Overview of Current RAP Research

RAP ETG

May 4, 2007

RAP

- RAP can be cost effective and environmentally friendly ☺

BUT…..

- Variability of material ☹
- Compactibility and workability ☹
- Designing mix ☹

Variability

- RAP stockpiles can contain:
  - Material with no known properties
  - Several sources
- Solutions:
  - Screening/ Fractionation
  - Characterization procedure

Characterization of RAP and Blend

- Material properties vary from source to source
- Unknown properties of RAP and virgin blended
- Solution:
  - Characterize RAP
  - Characterize Blend

Characterization of RAP

- Advanced Asphalt Technologies
  - Ray Bonaquist
  - Plant Produced 35%-45% RAP mixes
  - Dynamic Modulus
    - Sensitive to binder changes
  - Backcalculate G* using Hirsch
    - Effective PG
  - Compared estimated binder to recovered
    - Good correlation
  - Possible to estimate stiffness

Characterization of RAP cont.

- Univeristy of Minnesota
  - Zofka, Marasteanu, Clyne, Li, & Hoffman
  - BBR mix specimens
    - 101mm X 10mm X 8mm
    - 0, 20%, & 40%
    - Creep compliance and stiffness
  - Backcalculation of effective binder stiffness via Hirsch Model
    - Phase angle log of contact factor (Pc)
    - Binder stiffness=3 x G*
  - Predicted and actual stiffness same trend
  - Predicted often resulted in lower stiffness values
    - Some beams too wide for supports
    - Additional work on refinement

RAP Stiffness Modulus

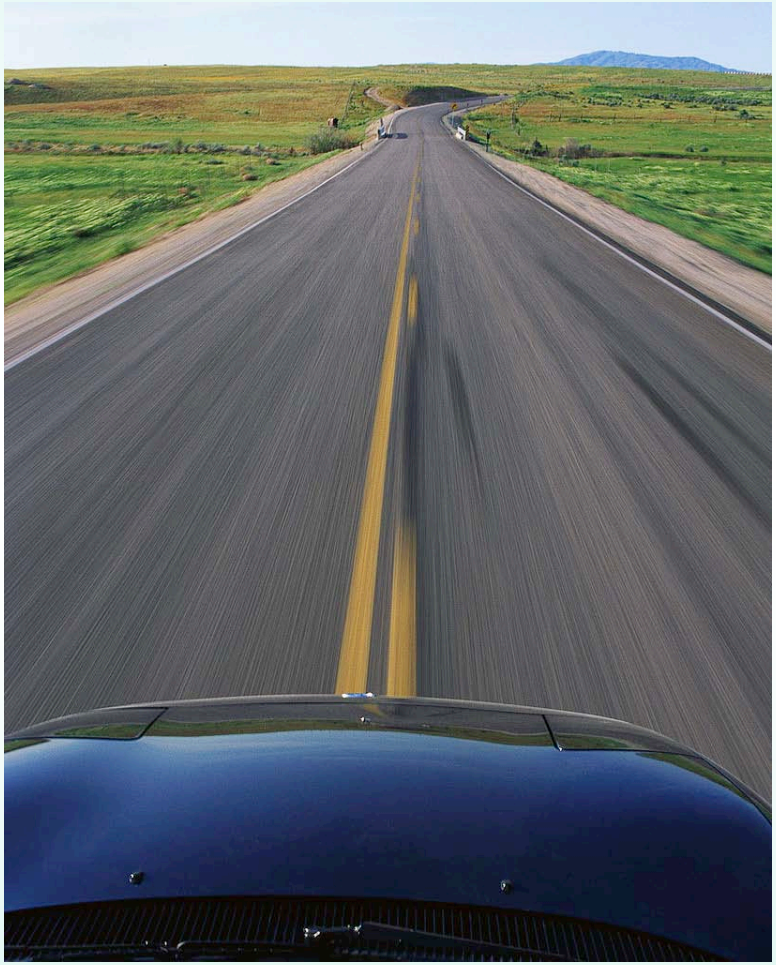
- Worcester Poly. Inst. & U of T El Paso
  - Mallick, Bradley, and Nazarian
  - Reclaimed layers
  - Stiffness modulus computed via seismic testing
  - Layer thickness
    - FWD and ground penetrating radar
  - Deflection and stiffness correlated
  - Feasible method for DOTs to determine modulus
    - MEPDG

Characterization of RAP cont.

- Auburn University
  - Carter (Stroup-Gardiner)
    - Indirect tension stress relaxation test
      - 5 and 22°C
      - Initial stress relaxation modulus
      - Curvature coefficient
      - Linear viscoelastic range (3 reps)
    - Compute required modulus based on knowing desired and RAP modulus
      - 0, 15%, 25%, and 50% RAP (2 sources)
      - 64-22 (neat) and 76-22 (mod.)
    - Use RAP % and RAP modulus to determine blend modulus

Bad RAP?

