

SYNOPSIS OF RECYCLED ASPHALT PAVEMENT (RAP) MATERIAL



June 2016

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16. Abstract (Limit: 200 words) Recycled Asphalt Pavement (RAP) is encouraged to be used in the construction of new roadways and pavements. Its use reduces cost and environmental impacts of road construction by reusing existing asphalt pavement. In Minnesota existing asphalt pavement material is often crushed and blended with other aggregates to create aggregate base or shouldering materials or transported to an Asphalt plant, crushed, and incorporated into new asphalt material. Both strategies reduce demand for virgin aggregates. Incorporation into new asphalt material has the additional benefit of reducing demand for asphalt binder material. It is recognized that a greater benefit to the environment and economy can be realized when incorporated into new asphalt material. This document was developed as a reference for local agencies that have minimal knowledge of incorporating RAP material into new asphalt and would like to understand more.			
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INTRODUCTION

The use of Recycled Asphalt Pavement (RAP) is allowed and encouraged in the construction of new roadways and pavements. Its use reduces cost and environmental impacts of road construction by reusing existing asphalt pavement. In Minnesota, existing asphalt pavement material is often crushed and blended with other aggregates to create aggregate base or shouldering materials, or RAP is transported to an asphalt plant, crushed, and incorporated into new asphalt mixture. Both strategies reduce demand for virgin aggregates. Incorporation into new asphalt

mixture has the additional benefit of reducing the required amount of new asphalt binder. Incorporating RAP into new asphalt pavement provide greater economic and environmental benefit than using RAP for base or shoulder material.

This document was developed as a reference for local agencies that have minimal knowledge of incorporating RAP material into new asphalt and would like to understand more.



Example of crushed Recycled Asphalt Pavement (RAP) Material

Source: FHWA



Newly paved roadway with RAP (CSAH 18 in Lake County, MN)

1

MINNESOTA SPECIFICATION

Minnesota Department of Transportation specifications for plant mixed asphalt pavement are intended to maximize the use of RAP material without compromising the performance and durability of the constructed asphalt pavement. MnDOT initially began incorporating RAP into plant mixed asphalt nearly 40 years ago and has maintained RAP usage within the standard MnDOT specifications for more than 30 years.



Pavement being constructed with 20% and 40% RAP (CSAH 18 in Lake County, MN)

During production of asphalt mixtures, RAP material is introduced into heated virgin aggregate. MnDOT specification controls the amount of RAP that may be included in an asphalt mixture based on the ratio of new added asphalt binder to total asphalt binder in the mixture. Ratios listed in Table 2360-8, excerpted on the next page from the MnDOT Specification 2360, represent the minimum proportion of binder in the asphalt mixture that must be virgin material. (i.e. For PG 58-34 wear and non-wear course a minimum of 80% of the total binder content must be from virgin material allowing up to 20% of the total binder in the asphalt mixture to derive from the RAP material.)

To evaluate compliance with MnDOT 2360 total asphalt content of the mixture is compared to virgin asphalt binder added to the mixture. An extraction of the asphalt mixture is required to determine the total asphalt binder content as placed. The amount of virgin asphalt binder added is known from the plant production records. The percentage of virgin asphalt binder added to the mixture is divided by the total extracted asphalt binder content, then evaluated against the allowable percentages shown in Table 2360-8 of the MnDOT 2016 Edition of the Standard Specifications for Construction. Check for updated versions of this specification: www.dot.state.mn.us/pre-letting/spec/index.html

Table 2360-8: MnDOT 2016 Edition of the Standard Specifications for Construction**E.7 Minimum Ratio of Added Asphalt Binder to Total Asphalt Binder**

Control recycled materials used in mixture by evaluating the ratio of new added asphalt binder to total asphalt binder as show in Table 2360-8.

Table 2360-8 Requirements for Ratio of Added New Asphalt Binder to Total Asphalt Binder ¹ min%:			
Specified Asphalt Grade ²	Recycled Material		
	RAS Only	RAS + RAP	RAP Only
PG XX-28, PG 52-34, PG 49-34, PG 64-22			
Wear	70	70	70
Non-Wear	70	70	65
PG 58-34, PG 64-34, PG 70-34			
Wear & Non-Wear	80	80	80

¹ The ratio of added new asphalt binder to total asphalt binder is calculated as (added binder/total binder) x 100

² The Contractor can elect to use a blending chart to verify compliance with the specified binder grade. The Department may take production samples to ensure the asphalt binder material meets the requirements. The blending chart is on the Bituminous Office Website.

³ X=S,H,V,E

Note: RAP = Recycled Asphalt Pavement

RAS = Recycled Asphalt Shingles

The following table is an update to the 2016 edition table above and is currently listed in MnDOT's special provisions. It will be incorporated in the 2018 edition of the Standard Specifications for Construction. The changes reflect MnDOT's adoption of the Multiple Stress Creep Recovery (MSCR) procedure, the latest national improvement to the PG Asphalt Binder specification.

Table 2360-8: MnDOT 2018 Edition of the Standard Specifications for Construction

Table 2360-8 Requirements for Ratio of Added New Asphalt Binder to Total Asphalt Binder ¹ min%:			
Specified Asphalt Grade ²	Recycled Material		
	RAS Only	RAS + RAP	RAP Only
PG 58X ³ -28, PG 52S-34, PG 49-34, PG 64S-22			
Wear	70	70	70
Non-Wear	70	70	65
PG 58X ³ -34			
Wear & Non-Wear	80	80	80

¹ The ratio of added new asphalt binder to total asphalt binder is calculated as (added binder/total binder) x 100

² The Contractor can elect to use a blending chart to verify compliance with the specified binder grade. The Department may take production samples to ensure the asphalt binder material meets the requirements. The blending chart is on the [Bituminous Office Website](#).

³ X=S,H,V,E

In addition to RAP material, MnDOT specifications also allow for the incorporation of shingle scrap, Recycled Asphalt Shingles (RAS), from manufactured waste (MWSS) or from tear-off scrap (TOSS). The specification allows adding either RAS or RAP separately to the mixture or a combination of both can be added to the mixture. When both RAS and RAP are added to the mixture, the requirements of Table 2360-8 remain applicable. Typically, because of the high

asphalt content in RAS, less RAP can be added to the mixture when a combination of the two are included in the mixture.

