refer to Item 316 for temperature and weather restrictions.

Season 1: AMA, CHS, LBB	May 15 to Aug 31
Season 2: ABL, ATL, BWD, DAL, FTW, LFK, ODA, PAR, SJT, TYL, WAC, WFS	May 1 to Aug 31
Season 3: AUS, BMT, BRY, ELP, HOU, SAT, YKM	May 1 to Sept 15
Season 4: CRP, LRD, PHR	Apr 1 to Sept 30

Note: Seal coats on routine maintenance contracts must be completed by August 31 unless otherwise shown on the plans.

Figure 1. Seal Coat Material Selection Table.

Asphalt Rubber Binders

A-R binders are mixtures of asphalt cement and crumb rubber modifier (CRM), which have been reacted at elevated temperatures. The A-R binders contain a minimum of 15% CRM and there are two A-R types allowed by the specification: A-R Type II and AR Type III. The Type III binder is softer than the Type II and may be better suited to the northernmost regions of the state.

For a given aggregate, A-R binders can be shot at a higher application rate than conventional ACs without contributing to flushing problems. The higher application rate provides for better sealing capability on cracked pavements and the tire rubber modifier is thought to provide increased flexibility to withstand the movement of the cracks. A-R binders have been used successfully by many districts as a stress-absorbing membrane interlayer (SAMI) between an old pavement and new overlay to reduce the rate at which reflection cracks reappear. A-R binders also have good adhesion and have been used to successfully seal Portland cement concrete pavement and bond subsequent layers to the concrete.

Asphalt Cement

Hot-applied asphalt cement is commonly used for seal coat construction in Texas and a pre-coated aggregate is usually required. Two types of polymer-modified asphalt cements have been used extensively for seal coats: AC-20-5TR and AC-20 XP. The AC-20 5TR contains 5 percent tire rubber while the AC-20 XP contains another type of polymer but both products are comparable to each other. Softer asphalts with less polymer modification include AC-10 2TR, AC-15P, AC-5 w/2%SBR, and AC-10 w/2% SBR; these products may be better suited to the northern districts.

Unmodified asphalt cements that can be used for seal coats includes AC-5 and AC-10 but are reserved for use on low volume facilities. Performance of seal coats is highly dependent on workmanship and correct application rates for binder and cover stone. However, the use of polymer-modified binders can be like buying insurance against workmanship issues. Rock loss typically occurs in the first few weeks after construction and polymer modified materials aid in holding rock even when too little asphalt may have been applied. Flushing/bleeding is usually caused by application of too much asphalt but polymer modified binders can minimize the severity of the flushing. The polymer-modified materials help to ensure better adhesion to the aggregate and existing pavement.

Emulsions

There are two general types of emulsions used for seal coat applications: cationic and anionic. The cationic emulsions include:

- CRS-2 (Cationic Rapid Set with no polymer modification).
- CRS-2H (Cationic Rapid Set with no polymer modification. The "H" means it has a harder base binder).
- CRS-2p (includes polymer modification).
- CHFRS-2p (Cationic High Float Rapid Set, polymer-modified.

The anionic emulsions include:

- HFRS-2 (High Float Rapid Set).
- HFRS-2P (High Float Rapid Set, polymer modified).

The advantages of emulsions over asphalt cement are that they are applied at much lower temperatures (140°F versus 300°F+) and can thus be more forgiving and easier to work with. They can readily coat damp aggregates and because they are composed of 30 percent water, the aggregate has an initially higher embedment depth. As the emulsion breaks, the residue is deposited up on the sides of the aggregate particles that can minimize the propensity for shelling or rock loss. Aggregates used with emulsions should not be pre-coated.

Cationic emulsions break quicker than anionic, are generally attracted to the rock more than anionic, and can be opened to traffic sooner. Cationic emulsions are a good choice in high humidity areas and if they aggregate is clean. Anionic emulsions, though slower to cure, are a good choice if the aggregate is excessively dusty and is in a low humidity area. The slower cure allows time for the binder to wick its way through the dust on the aggregate and achieve a good bond.

The residual asphalt used in high float emulsions is resistant to flow. In theory, high float products should not be as prone to flushing and less likely to migrate through an overlay when used in underseals. Polymers are added to improve adhesion, shorten return to traffic times, and to reduce the temperature susceptibility the binder may see in-service translating to less propensity for flushing in high temperatures and better cracking resistance and rock loss at low temperatures.

OBJECTIVE

In 2012, TxDOT commissioned the Texas Transportation Institute to conduct a research project in order to ascertain the experience and opinions of TxDOT district personnel, contractors, and material suppliers with the seal coat binder specification. This study is to be followed by another where the performance and cost of the binders are to be evaluated.

SCOPE

This research project evaluated the success of this system to date by 1) identifying districts with chip seal projects accomplished under this system, 2) interviewing TxDOT personnel, material suppliers, and contractors with experience under this system, 3) summarizing the experience of the various parties, 4) analyzing the information, and 5) reporting the results.

RESEARCH APPROACH

STAKEHOLDERS

TxDOT Districts

The researchers first sought to ensure a geographical distribution of districts including the west (Odessa), north (Lubbock), central (Brownwood and Bryan), east (Lufkin and Tyler), and south (Pharr). However, opportunities arose to receive input from a number of other districts including San Angelo, Amarillo, Childress, Abilene, Paris, and Atlanta. Figure 2 shows the districts that participated in the discussions. All of these meetings took place in district offices over an approximately one-month time frame. Participants in the district meetings varied from one to another but generally included district engineers, area engineers, maintenance and operations engineers, designers, materials engineers, construction engineers, planners, seal coat supervisors, and maintenance supervisors.

