U.S. Department of Transportation
Federal Highway Administration

Office of Pavement Technology

RAP Mix Guidelines and Discussion

Towards a Standard Recommended Practice for RAP Use in HMA

Audrey Copeland
Asphalt Pavement Engineer

RAP ETG Meeting
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Top 10 Needs for Increased RAP Use

1. Performance test(s) for evaluating RAP
2. Best practices for mix design and construction including advantages of RAP and guidelines for producing a quality mix with varying levels of RAP
3. Characterize RAP without hazardous solvents
4. Necessary binder grade changes
5. Co-mingling of binders (RAP/virgin) in plants
6. Field performance of high RAP mixes
7. Replicating RAP and virgin plant heating in labs
8. States with no or low % RAP specs up to speed with current practices
9. Variability of RAP—(aggregate, AC content, modification, binder characterization)
10. Processing RAP including fractionation.

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Why do we need mix and best practices guidance?

- The majority of State DOTs use between 10 and 20% RAP.
- **Greatest single upfront cost saving** measure available to highway agencies is increasing RAP in construction and rehabilitation of asphalt pavements.
  - Agency RAP specs appear to be factor in increasing RAP contents (NCAT survey 2008)
- Contractors can effectively use RAP often and in high amounts with processing and production best practices.
- Need for clear engineering test methods and performance standards.

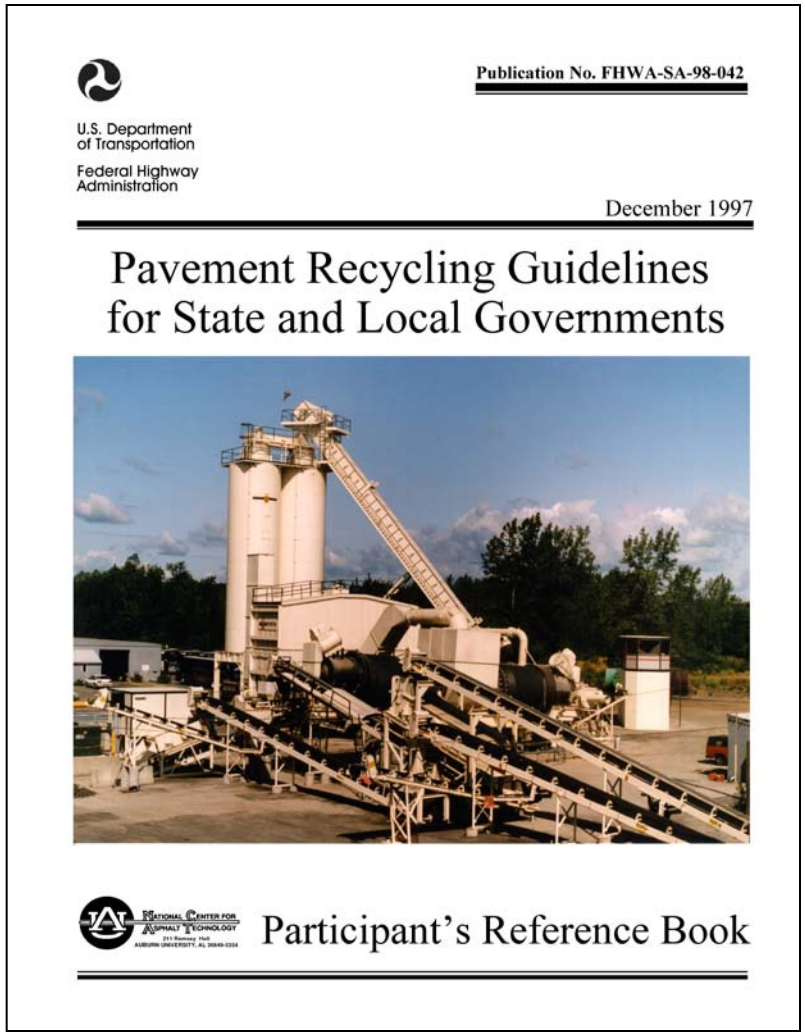
Presentation Outline

- **Available Guidance**
  - FHWA
  - NCHRP 9-12
  - AASHTO M323
  - Industry
  - Issues
- **Coming soon…**
  - NCHRP 9-33 HMA Mix Design Manual
  - NCHRP 9-46 Mix Design for High RAP

- **Discussion**
  - What do we need to do?
  - RAP ETG document

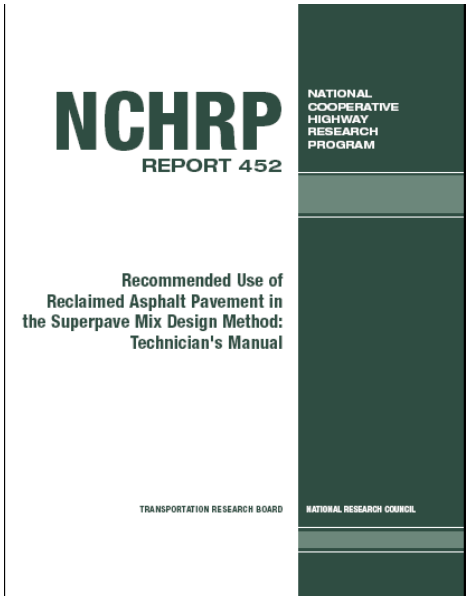
Pavement Recycling Guidance

- Construction Methods & Equipment for Batch and Drum Plants
- Materials and Mix Design
  - Limited Superpave Information
  - Useful information on sampling
- Case Histories & QC/QA