If the contractor elects to use the MnDOT blending chart for verification of compliance with specified composite PG binder grade this chart can be found at: www.dot.state.mn.us/materials/bituminousdocs/Doc_Aids/Blending%20chart%20procedure1.pdf

1.1 General Considerations to Improve Mixture

- Crushing and screening processes are recommended to help remove crack sealing material and other unwanted materials/debris.
- Screening, fractionation, blending, and RAP testing provide control and consistency of produced product.
- It is important that the RAP and the virgin aggregate materials have low moisture content during production.
- It's important to note that if you plan on utilizing RAP, it's a good idea to mill your roadway rather than just do an overlay.
- Milling presents the added benefit of providing contractors with material to recycle.
- Inspectors should be checking material as it goes through the plant.
- It's good practice to check the quality and uniformity of the material in stockpiles.

2

RAP USE SURVEYS

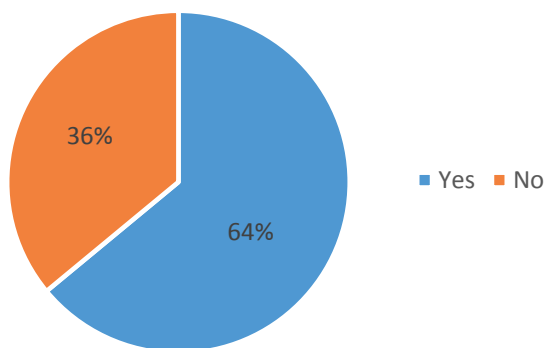
Two surveys, one at a national level and another at a local level in Minnesota, were conducted on the usage of RAP. The goal of these surveys was to understand how RAP is used by local agencies. Survey findings are presented below.

2.1 Minnesota RAP Use Survey

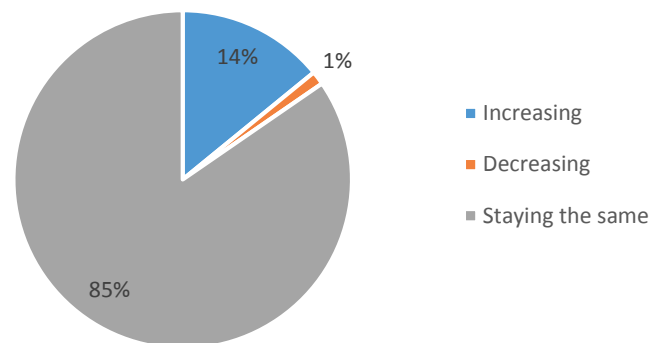
In 2014, MnDOT Office of Materials and Road Research surveyed the cities and counties of Minnesota to understand the extent agencies were allowing the incorporation of RAP within asphalt mixtures and if these same agencies followed MnDOT standard specifications or other criteria based upon their experiences and beliefs. Additionally, asphalt mix producers were surveyed to understand their experiences with RAP use. The full survey findings are provided in Appendix A.

General survey finding:

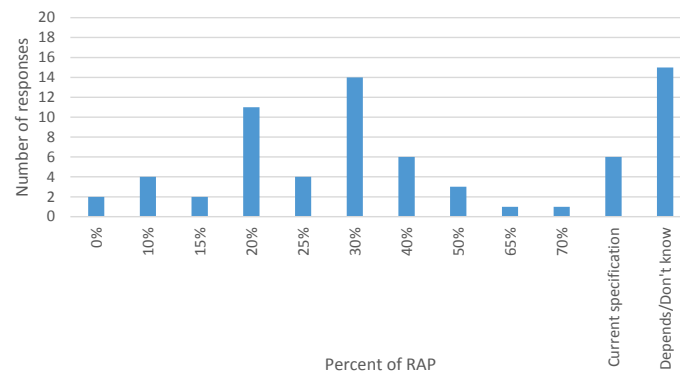
- This survey was completed by 96 city/county agencies and three asphalt mix producers.
- 97% of agencies follow the MnDOT requirements for ratios of added new asphalt binder (Table 2360-8) 70% or 80% based on asphalt grade.
- Out of 86 responses, 64% feel RAP mixes perform as well as virgin mixes



- 14% of agencies indicated that their RAP usage is increasing



- The most common maximum percent of RAP agencies are comfortable adding without decreasing the durability and long term performance of their pavement is 30%:



2.2 National RAP Use Survey

Each year, the National Asphalt Pavement Association (NAPA) Federal Highway Administration (FHWA) conduct an Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage. Full survey findings for 2014 are provided at these links:

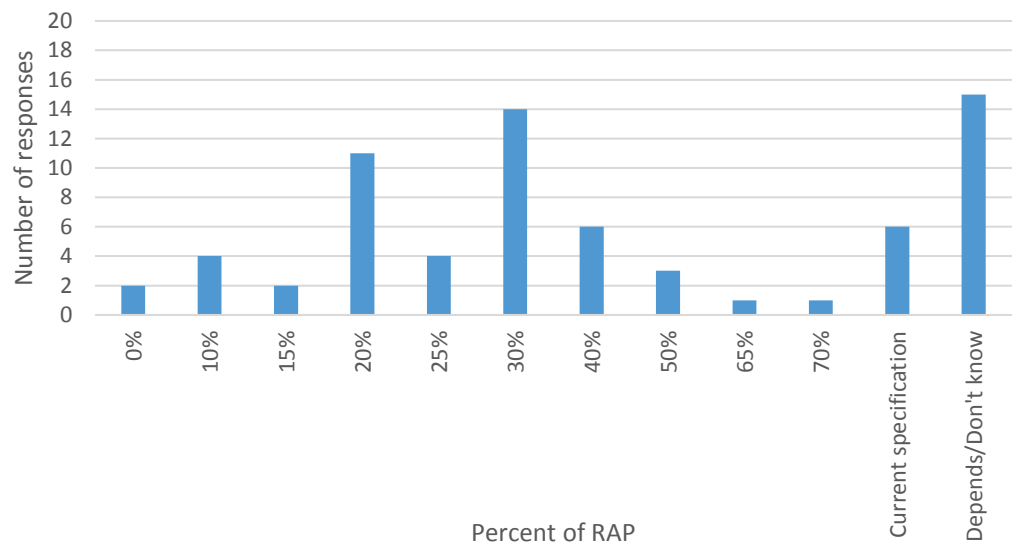
- Full Final Survey: www.asphalt pavement.org/PDFs/IS138/IS138-2014_RAP-RAS-WMA_Survey_Final.pdf
- Appendix: www.asphalt pavement.org/PDFs/IS138/IS138-2014_RAP-RAS-WMA_Survey_Appendix_B_Final.pdf

General survey finding:

- This survey was directed at asphalt mixture producers and state asphalt pavement associations nationwide to quantify the amount of RAP being used in relation to total asphalt

being produced, resulting in % RAP utilization across the country and savings in virgin materials, asphalt binder and aggregates.