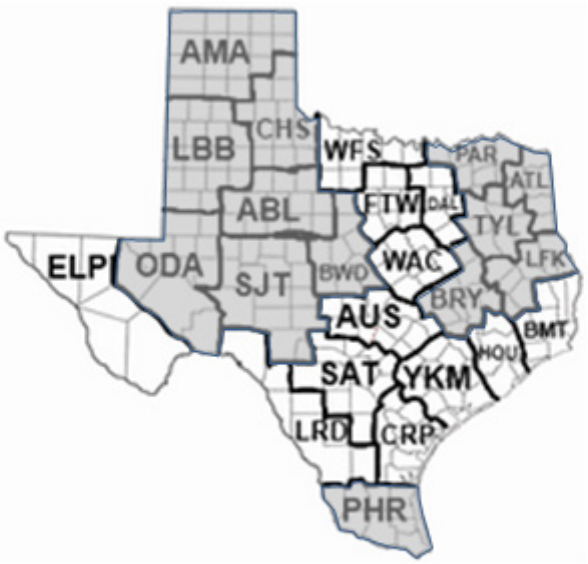

Figure 2. TxDOT Districts Interviewed

Figure 2. TxDOT Districts Interviewed.

Construction Contractors

Seal coat contractors were identified in discussions with the Associated General Contractors (AGC) Texas Chapter and in discussions with various TxDOT districts. Seven contractors were contacted and three participated in a teleconference, a fourth was interviewed in his office, and fifth participated in a telephone interview. These included:

- Brannan Paving Co. of Victoria, Texas.
- Clark Construction Co. of San Antonio, Texas.
- Cox Paving Co. of Blanco, Texas.
- Jones Brothers Dirt and Paving Contractors, Inc. of Odessa, Texas.
- Lipham Construction Co., Inc. of Aspermont, Texas.

The conference call took place at 2:00 p.m. on July 3, 2012, and the telephone interview was conducted on July 19, 2012.

Material Suppliers

Seal coat material suppliers were identified by TxDOT district and central office personnel as well as the Texas Asphalt Pavement Association. A teleconference with suppliers was held on August 2, 2012, at 2:00 p.m. The following five materials suppliers and the seal coat binder types they provide were represented on the conference call:

- Cox Paving Co. – Asphalt-Rubber (A-R).
- Martin – All binders except A-R.
- Pelican Refining – All binders except A-R and emulsions.
- Valero – AC, AC-15P, AC-20XP.
- Wright Asphalt – Tire Rubber (TR) and Tire Rubber Emulsion.

QUESTIONNAIRES

Questions to be addressed by each of the interested parties were initially drawn up by the research team and refined in consultation with TxDOT research project representatives. These questions were intended to elicit unbiased responses from the participants regarding their experiences with the tiered system of seal coat binder selection. The questions for each group are presented in the results section of this report.

CONDUCT INTERVIEWS

Interviews were conducted in person with the TxDOT districts and a few contractors, and by conference call and individual telephone calls with most of the contractors and all of the material suppliers. While individual interviews with all parties would have been preferable, time constraints for the project did not allow this to occur. During the interview process, participants were told that their responses would not be attributed to specific individuals.

SUMMARIZE INFORMATION

As information was gathered, the research team compiled the detailed comments and searched for common responses. While there was not a unanimous response among participants to any given issue, the consensus of the responses was synthesized and the minority responses

were noted. Again, there were no attributions to individuals or particular organizations during the processing of the information.

RESULTS

TXDOT

TxDOT personnel were interviewed in district offices. In some cases, personnel from districts other than the one hosting the meeting traveled to the meeting to provide input. All of the TxDOT interviews were conducted between April 30 and May 24, 2012. At these meetings, the following questions were asked of the attendees:

1. What is the purpose of the Table of Binder Alternatives?
2. Do you use the Table as it was developed in your District?
    a. If not, how has it changed?
    b. Why was it changed?
3. Are you satisfied with the alternative binder specifications?
    a. If not, what changes would you make to the existing specification?
4. Have you saved money on construction with the alternative binder specifications?
    a. Asphalt binder shot quantities (do they vary with binder types, if so how much)?
    b. Pay by hot or cold gallon or by ton?
    c. Asphalt binder quantity vary by aggregate (grade 3, 4,5)?
5. Is cost information available in the district or state wide?
6. Are construction contracts easier or more difficult with the alternatives?
7. What are the performance problems you have noticed with the use of the new specification? (early stone loss, early bleeding, first cool weather stone loss, first cold weather stone loss, 1st summer bleeding, etc.)
8. Is aggregate selection a problem (light weight versus normal weight, coated versus not coated, etc.)
9. Do you consider the alternative binders equivalent for the applications?
    a. In terms of performance?
    b. In terms of life cycle cost?
10. What feedback have you gotten from your contractors?
11. What feedback have you gotten from material suppliers?
12. What feedback have you gotten from maintenance personnel?
13. Do you have any other comments on the alternative binder specifications for seal coats?

