SUMMARY REPORT:
BREAKOUT SESSION 1

Fundamentals

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Breakout Session 1 started at 10:00 a.m. with self-introductions and circulation of an attendance sheet (see the list at the end of this report). Brief technical presentations were scheduled. The facilitators proposed three primary modes of moisture damage to get the participants thinking:

- Chemical—bond/debond;
- Physical—rugosity, surface area, and absorption; and
- Mechanical—stone breaking and scrubbing, hydrostatic pressure.

The facilitators reminded the working group of its charge to accomplish the following tasks by the end of the day:

- Identify best practices.
- Identify gaps in knowledge and barriers to research and implementation.
- Identify research needs.
- Develop the strategic plan.

The following mechanisms and causes of moisture-related distress were identified by group brainstorming:

- Adhesive failure;
- Cohesive failure—asphalt weakens, aggregate dissolves;
- Binder aging—by oven, in-place over time, thermodynamic effects;
- Asphalt aggregate interface—changes over time, molecular reorientation;
- Binder stiffness—viscosity effect, use of modifiers;
- Trapped moisture in the pavement structure;
- Binder "film thickness";
- Asphalt emulsification—regular [asphalt cement (AC) in H_2O] and invert (H_2O in AC) (chemistry or mechanical working or both);

- Aggregate aging mechanisms? time frames from crushing to use in HMA? Highly siliceous aggregates may improve by aging;
- Lime aging—carbonation onto aggregate surface;
- Aging of moisture treatments in general;
- Salt in the binder—effects of sodium, calcium, potassium, and other mineral salts;
- Diffusion of moisture into asphalt binder;
- Mastic failure—sheds minus No. 200 and migrates;
- Filler (minus No. 200) issues;
- Clay and dust;
- Aggregate type/binder type—compatibility;
- Aggregate morphology—rugosity, shape, and so forth;
- Environmental effects—moisture, temperature, temperature differential, kinetics;
- Drainage—surface and subsurface;
- Water transport, including permeability;
- Mixture aging; and
- Modifier effects, including compatibility.

Issues identified during the discussion of each item listed above include the following:

- Multiple mechanisms: Moisture damage is often a result of multiple mechanisms rather than a single cause.
- Components versus system—Effects of incorporation into the mixture on component properties/behavior.
- Durability.
- False positives: Attributing problems to moisture damage that result from other causes, such as poor construction or durability issues. Can also apply to test results that indicate opposite result to that which occurs in service.
- Definitions.

Presentations and related discussions followed.

PRESENTATION 1

Ken Thomas, Western Research Institute

Ken reported on emulsion work at Western Research Institute (WRI) performed for FHWA, which addressed chemical effects of asphalt aging. When RTFO- or PAV-aged AC is dissolved in toluene and hand shaken with water, some asphalts form an emulsion and the pH of the water turns highly acidic. Aging AC at 80°C for 20 day ys changes sulfur components, increasing the concentration of alkyl sulfides. Ken reported a correlation of more than 90% between concentrations of sulfur/alkyl sulfide and strong acid in such asphalts, as detected by nonaqueous potentiometric titration. The sulfonic acids produced are organic analogs of sulfuric acid that attack and change the AC and dissolve aggregates.

Ken reported that the Strategic Highway Research Program asphalts and aggregates were tested for moisture resistance by coating a particular size fraction of each aggregate with 5% AC by weight. Researchers developed a matrix of selected materials treated with DBSA, a detergent compound containing sulfonic acid that lowers AC pH and acts as an emulsifier. DBSA reportedly artificially ages AC by adding sulfonic acid, which appears to promote moisture damage, owing to strong surfactant effects that are more pronounced than those of carboxylic acid. Lime may deactivate the acid by forming a nonionic compound, which might slightly offset the lime's effectiveness in resisting stripping. Ken suggested that on the basis of limited data at high acid concentrations, it may be the properties of aged AC that determine the moisture susceptibility of asphalt pavements.