- Are there pavements that should not be recycled?
- Are certain additives bad?



Crumb Rubber RAP

- GA. Southern U., Chongqing Jiaotong University, and Clemson
  - Shen, Amirkhanian, Lee, and Putnam
  - Evaluated use of old crumb rubber pavements used as RAP
  - 3 crumb rubber RAP & 3 virgin mixes
  - Artificially aged mixes
  - 15% RAP
  - Crumb rubber pavement can be recycled using normal recycling procedures

Effects of RAP on Performance

- How does RAP affect mix properties?
- Are differences positive or negative results?

Mechanistic and Volumetric Properties

- University of New Hampshire
  - Daniel and Lachance
  - 0%, 15%, 25%, 40% RAP
  - Processed and unprocessed RAP
  - Dynamic Modulus, creep compliance, and creep flow
  - Changes in dynamic modulus and VMA

Mechanistic Properties Cont.

- N. Central Superpave, Heritage, FHWA
  - McDaniel, Shah, Huber, and Gallivan
  - RAP and Virgin Mixes
    - 0, 15%, 25%, & 40% RAP
    - PG 64-22 & PG 58-28
  - Complex Dynamic Modulus |E*|
  - Low temp. creep compliance and indirect tensile strength
    - Estimate critical cracking temp
  - No drastic changes in properties with RAP

Mix Design

- Do typical mix design procedures work?
- Is additional testing requires?

Mechanical Characterization

- U. of Minhu & U. of Coimbra (Portugal)
  - Pereira, Oliveira, & Picado-Santos
  - Investigated if Marshall design can be used for 50% RAP mixes
    - Compared to 100% virgin
  - Four point beam fatigue and repeated simple shear test (deformation)
  - Results positive thus far, but research continues

Pavement Design with RAP

- Indian Inst. of Tech. Kanpur
  - Aravind & Das
  - Marshall tests to evaluate performance
  - Aimed for desired viscosity and performance
  - Two RAP mixes & one virgin mix
    - Dense-graded
  - Aim target viscosity
    - Based proportions on visc. calculations

Sensitivity of MEPDG to RAP

- Penn State & UNH
  - Chehab and Daniel
  - Pavement properties and conditions constant except surface
  - Varied RAP content and effective PG
  - MEPDG sensitive to assumed PG
    - Thermal cracking and rutting
  - Important to determined effective PG correctly when using MEPDG

Blending of RAP

- U. of Tenn. and LSU
  - Huang, Li, Vukosavljevic, Shu, and Egan
  - Evaluated 20% of RAP blended with virgin
  - Staged extraction
    - 3 min TCE soaks (4 soaks)
  - Small % of RAP binder mixed with virgin materials
  - Rest black rock

Resilient Modulus

- University of Nevada
  - Hajj & Sebaaly
  - Evaluated blending chart, mixing of blends, and M_r as performance test
    - 3 RAP sources, 2 binders, 3 aggregate sources, 3 percentages (0%, 15%, 30%)
  - Blending chart worked
  - Mixing process adequate
  - M_r correct for thermal cracking, but not rutting and fatigue

Workability and Compactibility

- RAP tends to be stiffer
- Requires higher temperatures during production
- Solution:
  - Additive to adjust viscosity of mix

Warm Mix in High Content RAP

- Iceland and Maryland
  - Kristjansdottir, Muench, Michael, & Burke
  - Warm mix additives
    - Improve workability & compactibility
  - Maryland
  - 35 and 45% RAP in HMA and WMA
  - Sasobit blown into HMA via fiber feeder
  - Stiffness, rutting, fatigue, thermal cracking, moisture sensitivity, & aging evaluated
  - No adverse effect on performance RAP HMA vs RAP WMA
  - Seemed more workable compared to RAP HMA

WMA and RAP cont.

- Worcester Poly. Inst. & Maine DOT
  - Mallick, Bradley, & Bradbury
  - Lab study evaluated compaction effort, stiffness, and retained tensile strength
  - 100% RAP (target)
    - Emulsion @ 3%, Asphalt @ 2%, and Sasobit @1.5%
  - Sasobit allowed for lower temperatures with equivalent workability and compaction
  - Asphalt dispersion improved with Sasobit

Warm Mix and RAP

- Hong Kong Poly. U. & Changsha U.
  - Gui-ping & Wing-gun
  - Compared permanent deformation of foamed asphalt RAP to virgin
    - 0%, 20%, 40%, and 60% RAP
  - Creep strain slope not affected by RAP
  - Permanent deformation not significantly affected by RAP in foamed asphalt