GENERAL OBSERVATIONS

The questionnaire began with general questions concerning the district's understanding and application of the Seal Coat Material Selection Table. The districts interviewed seemed to have very clear ideas about why the table was developed. Most believed that it was intended to increase competition between contractors while some mentioned lowering costs, increasing contractor flexibility, improving the uniformity of contracting practices statewide, and finally matching the binders to the appropriate roadways. Likewise, most of the districts use the table as it was developed or with changes they deemed necessary to make it work for them. These modifications included the development of a separate table for under-seals, separate tables for emulsions and hot AC, using the table only for the district-wide program (DWP), and modifying

binder choices by subdividing traffic levels within a given tier. There was a wide variety of views among the districts about what was necessary to make the tier system work.

When asked if they were satisfied with the table, there was a wide range in the responses. Some were very happy with the table and others would like to do away with it. One responded that the tier system provides greater confidence in the materials selection process and allows them to use seal coats on high volume roadways. Others expressed a level of satisfaction with the table, and mentioned specific advantages such as giving contractors greater flexibility while lowering contract prices and an appreciation of the inclusion of construction dates for the use of specific binders. Others would like to see the tier system ended because it has not worked well for them or saved money. In these cases, they would keep the idea of allowing alternatives but would like the flexibility to more actively engineer their projects by selecting specific binders to address specific roadway conditions. There were some who expressed the opinion that the design engineers did not understand the table or its intent and others who were uncomfortable with the restrictions that the table imposes on the design process (construction dates, traffic levels, etc.). Another district mentioned that contractors were adjusting their bids to address risk due to construction season uncertainty with respect to availability of asphalts in different areas of the state.

There were a number of suggestions made in terms of changing various aspects of the table. The most common suggestion being that the district would like to have the flexibility to specify a single binder in certain instances where past performance would warrant its use. Most districts felt that the table was an appropriate mechanism for specifying binders in their DWP, but again, they would like to have the flexibility to change the binder in the DWP, if required. One district suggested that the table be used as a best practices guideline rather than a mandatory system so that solutions could be designed for specific problems. Two other districts recommended replacing the table with a more comprehensive best practices guide that would leave them with greater flexibility. In almost all cases, the engineers believed that alternatives should be left in bid documents wherever they would be appropriate.

Some districts believed that some of the asphalt binders in Tier I were not appropriate for their applications. In the west, some districts expressed a desire to use asphalt-rubber (A-R) in certain instances to reduce cracking, but found that A-R was not competitive to other choices within Tier I because of its greater application rate. Other districts would like to specify only AC-20-5TR for higher volume roads with more truck traffic. There were also engineers who thought that Tier I asphalts should be applied in certain instances to Tier II roads, especially if there were a large number of commercial trucks or turning movements. It was the experience in one district that anticipating which binders in the table will be available in a given year is difficult as binder suppliers may or may not provide certain products. Another district stated that hot asphalt binders should not be in the same tier as asphalt emulsions.

Tier III, as it is established in the Table, seemed to be the most problematic feature. Because Tier III is for roads with less than 500 ADT, the binder selection is limited to unmodified asphalt and emulsions. Five of the districts interviewed have eliminated Tier III

from consideration because higher commercial truck traffic on low volume roads have dictated the use of higher quality binders than are currently listed. The use of these roads by logging trucks and energy development companies was cited as a reason to use higher quality materials. The districts also mentioned that the intervals between seal coat applications on low volume roads is getting longer, sometimes as long as 14 years, and this requires the use of higher quality polymer modified binders. Several districts expand their DWP by using Routine Maintenance Contracts to seal coat lower volume Tier III roads, while others use only in-house forces to accomplish Tier III work.

The use of Tier III binders in under-seals also elicited comments that encouraged change. Two districts suggested that Tier III binders should not be used for under-seals because traffic would be traveling on the seal coat during stage construction. This agrees with another district that suggested the use of Tier III binders in under-seals is satisfactory so long as the overlay is placed quickly. Another district said it would like separate tables for under-seals and surface applications.

Some TxDOT personnel believe that traffic criteria for selecting tiers and binders should be refined, which is somewhat validated by one district's observation that Tier II is 85 to 90 percent of their program. One engineer thought the traffic volumes were too broad, while another stated that the amount of truck traffic and consideration of site conditions (turning and stopping movements) should be included in the binder selection. Two others suggested the use of cumulative traffic in terms of total vehicles or equivalent single axle loads expected between seal coats be used to define the tier levels. One district suggested that the criteria should include long-term economics such as an annualized cost. Another engineer stated that traffic levels should be left off the table provided in bid documents and made available only to the designer.

As discussed above, the expectations for performance are changing, especially for Tier III roads where the districts may wait as long as 14 years between seal coats. In one district, their typical seal coat life is about five to six years. One district encouraged the use of engineering judgment of when to re-seal a road rather than using pre-defined cycle times.

Economics

There is not a consensus among districts of whether the tier system is saving the department money. One view from at least three districts is that seal coat prices have been very good in recent years because of the table. Their districts have been able to seal more miles of roadway and competition among contractors is improving. On the other hand, some districts were using alternative binders before the table was published, and they were not sure they were saving money when compared to their previous practices. One district noted that while recent prices have been very good, the fluctuations in price may be masking the potential benefits. It was cheaper to place hot AC with pre-coated aggregate than use an emulsion according to another district.

Cost data compiled by Gerald Peterson of TxDOT shows that from 2010 through the middle of 2012, TxDOT has saved money using the tiered approach to seal coat binder

specifications (Table 2). Over the 2.5 years that the tier system has been in place, compared to non-tier projects, the savings have amounted to more than $33 million. In 2011 and 2012, this amounted to 16 and 18 percent savings, respectively. This is potentially a reflection of the increased competition.