- Values provided as nationwide and state-by-state averages
- Details benefits regarding overall improved compaction that is believed to improve performance, extending the paving season by allowing compaction at lower temperatures and the mixture process warm mix asphalt (WMA) can have as compared to hot mix asphalt (HMA). Long term testing is noted as incomplete.
- Reported statewide percent RAP used in asphalt mix based on tons of RAP used and total Hot-Mix Asphalt and Warm-Mix Asphalt produced. Minnesota’s neighboring states reported using the following percentages:



* North Dakota and South Dakota did not provide their RAP use percentages to the survey

3

NATIONAL TRENDS

3.1 National Guidance: RAP Material Sources, Processing and Stockpile Management

In Minnesota project specifications generally regulate the amount of RAP material that may be incorporated into new asphalt mixtures based upon a set of criteria, some of which are founded on past experiences and the understanding that reduced performance can occur from a lack of uniformity, consistency, and information of the RAP being incorporated into new asphalt material. Variability of RAP material in terms of gradation, asphalt content and asphalt characteristics or quality lead to variability in the characteristics and volumetric properties of the produced asphalt material. The best understood and manageable approach to limiting variability is to regulate the amount of RAP that can be introduced into new asphalt mixtures.

Variability in RAP is created in the following ways:

- When RAP is removed from an old roadway, it may include the original pavement and subsequent overlay materials, plus patches, chip seals, joint sealant, and other maintenance treatments.
- Surface and base courses with differing binders and content are intermingled.
- RAP from several projects, multiple source RAP, may be combined into a single stockpile.
- RAP stockpiles may include waste trial batches of asphalt mixes.

To control the variability of RAP material and allow for increased percentages of RAP to be incorporated into new asphalt mixtures, good stockpile management practices will be necessary. Eliminating some sources of variability can be uneconomical but reduced variability within a RAP material can be attained through stockpile management practices and processing techniques.



Road being milled and material collected for RAP use

Key issues to address are:

1. Elimination of contamination within RAP stockpiles
2. Where possible keep discrete stockpiles or RAP material uniform and consistent in gradation and asphalt content and separated by source. (Millings from large jobs and wear courses with surface treatments or polymer modified binders can be kept in isolated stockpiles to provide a more consistent RAP product.)
3. For stockpiles derived from multiple sources blend RAP material thoroughly before processing or fractionating. Additional blending may be needed after crushing or fractionation.
4. Avoid over-processing to avoid generating too much fine material.

5. Fractionating RAP (FRAP) material, stockpiles separated based on aggregate size, increases control and reduces variability.
6. Use good practices when storing processed RAP.

7. Inventory and characterize RAP stockpiles through testing before and after processing.

Source: Report Number FHWA/TX-10/0-6092-1, Rap Stockpile Management and Processing in Texas: State of the Practice and Proposed Guidelines



RAP Processing Machine



Processed RAP

3.2 Laboratory Characterization of RAP Materials

The results from laboratory testing on RAP materials can be used to manage discrete stockpiles from a single source or after thorough blending when originating from multiple sources.

1. Asphalt Content, Average and Standard Deviation.
2. PG testing of Extracted Asphalt Binder Recovered
3. Extracted Aggregate Gradation
4. Aggregate Properties including Bulk Specific Gravity and Aggregate Quality

It is a recommended practice to perform sampling and testing at regular intervals during production or if RAP material is derived from multiple sources to sample and test after thoroughly blending. Testing should be performed at rates that reflect expectations of percent binder replacement. General FHWA recommendations

are for performing testing on a minimum of 5, but preferably 10 or more, individual samples to determine uniformity of a RAP stockpile. The frequency of testing should be increased based upon size of the stockpile, as binder replacement levels increase, and if multiple sources or sources of unknown origin are incorporated.

The introduction of RAP into an asphalt mixture generally incorporates stiffer-aged binder. FHWA guidelines recommend adjusting the low temperature PG grade of the virgin binder to offset the effects from incorporating the aged binder into the composite mixture.

- $\text{RAP} < 15\% \rightarrow$ No change in binder low temperature PG grade
- $15\% \leq \text{RAP} \leq 25\% \rightarrow$ Select virgin binder one grade softer than initial design
- $\text{RAP} > 25\% \rightarrow$ Follow blending charts in AASHTO M 323 Appendix

Mix Design Testing

The asphalt binder content of RAP material provides great value to the contractor due to savings from reducing the amount virgin asphalt binder added to the asphalt mixture. The aggregate portion provides additional value by reducing virgin aggregate demand.

For RAP material an extraction of the binder and gradation of the remaining aggregates is necessary to characterize reductions and meet required material specifications. The incorporation of RAP into an asphalt mixture does not relieve the contractor's obligations to meet production requirements that include:

- Extracted gradation of the composite asphalt material with RAP
- Coarse and fine aggregate crushing
- Asphalt Binder content
- Asphalt film thickness
- Production air voids

Fractionation of the RAP material, separating the RAP material into stockpiles of discrete size ranges and reducing or isolating finer material, has been shown to be effective at providing better control of the volumetric properties of an asphalt mixture. As RAP content in an asphalt mixture increases the benefits with respect to uniformity provided to the asphalt mixture from fractionation increase as well.

Contractor and producer Quality Control and Agency/Owner Quality Assurance or Verification testing is recommended to verify material produced and placed meet mix design and agency requirements. The following performance measures and corresponding tests can characterize predicted performance of asphalt mixtures with or without RAP material:

- Permanent Deformation (Rutting)
 - Asphalt pavement analyzer
 - Hamburg wheel tracking device
 - Repeated load triaxial creep
- Moisture Sensitivity (Stripping)
 - Tensile strength ratio
 - Hamburg wheel tracking device

- Fatigue (Elasticity – Cracking)
 - Four-point bending beam fixture
 - Dynamic modulus-continuum fatigue damage
- Thermal Cracking (Thermal, Cold Temperature Cracking)
 - Thermal stress restrained specimen test
 - Indirect tensile test

Recycling and rejuvenating agents, generally consist of organic compounds derived from petroleum extracts, can be classified into three major types by ASTM D4552:

1. Soft asphalt cements
2. Napthenic (aromatic) oils
3. Paraffinic oils

A literature review was conducted to determine what research on RAP has been completed at a national level and within Minnesota.