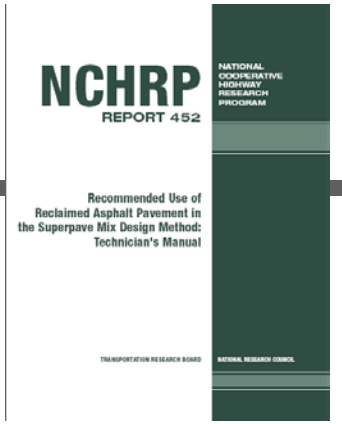
Current Guidance for RAP with Superpave

- NCHRP Project 9-12 *Recommended Use of RAP in Superpave*
- AASHTO M 323 *Standard Specification for Superpave™ Volumetric Mix Design*



Recommended Virgin Asphalt Binder Grade	Percent (%) RAP
No change in binder selection	< 15
Select virgin binder grade one grade softer than normal	15 – 25
Follow recommendations from blending charts	> 25

Findings of NCHRP 9-12



1. **Does RAP act like black rock?**

   No, some blending occurs.

2. **Binder effects – Can we use Superpave protocols to evaluate RAP and blended binders?**

   Superpave binder tests (AASHTO M320) and linear blending equations are appropriate (RAP contents less than 40%).

3. **How does RAP content effect the mixture?**

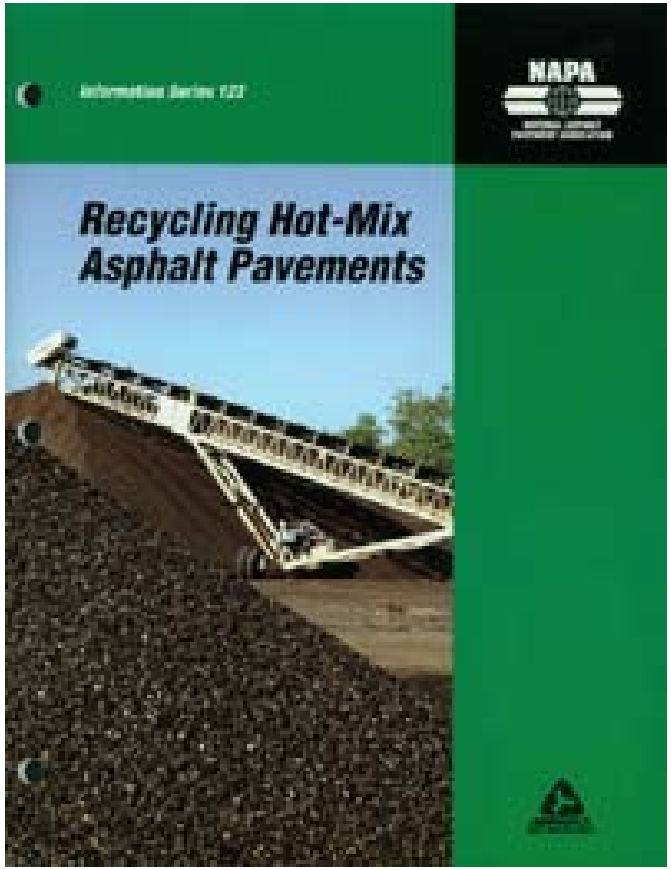
   At low RAP contents, mixes behave similarly. As RAP content increases, there is an increase in stiffness supporting use of softer binder and blending equations.

NCHRP 9-12 Recommendations

- Standard Superpave Mix design procedures
- Estimating RAP Aggregate Specific Gravity
- Account for weight of asphalt on RAP when batching
- Reduce new, virgin binder content to account for RAP
- Consider lower virgin binder grade to account for RAP binder aging