Table 2. TxDOT Savings Using Tiered Seal Coat Binder Specification.

Year	Non-tiered Seal Coat Binder Avg. Unit Cost, $/gal	Tiered Seal Coat Binder Avg. Unit Cost, $/gal	Difference in Binder Avg. Unit Cost, $/gal	Total Tiered Seal Coat Binder, gal.	Total Binder Savings in Tiered Seal Coats, $
2010	$2.57	$2.31	$0.26	14,287,879	3,715,000
2011	$3.43	$2.87	$0.56	42,859,876	24,002,000
2012 through June 6	$3.82	$3.14	$0.68	7,815,396	5,314,000
Total for 2.5 years					33,031,000

Construction Contract Administration

Five of the districts interviewed stated that the administration of seal coat contracts have been easier due to the tier system. In two instances, the engineers noted that change orders are not necessary when contractors need to switch between binders that are selected within the same tier. In at least three districts, the engineers said that they got Tier I binders for all DWP jobs, regardless of whether they were categorized as Tier I or Tier II. Two districts stated that they were allowing binder alternatives before the tier system was implemented, and that the change in administration effort has not been noticeable. One district noted that the table creates administrative issues when the contractor needs to change to a binder that is not designated because of bid codes and trying to determine a reasonable cost. From an administrative point of view, the table appears to have made contract management generally easier.

TECHNICAL OBSERVATIONS

Materials

The districts were asked whether the application rates vary between types of binders. One district said that the application rate on any given project was established at the beginning of the work by the inspector, maintenance superintendent, and the contractor. The general response was that shot quantities do vary between the different binders as well as different job conditions. Asphalt-rubber binders needed to be applied thicker than other binders, and they were needed in situations that were different from other types of binders. Specifically, A-R binders were seen as providing better service for applications over cracked asphalt pavement and concrete pavement.

The tire rubber (TR) binders performed better over a range of application rates than other seal coat binders and were more tolerant of variability.

Asphalt is paid for by the hot gallon, which was seen as being problematic by some TxDOT personnel. Because there is not a specific temperature at which the binder volume is measured or a specific temperature to which it is corrected, then the unit price, which is applied to the binder is not well defined due to volumetric variations. Volume expansion due to foaming may take place with some binders, which would also make the volume measurement suspect. Presently, one option for determining the volume of binder is to strap the asphalt tank (manually measure the level of asphalt in the tank) before work begins and again either at the end of the day or the end of the job. TxDOT also allows measurements to be taken from gauges on computerized distributor trucks after calibration with manual strapping. In either case, an inspector must be present to take the measurement or reading. Two districts mentioned that for large projects they would rather pay for the binder by the ton on large projects and by the gallon on small projects.

The required amount of asphalt binder on the roadway varies according to the size of the aggregate with Grade 3 aggregate typically requiring a binder shot rate of 0.45 to 0.50 gal/yd^2 and Grade 4 (smaller) aggregate requiring a typical shot rate of 0.38 gal/ yd^2. In one eastern district, once they were able to bring their roads up to a level where only preventive maintenance was required, they went from using Grade 3 to Grade 4 aggregate, which allowed them to save 25 percent on binder costs. A northern district has started using Grade 4, which allows them also to reduce the amount of binder they apply. The same northern district said they have reduced the amount of Grade 3 aggregate they use because it makes for a more expensive seal coat and they expect only two more years of life from it and it increases windshield breakage. One district noted that most of their in-house work is done with Grade 4 or 5 aggregates.

From a bidding point of view, one districted said they had received criticism from aggregate suppliers when only one aggregate was selected in the table. However, for that district, there are no local sources of adequate natural aggregates and they do not use lightweight aggregate on interstate highways due to its tendency to abrade. One panhandle district uses pre-coated aggregate on high volume roads, and they have a natural source of lightweight aggregate in New Mexico. One district believes that paying for aggregate by the cubic yard encourages waste on projects and would rather see TxDOT pay for aggregate on the basis of square yards in place.

Performance

The critical periods for performance, as identified by district personnel, are immediately after construction, the first cool weather, and the first summer. The time immediately after construction is crucial in terms of potential aggregate loss and/or bleeding that may occur. Cool weather following construction will show whether there is a tendency for aggregate loss or shelling that may occur as the aggregate loses adhesion. The first summer will provide a good indication of the potential for bleeding to occur. Intersections and roads with a high number of

turning movements were also mentioned as being problematic in terms of bleeding and loss of aggregate.

Beyond climate and traffic characteristics, construction was seen as being crucial to the performance of seal coats. Preparation work on rehabilitation is very important, especially the leveling, according to one district. One district commented that the contractor on a particular job could dictate the performance of the roadway. Another stated that the quality of the binder was dependent upon the individual supplier. Also, high shot rates were mentioned as a leading cause of bleeding in seal coats. At least two districts mentioned the use of lime water to mitigate the effects of excessive binder application, and one additionally used bottom ash as a way to preclude bleeding. However, snowplowing is a concern in the panhandle and more asphalt is needed to hold the aggregate in place. One district in the north mentioned that AC20-5TR is good for this.

Many of the western districts experienced problems with bleeding last year. It was speculated that this could have been due to a combination of the use of Tier II or III asphalt, Grade 4 aggregate, and abnormally hot weather. The observation was made that Grade 4 aggregate quality has slipped over time to where there is typically more fine material these days.