4.1 Minnesota Resources

- a. *Memorandum City Engineers Presentation Recap and Recommendations (based on Selecting the Best Mix for Your Asphalt Paving Project presentation); February 2014, John Garrity, MnDOT (Provided in Appendix B)*
 - Provides a summary of the presentation that John Garrity gave at the City Engineer conference. The summary provides general asphalt mixture guidance on mixture selection, mixture placement, compaction and plant inspection for increased asphalt pavement performance.
- b. *Local Road Research Board (LRRB): Recycled Asphalt Pavement: Study of High-RAP Asphalt Mixtures on Minnesota County Roads (2013)* www.lrrb.org/media/reports/201315.pdf
 - Objective was to evaluate performance and characteristics of asphalt mixtures with 30% or more RAP. The study provides characterization of materials from laboratory testing and lessons learned with respect to field performance.
 - Eight mixture designs were produced for laboratory evaluations. The designs used PG 58-28 and PG 58-34 asphalt binders with RAP contents ranging from 0 to 55 percent. Indirect tensile (IDT) and semi-circular bend (SCB) testing were performed at the low temperatures.
 - Key findings include:
 - RAP mixtures appear slightly stronger, measured by laboratory testing, but also appear stiffer, an indicator of reduced low temperature cracking resistance compared to non-RAP mixtures.
 - Adding RAP to asphalt mixtures increases the low temperature threshold at which the bituminous material becomes brittle and more susceptible to cracking.
- c. *Local Road Research Board (LRRB): MnROAD Study of RAP and Fractioned RAP (2012)* www.lrrb.org/media/reports/201239.pdf
 - This report summarizes field and laboratory performance of Recycled Asphalt Pavement (RAP) and Fractionated Recycled Asphalt Pavement (FRAP) test cells at the Minnesota Road Research Project (MnROAD) between 2008 and 2012. The project scope included: developing specifications for FRAP, construction of FRAP and RAP test cells at MnROAD, field performance evaluations, and laboratory testing of binders and mixtures.
 - The laboratory evaluation of materials and mixtures included dynamic modulus testing and fracture testing of the asphalt mixtures as well as complex shear modulus testing of corresponding extracted asphalt binders. The major outcomes were:
 - Extracted binder grades met or exceeded design values.
 - Fracture energy from semicircular bend (SCB) data was useful in categorizing expected

- mixture performance in terms of recycle percentage.
 - The process of fractionating the RAP into two different sizes resulted in less blending than anticipated as determined from qualitative comparisons of dynamic modulus tests to their counterpart predicted using the Hirsch model.
 - Pavement performance evaluations at MnROAD has shown that the RAP, FRAP, and other mixtures performed very well after four years of service. During the fourth year of service, several non-overlay study cells began to exhibit some transverse cracking.
 - Additional cracking is anticipated as the pavements are continually exposed to typical low temperature conditions.
- d. Local Road Research Board (LRRB): *Best Practices for RAP Use Based on Field Performance* (2009) www.lrrb.org/media/reports/200915.pdf
 - This study included a survey of practicing local engineers, field performance observations of new bituminous and bituminous overlay construction, and laboratory testing.
 - The most common binder performance grades were identified along with the most common percentage of recycled asphalt in bituminous mixtures.
 - After reviewing the surveys, field observations, and lab samples, the authors make best practice recommendations for recycled asphalt pavement (RAP), including suggesting that agencies review their policies and consider including RAP in the wear course.

4.2 National Resources

- a. FHWA: *Asphalt Pavement Recycling with Reclaimed Asphalt Pavement (RAP)* (2015) www.fhwa.dot.gov/PAVEMENT/recycling/rap/index.cfm
 - Provides sources and summary findings for different RAP development and application related topics including:
 - Performance testing
 - Mix design and material management to produce sufficient performance with high-RAP
 - Advanced research to improve reliability of anticipated RAP performance
 - Low temperature properties and performance of RAP
 - Pavement recycling process
- b. Iowa Highway Research Board: *Development of Quality Standards for Inclusion of High Recycled Asphalt Pavement Content in Asphalt Mixtures – Phase II*. publications.iowa.gov/19151/1/IADOT_UI_TR-658_Lee_Devo_Quality_Standards_High_RAP_Aspalt_Mixtures_Phase_2_2015.pdf
 - To determine if the higher percentage of RAP materials can be used on Iowa's state highways, three test sections with target amounts of RAP materials of 30%, 35% and 40% by weight were constructed on Highway 6 in Iowa City
 - Study assessed rutting potential from laboratory performance testing that included dynamic shear rheometer, bending beam rheometer, and the semi-circular bending.
 - A condition survey of the test sections was conducted to evaluate their short-term pavement performance about 8 months after construction. Throughout the test section no distress was observed other than transverse cracking. The dominant type observed was reflective joint cracking, which were typically spaced at about twenty-foot intervals. This extensive transverse cracking was likely caused by a combined effect of underlying deteriorated concrete pavement joints and one of the coldest Iowa winters on the record with many freeze and thaw cycles.
 - The use of Fractionated RAP (FRAP) materials, which removed fine RAP materials passing a specific sieve size, is also addressed.
- c. NAPA and FHWA: *Best Practices for RAP and RAS Management* (December 2015). [www.asphaltpavement.org/PDFs/EngineeringPubs/QIP129_RAP - RAS_Best_Practices_Ir.pdf](http://www.asphaltpavement.org/PDFs/EngineeringPubs/QIP129_RAP_-_RAS_Best_Practices_Ir.pdf)

- This document covers the current best practices for management of recycled asphalt pavement (RAP) and recycled asphalt shingles (RAS) in an asphalt paving mixture as of 2015. The goal of this guide is to facilitate the most effective utilization of RAP as a component in asphalt paving mixtures. This document provides guidance for management of RAP from the time of collection through processing, sampling and testing of RAP for mix design, and quality control practices during production of asphalt mixtures containing RAP. A brief section also presents best practices for management of RAS for use in asphalt paving mixtures.
 - This document is organized to follow the sequence of handling and evaluating RAP materials from the point of reclaiming RAP through quality control practices during production of asphalt mixtures containing RAP. Chapter 1 provides guidance on reclamation processes. Chapter 2 covers decisions and practices for processing and inventory management of RAP materials. Chapter 3 presents best practices for sampling and testing stockpiled RAP materials. Chapter 4 discusses production concerns for mixes containing RAP. Chapter 5 provides additional guidance on best practices for handling Recycled Asphalt Shingles (RAS). Chapter 6 provides a summary discussion. Appendix A
- d. FHWA: *Reclaimed Asphalt Pavement in Asphalt Mixtures: State of Practice* (2011).
www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/11021.pdf
- Goal of the report is to express state-of-the-art practices for implementing higher percentages of RAP (>25% by weight) effectively
 - Provides widespread recommendations for RAP use in asphalt mixtures
 - Best practices are broken down into sourcing, processing, stockpiling, testing, designing, evaluating, producing and placing stages
 - Details state of practice of RAP use across the nation