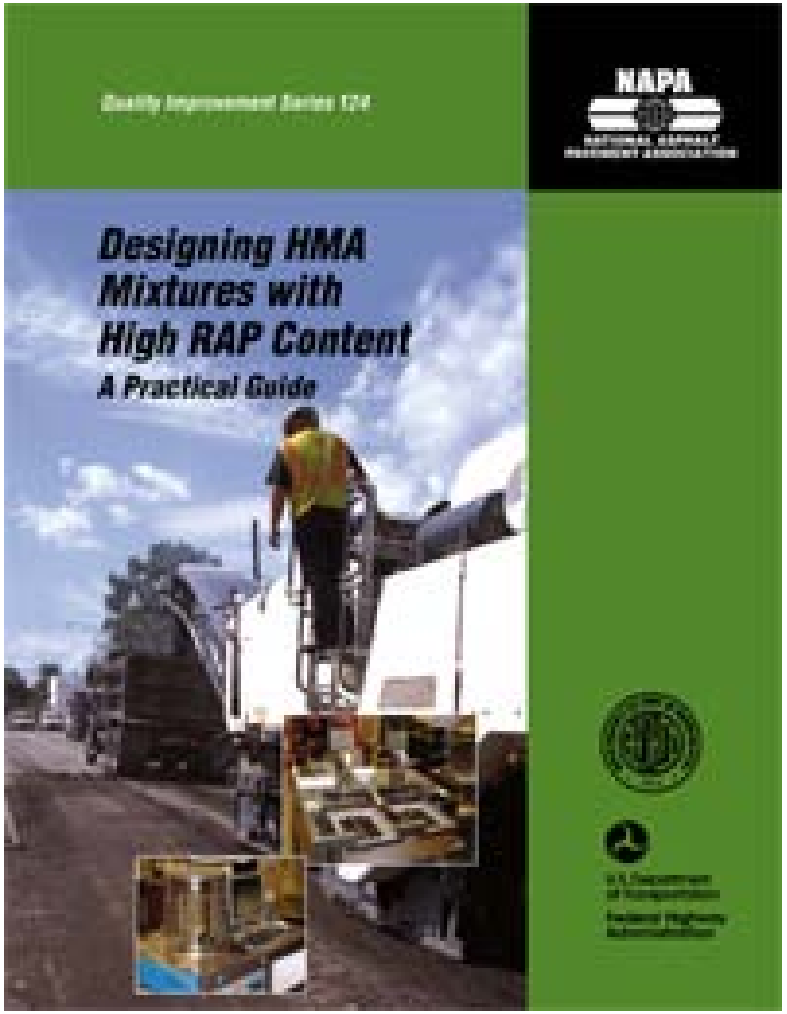
Industry Guidance

- "How to Recycle"
- Summarizes equipment and methods
  - Reclaiming
  - Processing and Storing RAP
  - Processing RAP in HMA plant
  - High % Recycling
  - Laydown and Compaction



Industry Guidance

- Practical guidance for using 30 to 40 % RAP in HMA
  - Material Selection & Evaluation
  - Mix Design
  - Plant Verification
  - Quality Control



Issues for Designing High RAP Mixtures

Talking Points

1. **Manner in which effective binder grade is changed by addition of RAP.**
   - High RAP content increases the stiffness and requires binder changes to achieve desired blended binder characteristics
   - Extraction and recovery procedures

2. **Meeting volumetric requirements**
   - Gradation of RAP may contain too much material passing the No. 200 sieve that will limit amount of RAP that can be used.
   - Consensus properties of aggregate

3. **Effect of RAP use on production variability**
   - RAP availability
   - Stockpile management
   - RAP moisture content
   - Plant limitations
   - Temperature restrictions

Future Guidance

NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

- NCHRP Project 9-33

  A Mix Design Manual for HMA

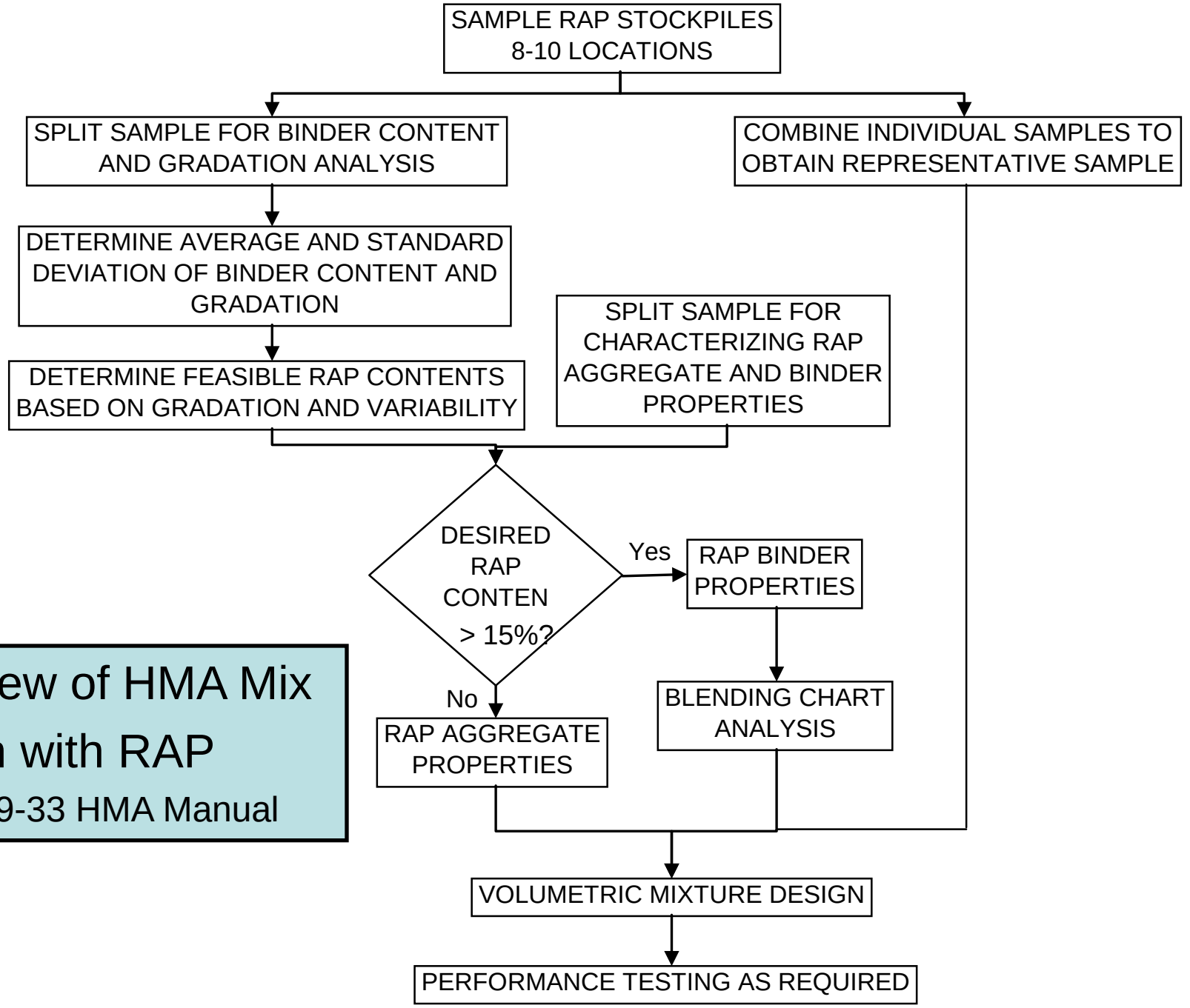
  Chapter: Recycled Asphalt Pavements and Other Recycled Materials