In northern districts, seal coats with AR binders tend to shell out along the centerline and edges. They have needed to apply a fog seal after the first frost in order to deal with this problem. The problem has been bleeding with AR binders in the eastern part of the state. The use of variable nozzles helps prevent flushing. When flushing has occurred, the district has used Grade 5 aggregate with light emulsion in the lanes, followed by sealing the road again the following year. In West Texas, however, A-R binders are seen as being useful in applications over cracked asphalt pavements, and in one eastern district, it is the only seal coat binder allowed on concrete pavement.

In East Texas, two districts noted that humidity always affects seal coats during construction, and that their performance problems were not related to the table. One district said that they have had problems with aggregate not sticking in multiple seal applications, and that a cold rain during or immediately after construction caused early performance problems. One district in the east cited performance problems with flushing on high-volume roads caused by traffic during construction as the main problem. Two districts have said that logging and oil field traffic on low volume roads have been responsible for bleeding problems.

Emulsions were seen as being problematic by some districts while others believe they provide adequate performance. One district claimed it had problems with unmodified emulsions (CRS-2) while CRS-2P worked adequately. Another district stated that they use emulsions for in-house maintenance projects only, not for contract work. A district in West Texas said that emulsion binders do not work well for intersections or instances where there are turning movements. In the south, they do not seal intersections for this reason.

Late season or cool weather sealing was seen as being very challenging. Emulsions, especially CRS-1P, were seen as being necessary for these conditions but they do not perform well once the temperature warms up and need to be covered in the next construction season

according to four of the districts. One district has recently started using CRS-1P for cool weather work but they are not sure how well it is working. One district is using RC-250 for winter work, noting that the cutback does tend to bleed in warmer weather but also commenting that it has better winter performance than CRS-1P. Another district has said that it has used AC20-5TR for winter construction of under-seals but that it is better to use it in warm weather if the under-seal must be subjected to traffic. This same district said that it has used AC10-2TR with some success in winter sealing and under-sealing. They claim that they do not experience shelling or bleeding with TR binders.

In terms of estimated performance life, a western district offered the following: AC-20-5TR provides about 7 years, AC 10-2TR gives about 3 years, and AR binders provide about 10 years. In the south, seal coats are being used to extend pavement surface life two to three years until an overlay is placed. These seal coats eliminate the need for an under-seal. In the north, AC20-5TR is getting softer and consequently the northern districts are getting a little more bleeding, but not as much cracking.

Binder Equivalencies

When asked if binders within a given tier were equivalent, there was not a consensus among the various districts, although most believe that within a given tier there are problems in equating performance among binders. The experience in three districts is that they do get equal performance from the choices in Tier II, while two other districts say that the binders are not equal, especially in Tier II. A southern district noted that even in the extreme heat of the summer of 2011, they had no more problems with the early performance than in previous years.

Some personnel expressed the opinion that A-R binders should not be on the table as they have a different application from the other binders in that they are used on more highly deteriorated asphalt or concrete surfaces to mitigate cracking. Some districts indicated very good performance of A-R binders. One district has had problems in getting A-R binders to adhere to aggregates in porous friction courses and they have not used them for seal coats. Another district said that A-R binders have not been available to them.

Tire rubber modified binders (AC-10-2TR and AC-20-5TR) are generally considered as providing very good performance. In some districts, AC-20XP and AC-15P were viewed as being equivalent to the TR binders while other districts were of the opinion that they did not provide the same level of service, particularly for Tier I roads. Locally available TR binder dictated its use. In one instance, AC-15P was not economical compared to other binders. One district expressed the view that contractors would choose either TR or XP binders and that these are too stiff. Latex binders in Tier II have not performed well in one district and so they are not selected for use. The AC-5 and AC-10 binders are considered more likely to bleed than other hot binders. In Amarillo, for Tier I, AC20-5TR is used most often; for Tier II, AC10-2TR is the most frequently used; and for Tier III, it is AC10 and some AC5 with occasional CRS-2 and HFRS-2.

As stated before, emulsions are not seen as providing a comparable life to hot binders. They are used in some districts for cold weather applications or under-seals that will be

immediately covered but some districts try to avoid this. Emulsions were noted to bleed in warm weather. However, in one district, emulsions were credited as working well on low volume roads and saving money. One district would like to see the use of inverted prime coats be addressed with use of RC cutbacks, which were viewed to perform better in cold weather.

Contractor Feedback to Districts

In most instances, district personnel stated contractors have commented neither favorably nor negatively to the development of the tier system. In two of the districts, contractors have commented that they like the competition resulting from the use of the tier system and, in one district, the contractors have stated they do not like the system. One district replied that contractors believe they have too many choices under the tier system, which increases the complexity of bidding. Another district noted that, in their area, the local binder supplier dictated the availability of particular binders. One district said that the contractors have been contacting them asking which binders will be available in the coming season.

A number of districts noted how the district-wide program for seal coating has been positively affected by the tier system. In two districts, the DWP contractor has decided to stick with the Tier I binder for all Tier I and II work in the district rather than trying to use different binders. In one district, this was the case in the past, but for the last two seasons the contractor has elected to use different binders for separate tiers.

Material Supplier Feedback to Districts

As with the contractors, most districts have not had much feedback from the materials suppliers. One district said that their material suppliers did not like the system because they had made substantial investments in developing special formulations to improve performance, and they did not want their products equated to unmodified asphalt. This is similar to another district that received a complaint from a supplier that the system was not fair to AC-20-5TR. One district noted that competition among binder suppliers in their area changes yearly. When a district tried to modify the table, they received a complaint from a material supplier that did not furnish materials in their district. Finally, one lightweight aggregate supplier complained that the table was not fair to their product.