APPENDIX A - SURVEYS OF RAP USE IN MINNESOTA

**Minnesota City and County Response on
RAP Use in Minnesota, June 2014**

**Asphalt Mix Producer Response on RAP
Use in Minnesota, March 2014**



June 2016

Surveys of RAP Use in Minnesota

Minnesota City and County Response on RAP Use in
Minnesota, June 2014

Asphalt Mix Producer Response on RAP Use in Minnesota,
March 2014

12 June 2014

Ed Johnson, MnDOT Office of Materials and Road Research

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City and County Response

1. Does your agency use MnDOT 2360?

See <http://www.dot.state.mn.us/materials/bituminousdocs/Specifications/2014%20Spec%20Book/2360%20PLANT%20MIXED%20ASPHALT%20PAVEMENT.pdf>

Yes	No	Total
95 (99%)	1 (1%)	96 (100%)

2. If “No”, please explain.

- (0 responses)

3. How closely does your specification follow MnDOT 2360 when using RAP? (select all that apply)

	Yes	No	Wear Course	Nonwear Course	With certain binder PG's	For certain pavement uses	Total Respondents
Does not modify 2360	71.60% 58	19.75% 16	19.75% 16	19.75% 16	4.94% 4	2.47% 2	81
Does not use RAP	15.52% 9	72.41% 42	20.69% 12	6.90% 4	0.00% 0	1.72% 1	58
Permits more RAP	3.64% 2	90.91% 50	7.27% 4	5.45% 3	0.00% 0	0.00% 0	55
Restricts RAP	23.21% 13	73.21% 41	12.50% 7	1.79% 1	0.00% 0	3.57% 2	56

4. Do you feel RAP mixes perform as well as virgin mixes?

Yes	No	Total
55 (64%)	31 (36%)	86 (100%)

5. If “No”, please explain.

- Binder content moves around a little bit, especially if RAP pile is not uniform (like multiple sources).
- I believe RAP mixes can perform as well as virgin mixes, if done correctly. I don't think in general terms all rap mixes laid are performing as well as virgin mixes.

City and County Survey Response

- I believe that RAP can be successfully used if the RAP is consistent (came from one project) but inconsistencies in the metro make this difficult to achieve.
- I do not allow rap in the wearing surface have noticed more cracking when we allow RAP. We do use it in the non-wear I can only assume that the old 120-150 oil does not perform as well as the new PG oils.
- Materials aren't as defined, but it is the right thing to do to recycle.
- More susceptible to cracking
- No real evidence to back it up, but it does seem to have reflective cracking faster. After 5 years or so I don't think you notice a difference.
- Performance is good, but lacks flexibility of new asphalt.
- RAP appears to lead to premature failure of the wear course and adversely affects maintenance with patching and seal coating
- Seems to be a "drier" appearance to the surface after several years.
- The oil in RAP appears to cause the pavement to become more brittle and crack at low temperatures.
- The RAP oil is of unknown origin, grade quality the typically is surface material that has oxidized.
- There is no idea what type of oil is in the mix or what was used for seal coating, or the quality of the aggregate, or what else may be in the old surfacing like crack sealing material etc. No testing is done on the material to determine if it is good or bad mix.
- Too much debris in the mix
- Unknown source and oil type is being used in a polymer mix. It can only degrade performance.
- Unpredictable oil quality????
- We occasionally see clumps or notice the surface is not smooth/tight.
- We recommend to our clients that virgin mix be used in the wear course.
- Why pay for high priced modified binder when you are just going to put in old aged binder that is going to reduce the benefitted properties in the new high priced modified binders?
- you lose some of the flexibility of the new performance graded oils when you add rap

6. Does your agency follow the MnDOT requirements for ratios of added new asphalt binder (Table 2360-8)? 70% or 80% based on asphalt grade.

Yes, minimum ratios permitted	No	Total
76 (97.4%)	2 (2.6%)	78 (100%)

7. Is your RAP use generally increasing, decreasing, or staying the same?

Increasing	Decreasing	Staying the Same	Total
11 (14%)	1 (1%)	66 (85%)	78 (100%)

8. If your requests for 0% RAP are increasing, what are the reasons? (skip if you use RAP in all cases)

- Better long term performance and no debris in mix
- I had a wearing surface that had failures in 2012. No one knew why it had failure areas or could explain what happened in these areas. I feel the only unknown is the RAP since it is not tested, so I am eliminating the RAP until there is a requirement in the specifications to test the pile to determine the quality of the material before it is used in the wear.
- Increased cost for virgin mixes by comparison to RAP mixes
- We do not allow RAP on Wearing course pavement lifts.
- Wear course only

9. If RAP usage is decreasing, is that because:

Contractor decision	Reduced because of our specification	Total
15 (63%)	9 (37%)	24 (100%)

10. Does your agency find there is a price benefit when using different RAP percentages?

Yes	No	Total
38 (49%)	40 (51%)	78 (100%)

11. If yes, please list the RAP percentages and \$/ton benefit:

\$/ton Benefit	RAP Rate	Comments
\$2	Per Specs	
\$5	Not Given	
\$5	20%	
\$5	Up to 40%	
\$6	25%	
\$2-5	Not Given	
\$2-5	30%	
\$5-7	30%	
\$5-8	20%	

City and County Survey Response

\$5-10	Not Given	
\$6-8	30%	
		Hard to calculate based on the difference in haul length and RAP availability.
		Not sure, Unknown (5)
Not Given	Not Given	10-15% savings

12. Does your agency adhere to MnDOT 3139 restrictions on objectionable material in bituminous aggregate?

Yes	No	Total
74 (96%)	3 (4%)	77 (100%)