- NCHRP Project 9-46

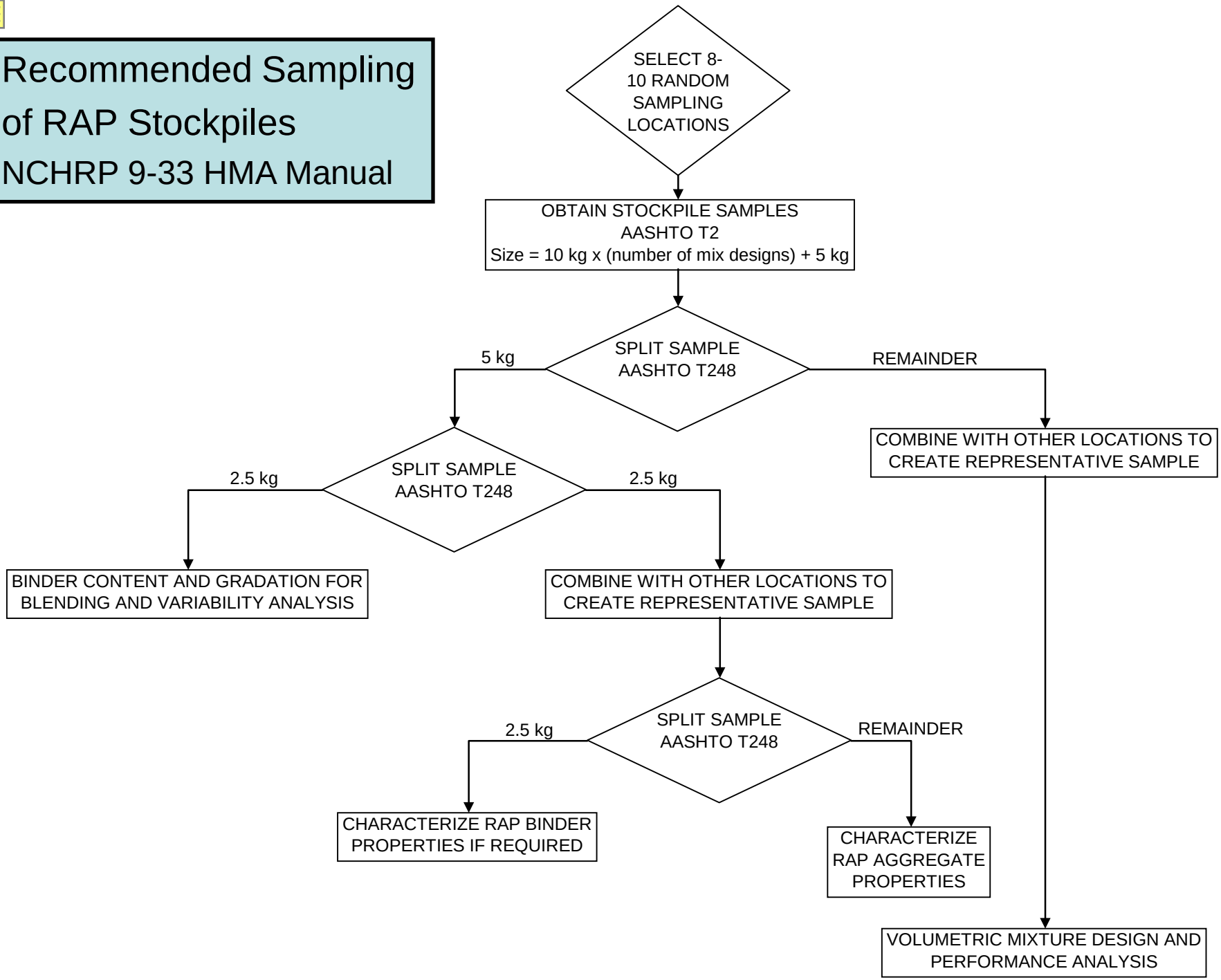
  Mix Design and Evaluation Procedure for High Reclaimed Asphalt Pavement Content in Hot Mix Asphalt