Maintenance Personnel Feedback

Feedback from TxDOT Maintenance Personnel ranged from no comments in three districts to that they were happy with system in three districts. In one district, in-house maintenance crews were used for low-volume road sealing due to budget restrictions. These crews used only emulsions in their work.

Other Comments

When asked if they had any other comments concerning seal coats and specifications, there were some suggestions made about possible improvements in information dissemination and specifications. A number of districts expressed an interest in technology transfer efforts that could include workshops, webinars, newsletters, or technical bulletins that provide feedback on seal coat performance, highlight best practices, and feature results of research efforts. One district suggested that the department consider the development of seal coat specifications modeled on the current asphalt mix specification. Another district said the department should consider developing a warranty specification due to the lack of inspectors at the district level.

SUMMARY

Based upon interviews with TxDOT district personnel, the following suggestions are made regarding seal coat work:

- Consider requiring the use of the Alternative Binder Selection Table on district-wide sealing programs only.
- Consider waiving the requirement of providing alternative binders in instances where the decision can be justified through engineering judgment.
- Consider requiring the designation of alternative binders in individual projects whenever possible.
- Continue to monitor program savings from the use of alternate binder specifications.
- Consider the development of a method to account for cumulative traffic and/or truck traffic in selecting seal coat binders.
- Consider developing generic specifications for seal coat binders.
- Sponsor research or encourage the development of a good winter binder that will perform well the following summer.
- Sponsor the development of technology transfer efforts, including:
    - Periodic webinars and/or workshops to demonstrate best practices for seal coats.
    - A newsletter or other periodicals that highlight best practices and provide references to resources.

CONTRACTORS

A conference call for seal coat contractors was held on July 3, 2012, with three representatives. A separate call was made to a fourth seal coat contractor on July 19, 2012, and a separate interview with a fifth contractor took place on July 21, 2012, at that contractor's office. Contractors represented included Brannan Paving Co., Clark Construction Co., Cox Paving Co., Jones Brothers Dirt and Paving Contractors, and Lipham Construction Co. The list of questions that the contractors were asked included:

1. What do you see as the purpose of the Table of Binder Alternatives?
2. Are you satisfied with the alternative binder specifications?
    a. If not, what changes would you make to the existing specification?
    b. Has it affected the availability of binders in your markets?
3. Have you gained any efficiency in construction with the alternative binder specifications?
4. Are you able to improve the competitiveness of your bid when the Seal Coat Material Selection Table is included in the plans?
5. Do asphalt binder shot quantities vary with binder types? If so, how much?
6. Are construction contracts easier or more difficult with the alternatives?
7. Have you noticed any performance problems with the use of the new specification? (early stone loss, early bleeding, first cool weather stone loss, first cold weather stone loss, 1st summer bleeding, etc.)
8. Do you have any other comments on the alternative binder specifications for seal coats?

In response to the first question, the contractors viewed the purpose of the Table of Binder Alternatives as a means of providing options to have different binders available for different roadways and as a means of getting the correct binder for a given pavement, noting that seal coats are more of an art than a science. They also noted that it was a means of spurring competition, especially among binder suppliers. One contractor noted that the taxpayers are the ones who see the real benefit from the use of alternate seal coat binders. Another noted that, on projects where alternates are appropriate, the bids were much more expensive before the table began to be used.

Most contractors expressed an overall satisfaction with the current system in that the specifications have been vetted through several revisions by all the parties involved. However, one contractor took the view that the tier system is not good because it allows the use of inferior binder, and the contractor must select the low-cost binder in order to be competitive. One contractor noted that styrene-butadiene rubber (SBR) modified binders included in the current table have not been used recently and that asphalt-rubber is only available from a relatively few suppliers. Asphalt-rubber requires a greater application rate than other binders. However, a supplier of A-R stated that it should be left in the table as an alternative in order to compete and maintain competitive pricing. One contractor stated that SBR modified binders should be kept in the table in case suppliers decide to manufacture them. Two contractors suggested that some designers circumvent the process by selecting one binder they want and another that cannot be reasonably obtained. Two contractors said that an education process for TxDOT engineers and inspectors is needed on the proper selection and application of binders. One also stated that there

are not enough inspectors allotted to provide coverage on large projects, and that they are overwhelmed.

Three out of the five contractors noted that the inclusion of aggregates in the table has made bidding problematic as they are now required to get bids from sources that may be unrealistically far from the project site. They believe that aggregates always should be obtained from the closest possible source and should be specifically called out in the project plans. These contractors want the aggregate portion of the table removed.

When asked whether the specifications have affected binder availability, most contractors stated that the availability is as good or better than before. There are more suppliers who are able to provide binders on a given project which results in more competition. Overall, the availability seems to have improved.

In general, the contractors interviewed felt that efficiency has improved since they no longer need to worry about the supply of a particular binder running short. Also, trucking has become a problem in Texas with many qualified truckers being hired by the energy development sector, so shorter haul distances from binder supplier to the project site are important considerations. Since they have the option, contractors can order binder from the nearest qualified supplier, reducing their transportation costs. One contractor said he has not seen an increase in efficiency, but rather has seen an increased focus on quality of the work rather than quantity.

