NCHRP 09-46

Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content

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Project Tasks

- Phase I
  - Task 1 – Literature review
  - Task 2 – Propose mix design & analysis procedure
  - Task 3 – Lab work plan
  - Task 4 – Interim report (Tasks 1-3)
- Phase II
  - Task 5 – Conduct lab work plan
  - Task 6 – Compare RAP mixes to virgin mixes
  - Task 7 – Evaluate min. of 3 field projects
  - Task 8 – Propose changes to standards
  - Task 9 – Final report

Task 1 Literature Review

- Mix design issues
  - Mix design procedures
  - Reclaimed aggregates
  - Binder content and properties
- Materials management
- Performance Tests

Task 2: Proposed Mix Design and Mix Evaluation

RAP Mix Design Philosophy

- Current guidelines for RAP in M 323 are sound, with a few possible exceptions for high RAP contents. Better guidance is needed for…
  - Determining RAP AC content
  - Determining RAP aggregate Gsb
  - Selection of virgin binder
  - Materials preparation and heating
  - Mixing and compaction temperatures
  - Basic calculations (see technician manual)

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RAP Mix Design Philosophy

- Follow R 35 and M 323 as much as possible
- Additional performance tests besides T 283 to assure durability
- Performance test selection
  - Use existing methods
  - Input from panel
  - Methods should be reasonable for a mix design lab (cost, time, complexity)

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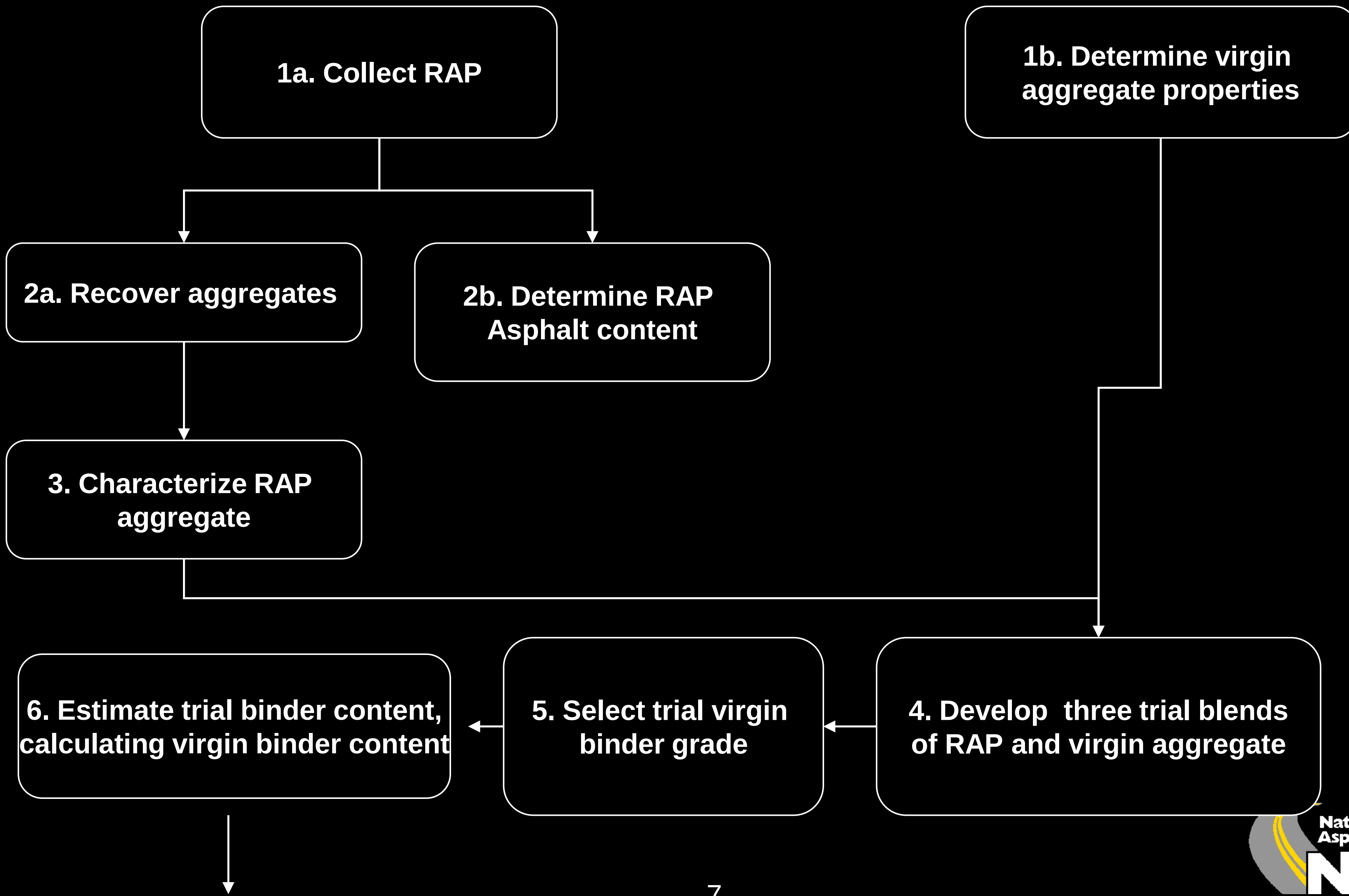