Overview of HMA Mix Design with RAP

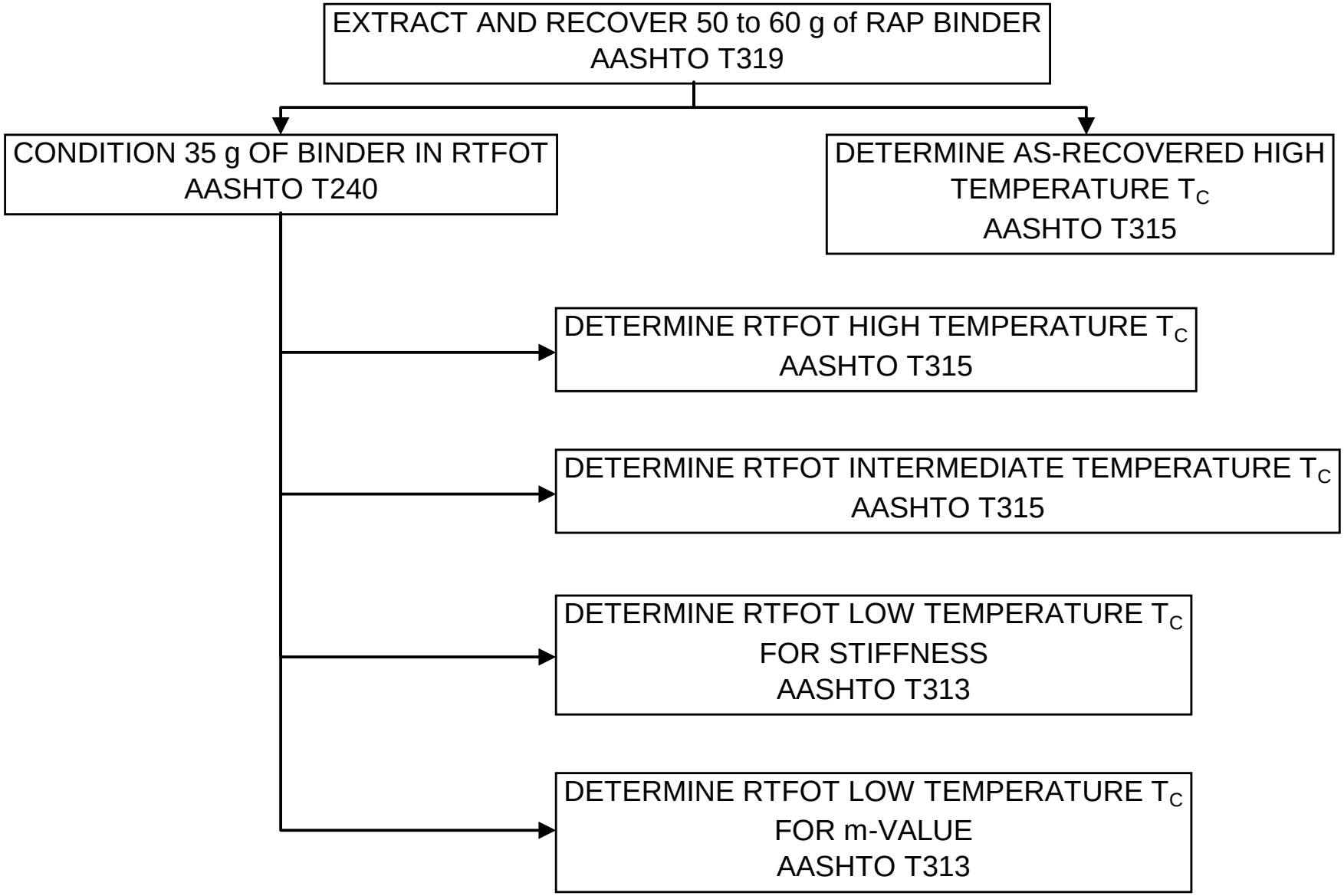
NCHRP 9-33 HMA Manual



Recommended Sampling of RAP Stockpiles NCHRP 9-33 HMA Manual



RAP Binder Testing
NCHRP 9-33 HMA Manual



5 Approaches for Utilizing RAP

1. HMA Tools spreadsheet with full RAP analysis
2. Design Charts
3. HMA Tools with simplified analysis in conjunction with design charts
4. Approach 1 with design charts used as educational tools only
5. Quality classification approach

Including RAP in Mix Design

Approach 1 - HMA Tools with Full RAP Analysis

- Limits amount of RAP based on RAP and blending variability
- Theoretically sound, but complex (e.g. multiple RAP samples)
  - Mathematics part of HMA Tools spreadsheet
- Requires substantial sampling and testing
  - 10 samples
  - Binder content and aggregate gradation
- Concerns
  - Complicated, Unnecessary?
  - Existing specs for handling RAP result in good quality material.