When asked if the Table of Alternative Binders has improved their competitive position, two of the contractors stated that competition has increased not because of the table, but rather because of the lack of work in the state. The volume of their work has decreased by 40 percent compared to four or five years ago. One contractor only used chip seals in conjunction with his construction work (underseals and two-course surface treatments), and from his perspective the table has removed the good-old-boy component. Another contractor stated that competition has improved as long as engineers understand the proper application of specific products, but in certain circumstances, the alternates can undercut the proper application.

There is a definite difference in application rates for different binders. A-R binders and emulsions require a higher rate than other binders, but the actual rate depends upon the condition of the pavement and the grade of aggregate being used. Typical A-R application rates are between 0.46 and 0.50 gal/yd^2 for Grade 4 aggregate and between 0.50 and 0.55 gal/yd^2 for Grade 3 aggregate. A-R is best used to delay reflection cracking and may get 12 to 15 years of performance. AC-5 and AC-10 binders require a lower application rate than a polymer modified binder. An AC-5 or AC-10 may be used with a Grade 3 aggregate on low-volume roads with low truck traffic (500 to 1000 ADT). However, for higher total traffic and truck traffic roads, a polymer modified binder would probably work better. Polymer modified binders also work to better waterproof the pavement. One contractor offered the view that AC-20-5TR was superior to AC-20-XP and better than AC-10-2TR in most cases.

Most contractors believe that construction contracts, with the exception of the aggregate issues, are the same or easier than before. With the tier system, a change order is not needed if a

binder is within the same tier as the binder being used. Having better uniformity in contracts, even within the same district, has been of benefit. However, one contractor mentioned that he has had to have multiple binder storage tanks and that poses some problems. One contractor felt that contracts were more complicated when district personnel are comfortable with their traditional materials and a supplier would like to introduce a new binder. On the whole, most contractors believed that the tier system helps construction contracts, but would like to see the aggregate removed from the alternate sheet and have the ability to introduce new materials in the districts.

The contractors acknowledged complaints of performance from summer 2011, but pointed out that the extreme heat and drought at that time affected the performance. Roadway temperatures were in excess of 180°F creating bleeding problems, and aggregate could not be washed prior to application due to water shortages resulting in aggregate loss. Thus, summer 2011 should not be used as a gauge of the tier system. It was mentioned that a 10 to 12 percent variation in shot rate between the spring and late summer was partially responsible for accelerated aggregate loss. One contractor felt that low shot rates for some binders resulted in aggregate loss, and he would like to see embedment and aggregate retention tests being required.

When asked if they had any further comments on the tier system, one contractor reiterated that the aggregate requirements should be removed as well as binders that are not being used such as those containing SBR. Another said to make sure the system is used as it should be, and it will continue to save money. One contractor added that TxDOT should more carefully survey roadways and ensure their proper preparation ahead of the sealing, noting that sometimes this is not done at all and that some districts do this better than others. Another contractor stated that the education of TxDOT personnel is the most important issue to be addressed and that every district should have a familiarity with each binder to ensure its proper application. This same contractor said that TxDOT needs more inspectors on projects, and that the lack of experience in the inspectors needs to be compensated for through education.

From these contractor interviews, the following conclusions may be drawn:

- There is an overall level of satisfaction among seal coat contractors with the Table of Alternative Binders and its application although one expressed the opposite opinion.
- TxDOT might consider eliminating the aggregate portion of the table and simply specify the aggregate required for a particular project or district-wide program.
- TxDOT may want to allow districts the latitude to engineer individual projects rather than requiring the table to be used on all projects.
- TxDOT may want to develop standards for preconstruction pavement evaluation and preparation ahead of seal coat applications.
- TxDOT may want to update the Seal Coat and Surface Treatment Manual to include use of the table, updated discussions of the different binders and their applications in addition to expanded guidance on seal coat inspection.

MATERIAL SUPPLIERS

A conference call was held with five seal coat binder suppliers on August 2, 2012, at 2:00 p.m. The binder suppliers represented included Cox Paving Co., Martin Asphalt Co., Pelican Refining, Valero, and Wright Asphalt. These companies represent all the binders listed in the Table that are currently used. During the course of the conference call, each representative was asked to respond to the following questions:

1. What do you see as the purpose of the Table of Binder Alternatives?
2. Are you satisfied with the alternative binder specifications?
    a. If not, what changes would you make to the existing specification?
    b. Has it affected your ability to sell binders in your market areas?
3. Have your customers gained any efficiency in construction with the alternative binder specifications?
4. Are you able to anticipate your production requirements with the alternatives?
5. Do you have a good binder for winter applications? If so, what is it?
6. Do you have any other comments on the alternative binder specifications for seal coats?

All participants agreed that the purpose of the Table of Binder Alternatives served to spur competition among suppliers and contractors. It was also seen as a means of providing options for binders to districts that may not have had them in the past, and also provided a way to specify the proper product for a particular application. In general, the specification table was seen as a positive development for TxDOT. One supplier said that he would like to see the districts specify whatever binder they wanted for a particular project. Two others stated that they would not like to see a situation where only one binder was specified for a given project. Most suppliers agreed that more education is needed for TxDOT personnel to identify and avoid causes of seal coat performance issues. One supplier stated that rate and coverage tests should be performed before sealing and that coverage should be checked during construction. He was also in favor of a performance test such as the Vialet test. Another supplier felt that binders are sometimes not sampled properly, and another believes that Grade 4 aggregate is specified too often, resulting in bleeding problems.