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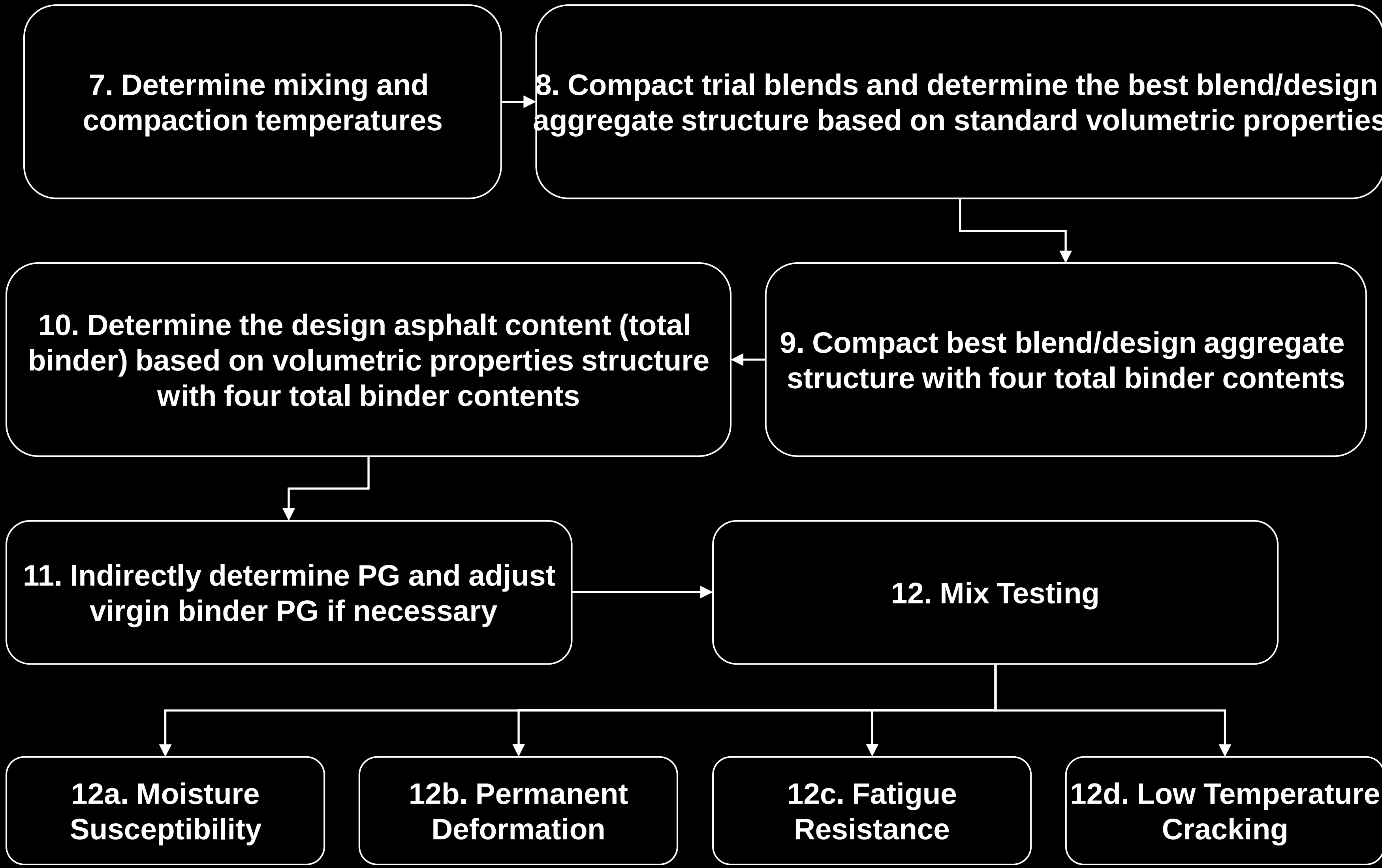
7. Determine mixing and compaction temperatures
8. Compact trial blends and determine the best blend/design aggregate structure based on standard volumetric properties
9. Compact best blend/design aggregate structure with four total binder contents
10. Determine the design asphalt content (total binder) based on volumetric properties structure with four total binder contents
11. Indirectly determine PG and adjust virgin binder PG if necessary
12. Mix Testing
12a. Moisture Susceptibility
12b. Permanent Deformation
12c. Fatigue Resistance
12d. Low Temperature Cracking