13. If "No", please explain.

- Do not allow scrap asphalt shingles.
- It is what it is

14. Has your agency modified MnDOT 3139 restrictions for objectionable material in bituminous aggregate?

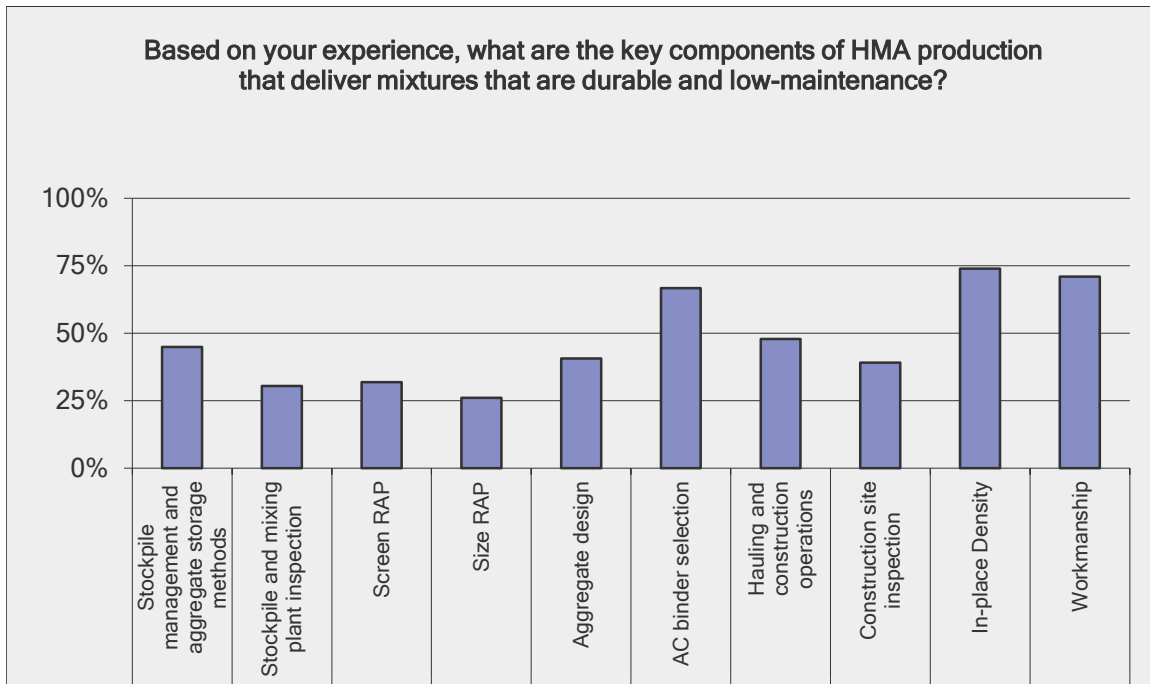
Yes	No	Total
4 (5%)	73 (95%)	77 (100%)

15. Please explain (#14):

- Isn't this already covered in the specifications? If not, shouldn't it be in the standard specs? We are told not to change the specs. So it is uniform for the contractors and the DOT to know what is going on.
- No modifications
- See no reason to modify
- Use to. We have found that the quality of separating techniques being used today are much better than when RAP and other objectionable materials were first being allowed. Most contractors don't want the material rejected.
- We have had success in requiring screening of the millings when we see issues in the bituminous mat.
- We have not modified MnDOT specification on objectionable materials.
- We use the MNDOT Specifications along with any supplemental specifications which are published.

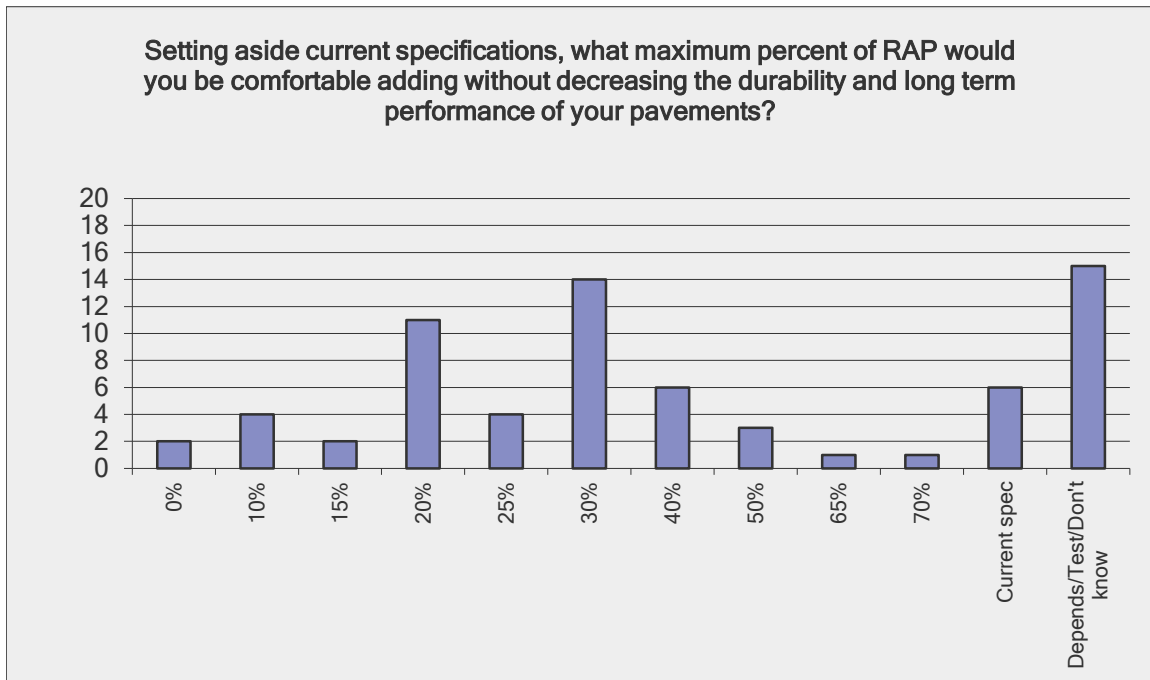
16. Based on your experience, what are the key components of HMA production that deliver mixtures that are durable and low-maintenance?

69 Responses:



17. Setting aside current specifications, what maximum percent of RAP would you be comfortable adding without decreasing the durability and long term performance of your pavements?

69 Responses:



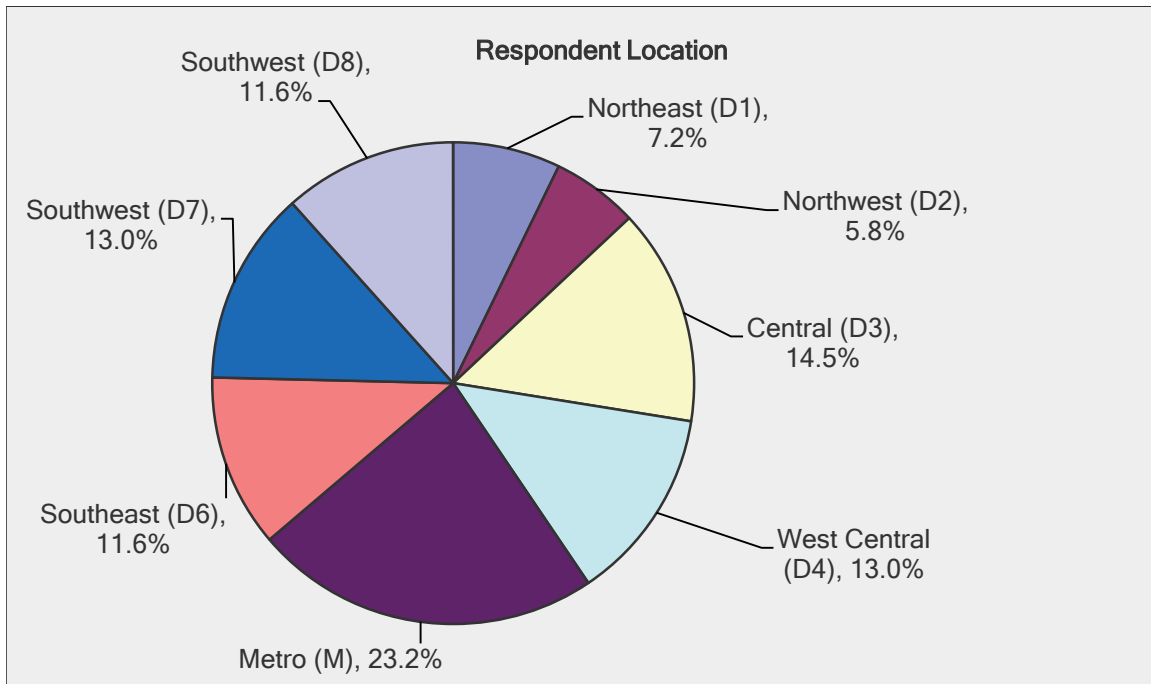
18. Please share any other comments.