PRESENTATION 2

Jack Youtcheff, FHWA, Turner–Fairbank Highway Research Center

Jack talked about work on permeability, solubility, water transport through an AC film, and the utility of the pneumatic pull-off test, which was developed on the basis of an adhesion coatings test apparatus. Test parameters were developed by Marek. The pull-off test starts by applying a thin (200-micron) film of AC mixed with 1% glass beads by volume (to act as spacers for load platen) to a smooth glass plate that is subsequently submerged in 25°C water. Cohesive failure occurs when both the plate and load platen remain coated. A series of tests was performed at varying soak times to develop a plot of pull-off strength (psi) versus soak time (hours). One straight run AC from Venezuelan crude was formulated with nine different modifiers to meet the same PG grade. Maltene content was evaluated. Typical plots of pull-off results showed a steep initial slope and then the strength leveled off. The binder modified with Elvaloy performed best in the pull-off test. The following conclusions were presented:

1. Stiffer binders have greater resistance to moisture damage due to decreased permeability, so oxidation tends to improve moisture sensitivity to a point. However, stiffening due to excessive aging may be detrimental to field performance.
2. Asphalts with high maltene concentration (stiffer, more viscous) are less sensitive to moisture damage. Asphalts that are high in asphaltenes appear more sensitive to moisture damage.
3. Mode of modification can affect moisture sensitivity.

Jack then discussed effects of lime and clay on asphalt moisture sensitivity. Montmorillonite clay was the worst tested; lime was no help. Lime is not a cure-all and is not always effective. He recommended use of the pull-off test to screen binders, but he cautioned that the findings are limited to the test conditions.

The group broke for lunch at noon and reconvened at 1:30 p.m.

PRESENTATION 3

Gayle King, Koch Pavement Solutions

Gayle talked about moisture damage to mastics and presented two conditions for such:

1. Binder being sensitive to moisture
2. Passing No. 200 material—"the hidden emulsifiers."

In mechanical stripping, the minus No. 200 particles on the surface are loosened, the mastic pumps up and comes apart, and the mixture matrix disintegrates. Mixes that fail in this manner reportedly often meet T283 requirements, but they fail in service and during Hamburg testing. Whether the fines are generated by pulverization of larger stones under the wheel or consist simply of the existing minus No. 200 is not well documented. Gayle cautioned against overpreparing specimens for moisture susceptibility testing. He recommended limiting cure time in the oven to 2 hours, possibly less if short hauls are anticipated. He pointed out the discrepancy with earlier advice to use aged asphalts for evaluating moisture sensitivity and stated that sulfonation is substantially offset by the stiffening effects of aging. He cited Hamburg definitions developed by Tim Aschenbrener of Colorado DOT during study of the Colorado "disintegrator" mixes. Modifiers can have good or bad effects, and Gayle believes that the Hamburg test can be used to distinguish between them. He reported that the Hamburg test shows whether clay is present very early in the test procedure. Sand equivalent is typically used to identify the presence of clay, but it does not characterize the plastic fines. The methylene blue test is considered quantitative because it identifies surface active fines and surface energy may also be used. Another screening test for AC binders is Branthaver's separatory funnel, in which the water that has been mixed with the AC settles out and its pH can be measured to determine acidity. He cited an incident in Oklahoma in which amines (antistrip) added to a phosphoric acid–treated AC binder reacted to form salts, which increased moisture sensitivity and caused the pavement to fail. Recommendations included the following:

- Confirm PG grade after amine addition.
- Use the separatory funnel test to check acidity.
- Minimize conditioning loose mixture samples before testing for moisture susceptibility.

PRESENTATION 4
Sundaram Logaraj, Akzo Nobel
Sundaram spoke about adhesion and active adhesion, and the effects of organic acids and bases. He defined active adhesion as coating and formation of chemical bonds in water. He presented a table excerpted from the *Shell Bitumen Industrial Handbook* (Shell Bitumen, Surrey, United Kingdom, 1995) that showed acid and base values in milligrams of potassium hydroxide (KOH) per gram for naphthenic and paraffinic asphalts. He stated that AC is generally weakly acidic and that siliceous aggregates may also have acidic surfaces. He recommended using tests that address both adhesion and cohesion, such as Lottman and wheel tracking, to evaluate potential for moisture damage.

MECHANISMS OF MOISTURE DAMAGE
Next, the facilitators referred the group back to the list of mechanisms and causes of moisture-related distress identified at the beginning of the breakout session. After considerable discussion, the group categorized these items with respect to the three primary modes of moisture damage that the facilitators had first presented, and then ranked the items within each category in order of importance.

1. Chemical
    - Bonding/debonding
    - Adhesive/cohesive
    - Asphalt or aggregate

Included are clay/dust/filler, mastic failure, salt in binder, aggregate aging, and molecular orientation over time.