Test	Moisture Damage	Permanent Deformation	Fatigue	Low Temperature Cracking
Moisture Susceptibility (AASHTO T 283)	✓			
Asphalt Pavement Analyzer		✓		
Hamburg Wheel Tracking Device	✓	✓		
Dynamic Modulus		✓	✓	
Repeated Load Permanent Deformation		✓		
Beam Fatigue			✓	
AMPT Fatigue			✓	
Overlay Tester			✓	
Indirect Tension Creep Compliance				✓
Semi-Circular Bend				✓
BBR with Mix Beams				✓

Research Team Recommendations

- Moisture Susceptibility
  - TSR
- Permanent Deformation
  - Repeated Load Permanent Deformation
- Fatigue
  - Beam fatigue, AMPT Fatigue, or Overlay Tester
- Low Temperature
  - SCB and BBR with mix beams

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Example Mix Design

Initial Mix Design Information

- Location: Wisconsin
  - Standard binder grade: PG 58-28
- RAP: Crushed and worked with a front end loader
- Virgin aggregate: Limestone

Step 1

- Identify available virgin aggregate and RAP materials
- Conduct sieve analyses on virgin aggregate
- Ascertain apparent and bulk specific gravity

Step 2

- Reclaim RAP aggregates
- Recommendations for reclaiming will be given
  - UNR cooperative study

Step 3

- Conduct a sieve analysis of RAP aggregate
- Ascertain the apparent and bulk specific gravities of recovered RAP aggregate
- Ascertain aggregate source properties

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Step 4

- Develop trial blends using virgin aggregates and RAP
- M 323 gradation criteria should be adhered to
- Evaluate combined aggregate properties for each trial blend
  - Coarse aggregate angularity
  - Fine aggregate angularity
  - Flat and elongated
  - Sand equivalent
- Batch specimens for trial gradation