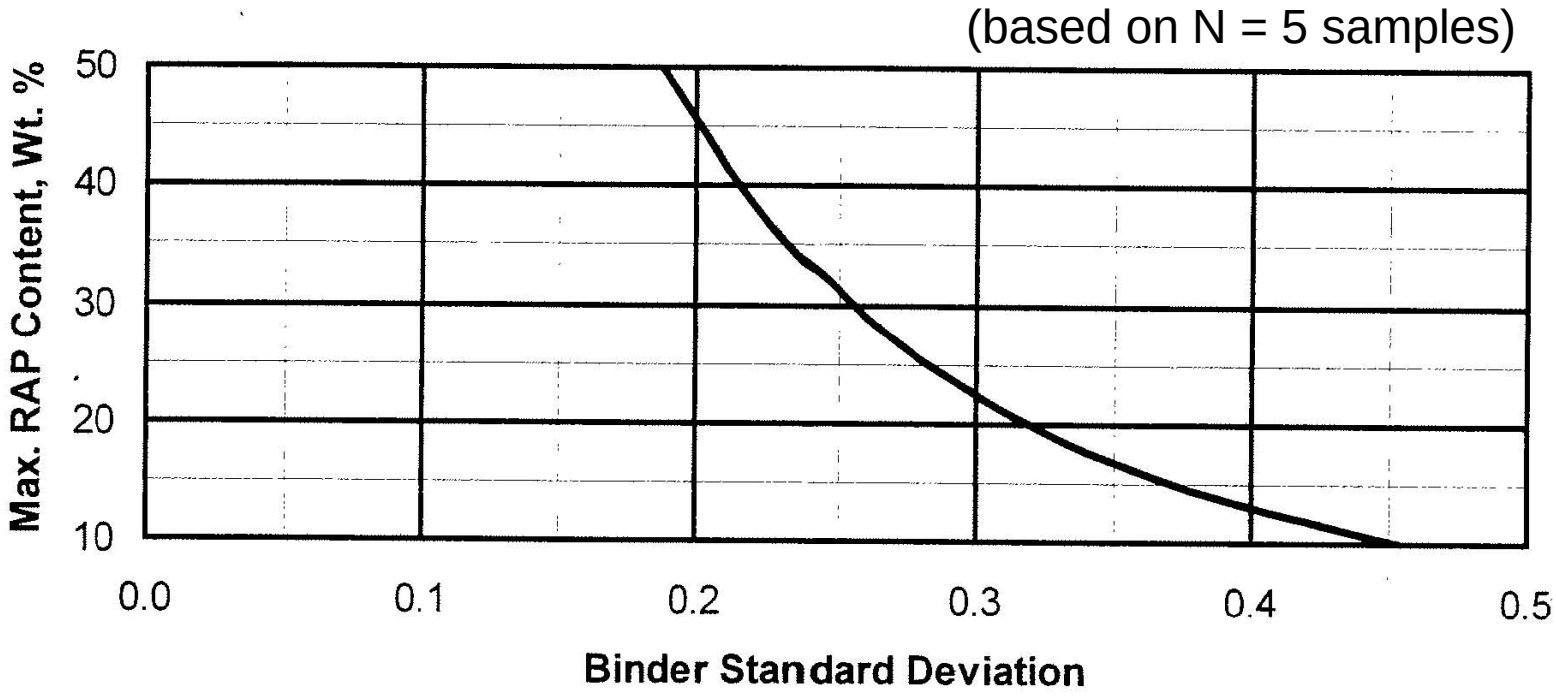
Including RAP in Mix Design

Approach 2 – Design Charts

- Determine Max Allowable RAP based on charts
- Same theoretical approach with reasonable simplifying assumptions to simplify calculations
- Easily see how and why RAP is limited

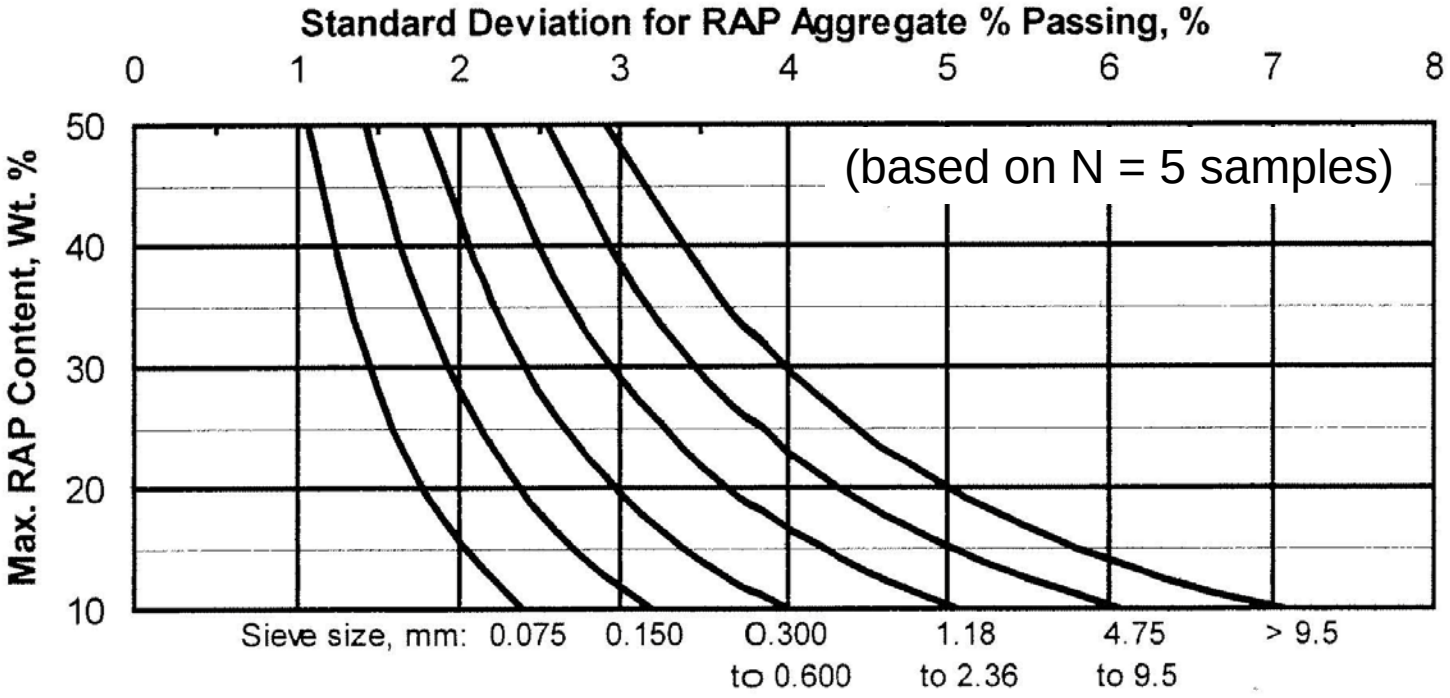
Including RAP in Mix Design
Approach 2 – Design Charts