- 13 Responses:

City and County Survey Response

- Contractor quality control for mixes with RAP have appeared to have improved (w/respect to objective material), but it's still a concern/risk
- I believe one of the issues with RAP is the consistency of the RAP itself in AC content and aggregate sizes.
- I don't like the change made to the objectionable material specification. It was changed in the wrong direction. So we modified it to make it clearer of what is not allowed. We also started requiring the crushing and screening of RAP. That was mostly done because our RAP piles are starting to have rubberized crack sealing material mixed in. Hopefully, the crushing and screening will remove most of that.
- I feel I have to be a Materials expert to answer this survey.
- It appears that RAP may be a leading cause in premature pavement failures in the city due to the amount of fines in the mixes and the amount of asphalt used with RAP's
- None.
- Quality control of RAP piles. Hardness of existing aggregate in RAP seems to be a big issue. Good quality RAP can make a difference in a good looking quality product.
- RAP is a good cost saving measure, but using bad RAP only makes bad new mix. We test and control everything else that we use in our mix to make it better, it makes no sense to not require the RAP to meet the same testing requirements before allowing it in the new mix. Bad RAP means less of the RAP should be allowed in the new mix design. Better RAP would mean allowing more RAP in the new mix.
- RAP is a good resource as long as it does not jeopardize the quality of the HMA. We can't come back in 10-years to fix or overlay. We need a durable long lasting product.
- RAP varied in quality when first allowed, but quality of RAP I believe is much better and consistent today. We allow rap in our aggregate base. As long as the junk is removed, oil content stays down and the gradations are followed it seems to be okay and helps keep costs down by reusing what we already have.
- Shingles should not be allowed in mixes.
- The quality of the product depends primarily on the contractor selected. If a European bid system were used the quality of the work would improve. (European system= Throw out the high and low and take the price that is closest to the average.)
- We try to mitigate the unknown RAP oil by using C oil in base and wear.

19. Respondent location:



Producer Response

1. **Your location is:**
 - Metro 3(100%)
 - Outstate 0
 - Total 3(100%)

2. **What is the approximate percentage of your product for:**
 - State Paving 38%
 - County/municipal streets and highways 52%
 - Other Commercial Paving 10%

3. **Are the cities' use of RAP generally**
 - Increasing 0
 - Decreasing 3(100%)
 - Staying the Same 0

4. **Are the counties' use of RAP generally**
 - Increasing 0
 - Decreasing 0
 - Staying the Same 3(100%)

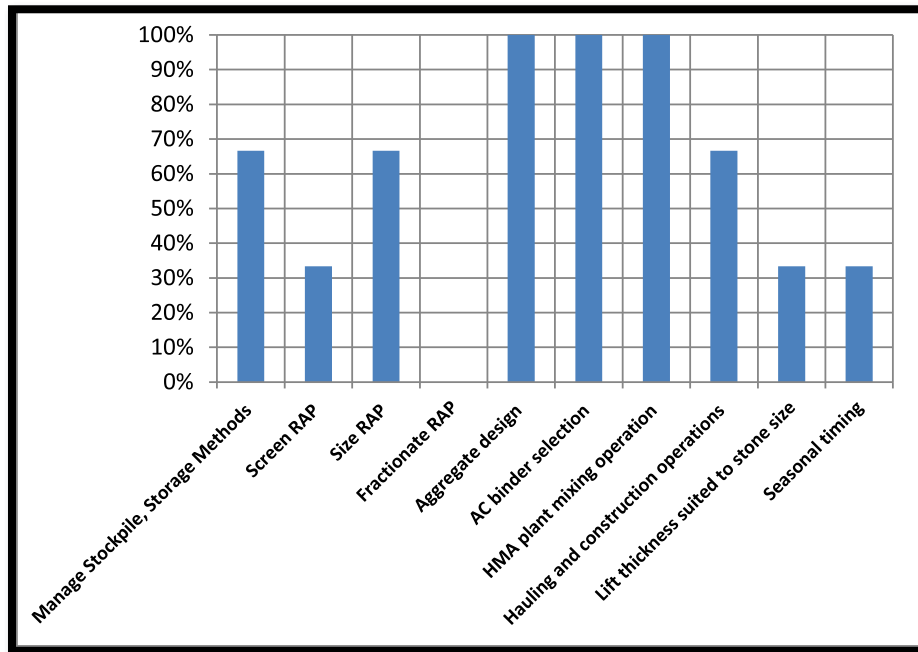
5. **In the past year, has your business seen an increase in requests for mixtures containing 0% RAP?**
 - Yes 3(100%)
 - No 0

6. **If yes to Question 5, do the requests come from:**
 - Cities 3(100%)
 - Counties 0

7. If yes, what are the known reasons for the requests for 0% RAP?

- Seeing what is perceived as contaminants in mix.
- Signs of Striping in the mix to be removed and engineers not knowing the benefits of RAP Deleterious Materials in mix (pine cones)
- Old specs, afraid to take risks even though the MnDOT spec protects the owner.

8. Based on your experience, what are the key components in producing HMA mixtures that are durable and low-maintenance?



9. Setting aside current specifications, with what maximum percent of RAP would you be comfortable adding without decreasing the durability and long term performance of your product?