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Step 5

- Use LTPPBind to aid in selecting standard binder
  - PG 58-28

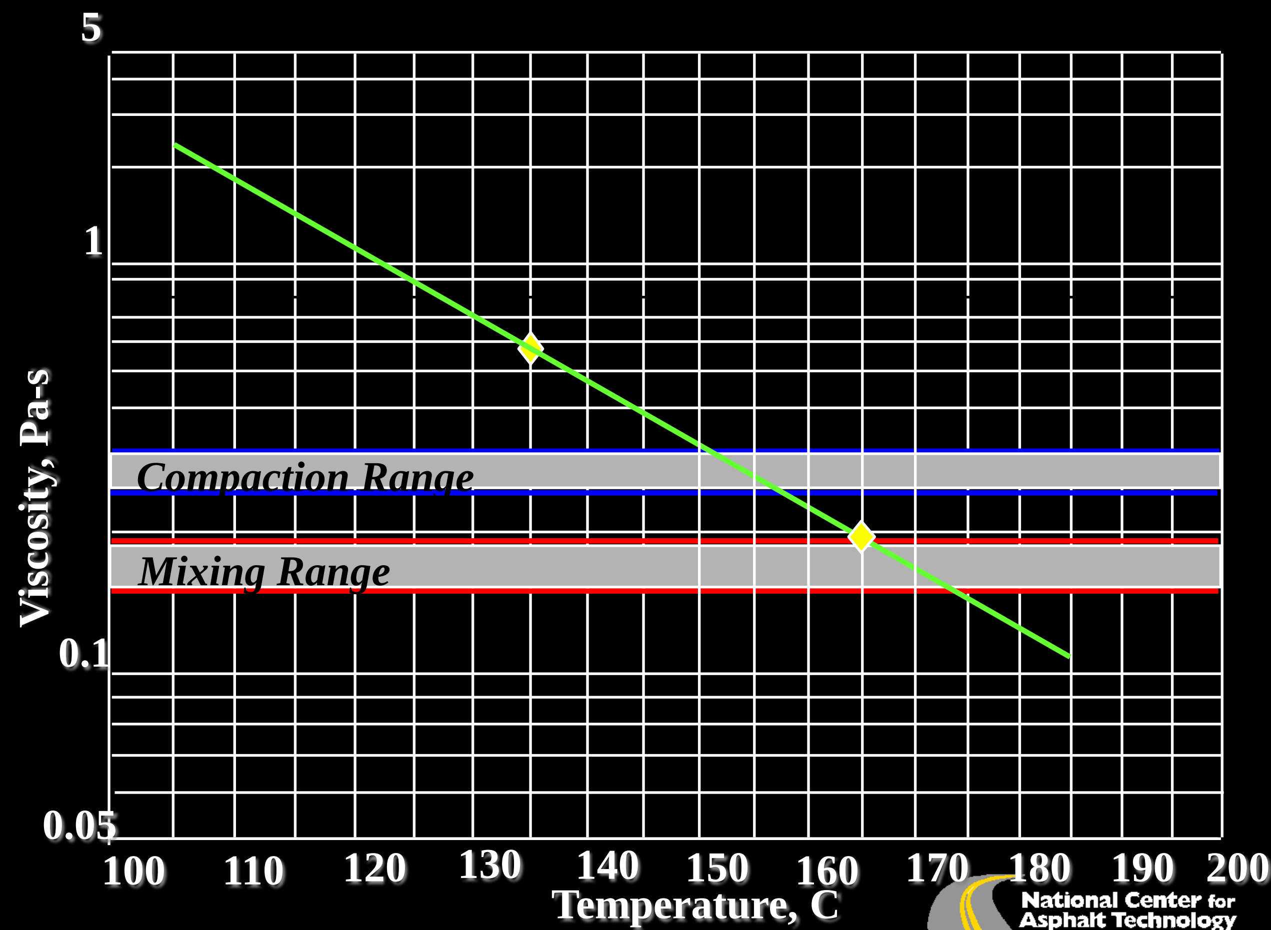
Step 6

- Estimate trial binder content for each trial blend that met the AASHTO M 323 aggregate requirements

- Experience or method outlined in AASHTO R 35
- Account for RAP asphalt

Step 7

- The mixing and compaction temperatures will be determined based on virgin binder



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Step 8

- Select number of gyrations to compact the trial blends based on expected traffic volume
- Heat batched aggregate (and RAP)
- Mix trial gradations with selected trial binder content at selected mix temperature
  - Binder used is the PG 58-28
- Age loose mix in accordance with R 30
  - 2 hours at selected compaction temperature
- Determine G_{mm}
- Compact to N_{design} gyrations and determine G_{mb}

SGC is insensitive to binder stiffness

- Numerous references in the literature
- SGC is a constant strain device
- If binder stiffness does affect the density, then…
  - Lower density will yield slightly higher AC content, which will help durability
  - The proposed method will evaluate mix and binder stiffness with E*. If they are too high, then the procedure will force the mix designer to iterate with a softer virgin grade
  - Mix performance tests will help avoid mixes which could have performance problems

Step 8 (cont.)

- Evaluate specimens in accordance with AASHTO R 35 section 9
- Select trial blend which appears to meet all volumetric requirements

Step 9

- Batch materials for the selected trial blend
- Make specimens using the selected trial blend at three additional asphalt contents
  - Trial asphalt content ± 0.5% and trial asphalt content + 1.0%
- Compact using same gyrations used in step 8

Step 10

- Evaluate for each total binder content:
  - Air void % vs. binder content %
  - VMA % vs. binder content %
  - VFA % vs. binder content %
  - Density vs. binder content %
- Identify which binder content yields 4.0% air voids at N_{design}