- Max Allowable RAP content as function of asphalt binder content standard deviation



Including RAP in Mix Design
Approach 2 – Design Charts

- Max Allowable RAP content as function of RAP aggregate sieve size and standard deviation



Including RAP in Mix Design
Approaches 3 & 4

- Approach 3 - HMA Tools with simplified RAP Analysis in conjunction with RAP Design Charts
  - Blending variability is ignored
  - Max RAP content function of RAP variability only
- Approach 4 – HMA Tools with Full RAP Analysis and Include RAP Design Charts as training/educational tool.

Including RAP in Mix Design
Approaches 1, 2, 3 & 4

- States already have guidelines and specs for RAP utilization

- Approaches 1- 4 could be incompatible with existing specifications.

Estimating Standard Deviation

- Estimating standard deviation is critical to all approaches.
- Using only 10 samples or less will result in uncertain estimate of standard deviation.
- Apply upper confidence limit
  - 80% used in HMA tools with full RAP analysis (Approach 1) and design charts (Approach 2).
    - "Underutilizes RAP"
  - 50% used in Quality Classification (Approach 5)

NCHRP 9-33 Panel Decision

- Approach 3 was chosen
- HMA Tools spreadsheet will include separate, stand alone worksheet for determining maximum allowable RAP content based on RAP variability (blending variability ignored)
- RAP content is limited to amount that will not increase overall variability of HMA
- Design charts will be included for illustration

Other considerations

- AASHTO Protocol: Procedure for determining blended binder grade for HMA containing RAP
- Max allowable RAP content based on binder grading determined in separate worksheet – RAP binders worksheet
- User can determine RAP content based on binder grade, variability, and/or other specifications.

What do we need to do?

- Clearly define high RAP
- Decide best manner to provide guidance/best practices for RAP use.
  - RAP ETG report?
  - AASHTO document?
- Scope (establish bounds) for standard practice
  - Key factors unique to RAP – identified by ETG
  - Provide references and/or insights
- Provide guidance and insure information in NCHRP 9-33 and 9-46 is accurate.

Thank you! Questions?

www.fhwa.dot.gov/pavement/recycling/rap

Proposed Standard Practice for Use of RAP in HMA

- Design considerations
- Processing and Storing RAP
- Requirements for Sampling and Insuring Quality of RAP
- Aggregate and Binder Requirements
- Mixture Design Requirements

Discussion Questions

- What are we trying to accomplish?
  - Increase use of RAP overall
- What is needed?

Including RAP in Mix Design
Approach 5 – Quality Classification

- Testing is limited
  - Verify classification of RAP quality
  - Ensure some objectivity
- Simple, easy to understand, flexible
- More compatible with existing guidelines and specs
- Matter of judgment

Including RAP in Mix Design

Approach 5 – Quality Classification

RAP Variability	Very Low	Low	Moderate
Maximum Allowable RAP Content, Weight %	50	30	15
Characteristic	**Description**		
RAP Source	Single source or screened & processed	Same mix type and NMAS; construction dates with 2 year time span*	Same mix type, NMAS within one size; construction dates within 5 year time span*
Typical documentation	JMF, complete QC data, pavement structure	JMF, limited QC data including contractor and date of construction	JMF, contractor, date of construction