- 3 responses: 35, 40, 30

10. Please share any other comments on the use of RAP.

- We utilize a lot of RAP. The issues we are seeing is that Cities will require a mill and overlay, but then not allow RAP. The millings coming off city streets are full of seal coat and crack seal material. They blame our facilities and controls for those contaminants, yet that stuff comes from their streets. There has to be a compromise somewhere
- Washington Co. used 100% RAP as there aggregated base this past year on 1 of their roadways. Would be a good project to watch. Also, 100% RAP should be allowed by all for subgrade stabilization.
- The following owners do not allow RAP in certain lifts: Met Council City of Golden Valley City of Cannon Falls City of Farmington City of Hastings City of West St. Paul

APPENDIX B - MEMORANDUM: CITY ENGINEER PRESENTATION RECAP & RECOMMENDATIONS





STATE OF MINNESOTA
OFFICE MEMORANDUM

Office of Materials
Mailstop 645
1400 Gervais Avenue
Maplewood MN 55109

DATE: February 12, 2014

TO: District State Aid Engineers (DSAE's) & CEAM

FROM: John Garrity
Bituminous Engineer

PHONE: 651-366-5577

SUBJECT: City Engineer Presentation Recap and Recommendations

Hello City Engineers,

I had the opportunity to speak at this year's Annual Meeting of the City Engineers Association of Minnesota about "Selecting the best mix for your asphalt paving projects". In the presentation I discussed decisions to be made in regard to asphalt mixture selection, asphalt mixture placement, and compaction. All of these items have an impact on long term pavement performance. After the presentation I was asked if I could summarize what I had presented and provide guidance on mix selection, placement, and compaction. I have addressed those items below and have also included some information on Plant Inspection and Materials Control Schedule. Hopefully, this recap will give you the information needed to get the best performance out of your asphalt paving projects.

Mixture Selection

Decisions to be made regarding mixture selection are: 1) wear or non-wear, 2) aggregate size, 3) traffic level, 4) design air voids, and 5) asphalt binder grade.

- 1) Local agencies should consider the top 3" of pavement as the wearing course "WE". Below 3" from the top of the pavement should be specified as non-wear "NW".
- 2) Typically, aggregate size "A" (-1/2") or aggregate size "B" is specified for most paving applications. I am recommending aggregate size "A" be specified for the final lift. Aggregate size "A" can be used for all lifts, but, it would be acceptable to use aggregate size "B" for all underlying lifts. The reason I am recommending aggregate size "A" for the final lift is:
 - a. Finer mixes are generally easier to compact, are less prone to segregation, and make a tighter joint.
- 3) Traffic level selection is based on design traffic. The specification provides for 4 different traffic levels, Traffic Level 2 to 5. The primary difference as you go from Traffic Level 2 to 5 is the amount of crushing (both fine and coarse) in the mixture with Traffic Level 2 having the least amount of crushing required and Traffic Level 5 having the most crushing. Traffic Level 2 is appropriate with an AADT less than 2,300 and Traffic Level 3 is appropriate for AADT of 2,300 to 6,000. Traffic Level 4 should be used when AADT is above 6,000. In situations where Traffic Level 2 would be the appropriate selection, but, there is a high amount of truck traffic or slow, stopping and turning movements it might be beneficial to "bump" up the Traffic Level from 2 to 3 or "bump" from 3 to 4, as the case may be, to minimize the potential for rutting.

-
- 4) Mainline wearing course mixtures are generally specified with 4% design air voids (shoulder wear with 3% air voids). However, I am recommending, in most cases, mainline wearing courses on city streets be specified with 3% design voids. The lower air voids will potentially increase the amount of asphalt binder in the mixture promoting which will improve the long-term durability. On very high traffic facilities or roadways with a large amount of heavy commercial traffic specify 4% design voids. The higher air void design will minimize the potential for rutting.
 - 5) Asphalt binder selection is very important, it plays a significant role in minimizing rutting, thermal cracking, and fatigue cracking. PG binder guidelines can be found at:
http://www.dot.state.mn.us/materials/bituminousdocs/Doc_Aids/PGGuide_2007_Dec.pdf

MIXTURE DESIGNATION CODE RECOMMENDATION FOR FINAL WEAR LIFT: SPWEA (1)30(2)

Where:

(1) is designated with the appropriate Traffic Level (2, 3, 4, or 5) and,

(2) is designated with the appropriate letter for the PG Binder Grade (Ex: “B” for PG 58-28 or “C” for PG 58-34).

Example Mixture Designation Code for Traffic Level 2 and B grade binder: SPWEA230B

Example Mixture Designation Code for Traffic Level 3 and C grade binder: SPWEA330C

Mixture Placement

Selection of the proper mix will not ensure success of the paving project. It is critical there be an Inspector on the project to monitor mixture placement. The following list includes some, but not all, of the more important things the Inspector must monitor during construction: 1) conformity with details, 2) tack coat application, 3) mixture segregation. Compaction will be discussed next section.

- 1) Ensure paving conforms to all project details including setting the correct crown, thickness, and width.
- 2) Apply a uniform tack coat at the correct application rate. Field dilution of tack material is not allowed.
- 3) Watch for mixture segregation. Segregation is the separation of the coarse aggregate particles in the mix from the rest of the mix. Segregation during mixture placement can be caused by folding the hopper wings (wings should never be folded during the day’s paving operations), running the hopper dry (the hopper should always be kept at least 50% full), too much raking of the asphalt mixture (especially at the joint), paving wide widths without auger extensions, and poor workmanship. Segregation can also be caused by improper loading operations at the plant. A segregated surface or texture of the mat allows water to permeate the structure and will eventually cause breakup.

Compaction

Density is probably the single most important factor that affects the long-term durability of an asphalt pavement. Research from the state of Washington showed that for each 1% increase in air voids (over 7 percent) resulted in approximately 10% loss in pavement life. The 2360 Specification has 2 density options; Ordinary compaction and Maximum density. With Ordinary compaction a growth curve is developed to determine the optimal rolling pattern, no cores are cut to verify actual in-place density. Once the growth curve is developed the Inspector must monitor rolling to see the correct number of passes, as determined in the growth curve, are actually being done. With Maximum density cores are cut to determine actual in-place density. The Inspector must determine core locations, mark all coring locations on the pavement, and monitor the Contractor’s weighing of cores. The Inspector must also transport the Agency cores, in a timely manner, to the lab for testing. It is critical the Inspector be on the project to monitor density operations for both types of density control. There are some instances where Ordinary compaction is the best density choice but in most cases I would recommend using Maximum density.

Plant Inspection and Materials Control Schedule

Implementation of the Specification 2360 is not complete without Plant Inspection. The Plant Inspector must identify items to be sampled and determine sampling and testing rates as set forth in the Schedule of Materials Control (SMC). The SMC outlines the minimum QC/QA sampling and testing rates required for materials used in highway construction. The Plant Inspector is responsible for reviewing Contractor's QC operations and obtaining or observing the obtaining of the Agency's Verification samples (a minimum of one per day). The Plant Inspector must then deliver, in a timely manner, the Verification samples to a laboratory for testing.

This memo is a review of some of the more important steps necessary to get the most out of your asphalt paving projects. It is not all inclusive. If you have any questions about this memo or need any assistance in project design or construction please contact me. Thanks,
John