None of the suppliers believed that the tier system has negatively affected their competitive position in their market areas. One did say that they scrutinize the market a little more closely than prior to the system's implementation. When asked if their customers had gained any efficiency with the tier system, all suppliers said that the contractors have not gained any productivity because the products are what the contractors are used to. One supplier noted that the contractors did enjoy having binder options under the system. None of the suppliers felt that there was any problem in anticipating the production requirements for a given season. One said that they know the larger seal coat projects ahead of time, and they produce accordingly. Another said his company only supplies A-R, and that they can produce according to demand. One said that they produce a wide variety of products and can anticipate the demand for products, while another said they focus on hot products only and that they can keep up with that market. One supplier noted that their biggest problem is with the current demand for trucking in the state.

Placing seal coats in the winter was seen universally as problematic. All of the suppliers said that winter applications should only occur for emergencies and under-seals that will be immediately covered with an overlay. The A-R binder can be placed in winter but it requires heated aggregate and is more expensive. Some of the other suppliers can produce winter binders, but they prefer not to make them because there are too many construction variables that will impact the performance, and people will most likely blame the binder for poor performance. Education of inspectors and attention to weather details were mentioned as very important issues as well as using a very experienced crew. It was stated that inspectors tend to view the weather only in terms of day-of-application air temperature, and that the previous week's temperature, rainfall, and the amount of moisture in the aggregate all need to be considered. It was also mentioned that operations should cease earlier in the day during the winter.

When asked if they had any further comments, most of the suppliers said that they would like to see districts open their selections to allow as many products as possible in a given tier, although one said that he would like to see a district be able to specify a particular binder if it is needed for a specific reason. One contractor felt it was important that all binders in a given tier have similar properties, and thus, similar performance. One reiterated that education of TxDOT personnel is of prime importance.

Finally, one last question was asked by the researchers: is seal coat performance the same in the north and the south? The responses were that different areas have different needs in terms of application rates and binder properties. There needs to be enough binder placed to hold the aggregate and each road has its own unique requirements. The northern districts need a softer binder than the south.

To summarize the input from the material suppliers, the following points can be made:

- The development of the Table of Binder Alternatives and the tier system has spurred competition and has been a positive experience.
- Education of TxDOT personnel in the identification and mitigation of seal coat pavement distresses and field inspection is important.
- The tier system has not impacted business practices in terms of anticipating product demand or impacting the efficiency of contractors.
- Winter sealing operations should be avoided unless they are under-seals that will be immediately covered. If winter operations must occur, then there needs to be more attention put on the weather monitoring and construction activities must be very carefully controlled.
- Most suppliers believe the tier system should be opened to as many binders as possible within a given tier, although one did express the opinion that the TxDOT districts should have the ability to specify a particular binder to address specific roadway issues.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the results of this study, the following conclusions are made:

- Tier system is working as it was intended for the most part. It has spurred competition among binder suppliers.
- There is a general sense of satisfaction with the current tier system although at least one district and one contractor expressed negative opinions about the system. The binder suppliers expressed appreciation of the system so long as it is being used as it was intended.
- The tier system is saving money as calculated by TxDOT. Over a 2.5-year period, it is estimated that the system has saved more than $33 million.
- There are opportunities for the tier system to be improved and these are captured in the recommendations made below.

The following recommendations are made to improve TxDOT's seal coat practices:

- TxDOT personnel, contractors, and material suppliers all agreed that more education and outreach was needed for TxDOT personnel designing, specifying, and inspecting seal coat projects. The opportunities for greater education could come in the form of:
    - Webinars/seminars for project personnel highlighting best practices for design, binder selection, construction, inspection, and troubleshooting.
    - Newsletter/periodical articles promoting best practices among the districts as well as national updates.

- Consider changing traffic requirements in the tier system to cumulative traffic or cumulative truck traffic. This would mitigate issues of low-volume roads with heavy truck traffic or with long maintenance intervals due to budget constraints.
- Keep using the tier system on district-wide programs. As of now, there is a general view that this is the best application of the tier system.
- Update the seal coat manual to reflect the best available information and current practices.
- Develop standards for pavement preparation ahead of seal coat application. Although standards for pavement preparation exist within certain districts, there is a view that they need to be more uniformly applied across TxDOT. This is one of the major issues impacting the life of seal coats.
- Allow flexibility to specify particular binder for a given set of circumstances. More than one district, contractor, and material supplier indicated that the districts need to engineer specific solutions in certain instances.

- Use tier system on individual projects where possible. Due to the demonstrated ability to save money by using alternative binder specifications, the districts should be encouraged to use the tier system on all projects that do not require a specific binder.
- Develop a generic binder specification. By having a generic specification, the opportunity for competition could be increased among suppliers, and all materials passing the specification would be considered equivalent in their performance.
- Remove aggregate requirements from the Table of Alternative Binders. Contractors believe that the inclusion of aggregate requirements poses a hardship in bidding and does not serve to reduce the cost of seal coats to TxDOT.
- Initiate research to develop a good winter binder. It is currently widely viewed that there are no suitable binders that can be applied in winter that would survive the subsequent summer. It may be to TxDOT's advantage to encourage the development of a winter binder and have specific requirements under generic binder specifications for a winter binder. Although it may be more expensive, the longer performance may make the investment worth it.
- Initiate research to develop seal coat test methods. Although such test methods exist, it may be to TxDOT's advantage to develop field requirements, especially for:

    - Aggregate embedment depth.
    - Aggregate and binder coverage rates.
    - Vialet or similar test to ensure early performance.