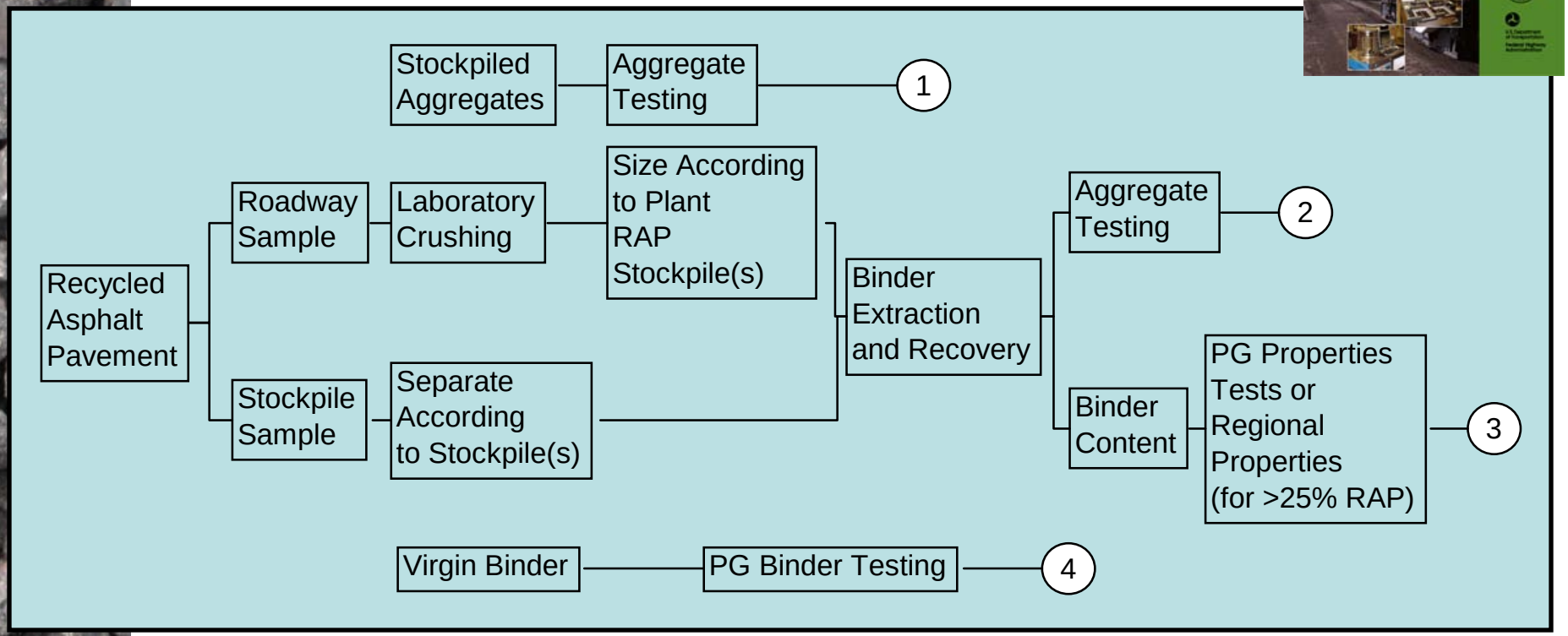
Including RAP in Mix Design
Approach 5 – Quality Classification

RAP Variability	Very Low	Low	Moderate
Maximum Allowable RAP Content, Weight %	50	30	15
Characteristic	**Description**		
Number of RAP samples used for mix design	10	5	3
Typical RAP QC testing frequency	> 2 per day	1 or 2 per day	1 or 2 per week

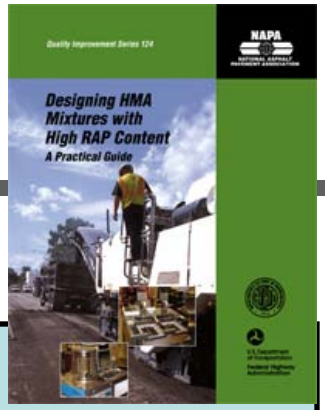
Including RAP in Mix Design
Approach 5 – Quality Classification

RAP Variability	Very Low	Low	Moderate
Maximum Allowable RAP Content, Weight %	50	30	15
Maximum Standard Deviation for Sample Size			
RAP Characteristic	N=10	N=5	N=3
% Passing 9.5 mm	4.6	6.2	9.0
% Passing 2.36 mm	3.4	4.6	6.6
% Passing 0,075 mm	1.7	2.3	3.2
Asphalt Binder Content	0.30	0.40	0.60

Materials Evaluation



Mix Design Procedures



1. Stockpile Aggregates
2. RAP Aggregates

→ Combine Aggregates to Meet Gradation and Quality Requirements

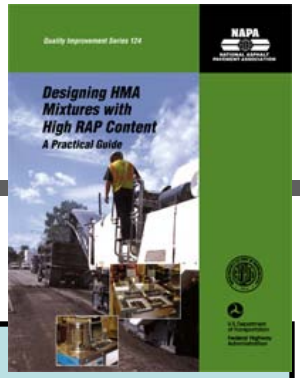
3. RAP Binder
4. Virgin Binder

→ Combine Asphalt to Meet PG Grading Requirements (for >25% RAP)

→ Choose Highest % RAP that Satisfies Both Gradation and PG Requirements

→ Perform Mix Design

Plant Verification Procedure



Set Plant Controls to RAP, Aggregate Binder @ Mix Design Proportions

Produce Mix: 1 hr Prod. In Batch Plant or 60 to 200 T in Drum

Take Sample from Truck

Compact 2 Samples @ Mix Design Level

Test Volumetrics $\%G_{mm1}$, VMA, VFA

Compare to Mix Design and Specs.-Air Voids VMA, VFA

Adjust Mix Proportions

Performance Testing-Rut, Perm. Def. Thermal Cracking, Fatigue, Modulus, Moisture Sensitivity Durability

Contruct Test Sections-Establish Roller Patterns, Check Density/Volumetrics