2. Physical
   - Rugosity
   - Surface area
   - Absorption

Included are water transport and permeability, environment, aggregate morphology and absorptivity, diffusion of moisture, stiffening viscosity diffusivity, and stiffening aging.

3. Mechanical/construction
   - Stone breaking
   - Scrubbing

Included are density issues, drainage, film thickness, trapped moisture, and mechanical working, including cracking under compaction and hydrostatic pressure in service.

However, there were considerable overlap and interrelationships among these categories. With further discussion, the group decided that regardless of the mode of damage (chemical, physical, or mechanical), all of the items listed could also be classified according to the following three primary mechanisms of moisture damage that the group had identified earlier:

1. Emulsification—includes clay, dust, filler, salts in asphalt, hydrostatic pressure by mechanical working, and so forth.
2. Adhesive failure—includes aggregate morphology, absorptivity and aging, molecular orientation at interface, permeability, and so forth.
3. Cohesive failure—includes water absorption, molecular orientation, mastic, aggregate, and so forth.

Many participants felt that these three mechanisms provided a better frame of reference for addressing the pertinent issues. The next step was to proceed with the charge to identify existing best practices for addressing these mechanisms.

EXISTING BEST PRACTICES FOR TESTING AND SPECIFICATIONS

The following are the best practices identified by members in attendance:

- Use Hamburg test to screen HMA mixtures; it addresses all three moisture damage mechanisms, although may yield false negatives. There was considerable discussion about listing T283 here and some of the group felt strongly that it should be. Instead it is considered as an item that needs more research.
- Use aggregate screening tests:
  – Methylene blue (washed),
  – Hydrometer,
  – Soundness,
  – Sand equivalent (washed), and
  – Plasticity index.

- Verify PG grading of binder after additive addition.

EXISTING BEST PRACTICES FOR PREVENTION OF MOISTURE DAMAGE

The following are the best practices identified by members in attendance:

- Achieve adequate compaction/density during construction.
- Provide adequate drainage of the pavement structure.
- Avoid marginal material combinations.
- Have an appropriate mixture design, including additives (such as binder modifiers, fibers, or other fillers, lime, liquid antistrip), based on sound volumetric principles.
- Use quality control and quality assurance for mixture production, placement, and compaction, including sampling behind the paver.

The group decided to combine the charges to identify gaps in knowledge and needed research, and it included consideration of barriers to implementation.

RESEARCH TO ADDRESS GAPS AND BARRIERS

- Hamburg—optimize/standardize test methods for HMA mixtures
- Identifying new and existing test methods for research, including T283 and screening tests for components and systems
- Emulsification
  - Methylene blue—optimize/standardize test method for screening aggregates
  - Establishing aggregate testing protocol
  - Emulsifiability of asphalt
    - Standardizing separatory funnel test
    - Bitumatic (shake or mixing test)
    - Salts—APT, ICP

  Pessimum voids and pore pressure
- Adhesive failure
  - Developing and standardizing surface energy measurement method
  - Molecular orientation at asphalt aggregate interface
- Cohesive failure, bitumen or mastic
  - Heithaus
  - Pull-off
  - Water absorption and diffusion test
- Aggregate
  - ECS
  - ICP
  - Atomic absorption
  - Solubility and X-ray diffraction of solution

The final charge was to develop a strategic plan for addressing the issues and needs identified by the Fundamentals working group.

STRATEGIC PLAN

- Circulate the results of the seminar and breakout sessions for comments and suggestions.
- Establish technical working groups to address issues and research needs.
- Develop a new TRB synthesis pertaining to moisture damage of asphalt pavements.
- Identify or construct field sections for validation of research findings.
- Perform forensics on existing hot-mix asphalt mixtures and materials.
- Present research needs and problem statements to AASHTO.
- Conduct TRB or ASTM symposia on moisture damage of asphalt pavements.
- Do additional technology transfer through white papers and short courses.

The Fundamentals Breakout Session adjourned at about 5:00 p.m. The facilitators and note keeper stayed to prepare the required summary PowerPoint presentation for Thursday morning. Gaylon Baumgardner of Paragon Technical Services helped prepare the slides and his assistance was greatly appreciated.

BREAKOUT SESSION ON FUNDAMENTALS: ATTENDEES

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