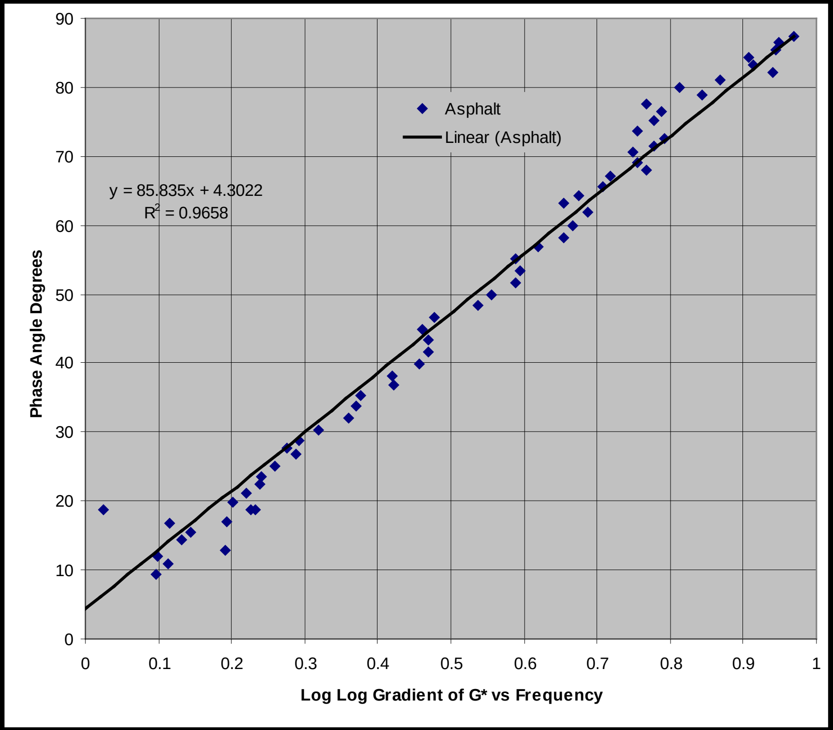
Step 11

- Dynamic Modulus Testing (AASHTO TP 62)
  - Loose mix aged for 4 hours at 135°C
  - Cut and cored specimens will have 7 ± 0.5% air voids
  - 4.4, 21.1, 37.8, and 54°C
  - 0.1, 0.5, 1.0, 5, 10, and 25 Hz
  - Condition specimens to desired test temperature
  - Develop master curve
  - Back calculate binder stiffness

Hirsch Model

- Relationship between |E*| of mixture and |G*| of binder, VMA, and VFA
- Developed for forward calculation of |E*|
- Can be used to backcalculate |G*| with mix information

Phase angle and |G*| relationship



- Rowe determined linear relationship between phase angle and log log slope of G* vs freq

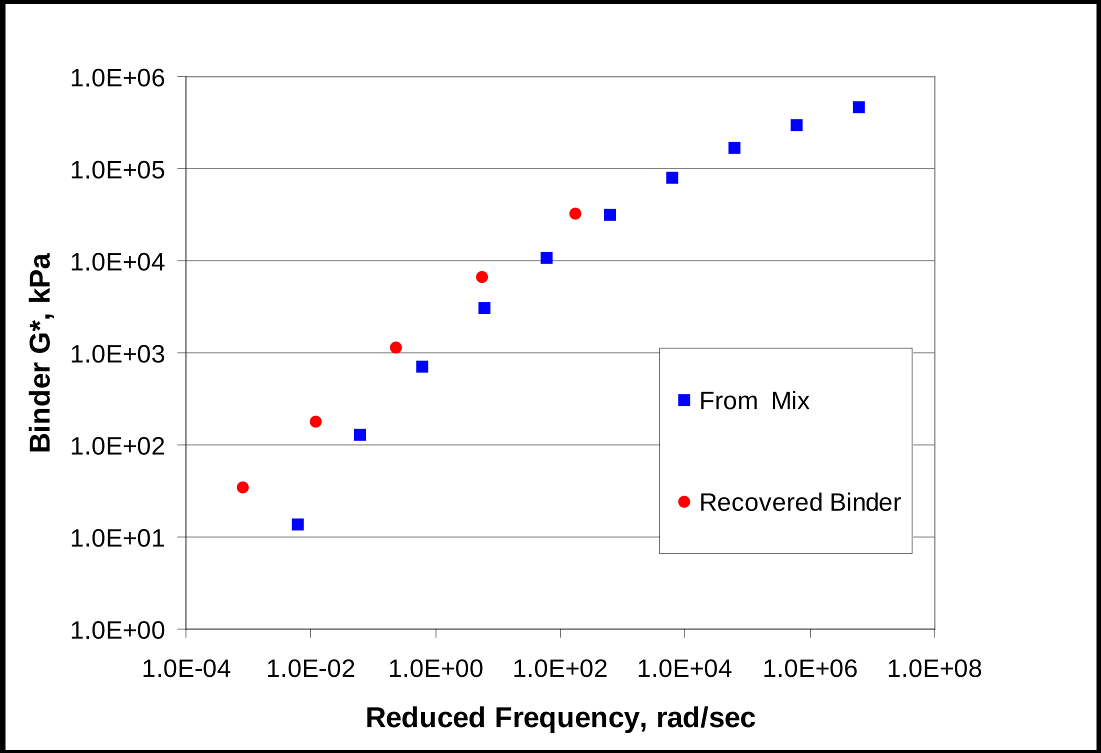
Backcalculation Procedure

- Measure |E*|, VMA, VFA
- Backcalculate |G*|
- Use relationship by Rowe to get phase angle

Forward calculation Procedure

- Following Bonaquist work
- Measure |E*|
- Extract binder and measure |G*|
- Calculate |E*| from |G*| (fully blended)
- Compare |E*| curves to evaluate extent of blending

Example of Forward Calculation



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Step 11 cont.

- Moisture susceptibility (AASHTO T 283):
  - Material mixed, cured, and short term aged in accordance with AASHTO T 283 section 6
  - Compact to 7 ± 0.5% air voids and stored for 24 hours at room temperature
  - Dry specimens placed in bag and then 25°C water bath for 2 hours
  - Wet specimens vacuum saturated to 70-80%, 1 freeze cycle (-18°C), thaw at 60°C for 24 hours, conditioned in 25°C water bath
  - Diametrically load at a rate of 50mm/min
  - Calculate tensile strength ratio

Step 11 cont.

- If moisture susceptibility results are 80% or better and dynamic modulus results are not too stiff continue with additional mix tests
- Criteria for back calculated stiffness will be based on conclusions from evaluating existing pavements

Step 11: Permanent Deformation

- Repeated load permanent deformation
  - Loose mix aged for 4 hours at 135°C
  - Cut and cored specimens will have 7 ± 0.5% air voids
  - Test temperature PG high -6°C
  - Condition specimens to desired test temperature
  - Confine specimens
  - Deviator stress of 70 psi
  - Confinement 10 psi

Step 11: Low Temperature Cracking

- Semi Circular Bend (SCB)
  - Loose mix aged at 135°C for 4 hours
  - Compact cylindrical specimens to 7 ± 0.5% air voids
  - Age specimens at 85°C for 120 hours
  - Test at PG low

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Step 11: Fatigue

- Beam Fatigue (AASHTO T 321)
  - Loose mix aged at 135°C for 4 hours
  - Compact beams
  - Age beams at 85°C for 120 hours
  - 400 microstrain level

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Step 11: Fatigue cont.

- Overlay Tester
  - Loose mix aged at 135°C for 4 hours
  - Compact cylindrical specimens to 7 ± 0.5% air voids
  - Age specimens at 85°C for 120 hours

Mixes to Evaluate

- Materials from 4 regions
- Southwest
  - Binder compatibility (binders from two sources)
  - Binder effect on volumetrics
  - WMA
  - Performance testing
- Northeast
  - Binder compatibility
  - Binder effect on volumetrics
  - Performance testing
- Midwest
  - Multiple freeze-thaw cycles
  - Performance testing
  - RAP with different NMAS
- Southeast
  - Performance testing
  - RAP with different NMAS

RAP Sampling and Testing

- Minimum frequency of 1 test/1000 tons
- Test minimum of 10 samples from random locations around RAP stockpile
  - Do not combine samples
  - Test AC content and gradation, calculate averages and standard deviations
  - Test methods to be determined
- Use average and standard deviation in blending variability analysis
- Tighter control of RAP stockpiles for higher RAP contents based on statistical analysis of combined variability of materials

RAP Management Best Practices

- Crushing
  - Minimize creating additional fines
- Stockpiling
  - Minimize moisture content
  - Minimize segregation
- Plant Operations
  - In-line crusher should only be used to break up agglomerations
  - RAP feed calibration
  - Superheating
  - Emissions
  - Warm mix asphalt technologies
- Processing and stockpile management should not be a method specification such as requiring fractionation

Questions and Comments

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