Road Map for Mitigating National Moisture Sensitivity Concerns in Hot-Mix Pavements

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One of the charges of the seminar on moisture sensitivity was to develop an outline for a road map for addressing the national concern of moisture sensitivity. That road map is presented in this paper. Implementation of the findings, best practices, and research needs presented in the road map are expected to be discussed by various materials and research committees within the transportation community.

There cannot be a road map to address the national issues related to moisture sensitivity in hot-mix asphalt (HMA) pavements without a vision, a mission, goals, and associated work tasks. Members of the national seminar steering committee have developed the following descriptions for these items:

- Vision: Eliminate moisture sensitivity distresses in HMA pavements.
- Mission: Provide the necessary tools to practitioners that can be used to eliminate moisture sensitivity in HMA pavements.
- Tasks: Identify the best practices, gaps in knowledge, and research needs to address moisture sensitivity in HMA pavements.

NEED FOR A ROAD MAP

Moisture sensitivity in HMA pavements is one of the leading pavement performance–related issues facing highway agencies. Most agree that the current test protocols for identifying moisture-sensitive mixtures do not accurately predict field performance.

A survey dated August 2002 of the state highway agencies, the FHWA federal lands offices, and selected Canadian provinces indicated that 45 of the 55 agencies responding identified a moisture-related problem in their HMA pavements, and they specify some type of treatment to mitigate the problem. More than 50% use a liquid antistrip agent, 30% use lime, and the remainder use one or the other.

Forty-eight of the 55 agencies perform a test on the mix at some stage of the mix design and construction process to determine the need for an antistrip agent. The types of tests include indirect tensile tests (AASHTO T283, ASTM D4867), compressive strength tests (AASHTO T165), and wheel tracking in combination with the tensile test. Slightly more than 60% test for moisture damage during the mix design phase, while the remainder test during the mix design or construction phases of the project.

Though considerable work has been done over the past 50 years to solve the problem of moisture sensitivity in HMA pavements, there is still no agreement on a solution for mitigating the problem. As a result, the road map that is presented in this document is expected to provide direction to the pavement community in solving the moisture sensitivity problem.

ROAD MAP OBJECTIVE, GOALS, AND TASKS REMAINING

Objectives

The following are the objectives to be achieved with this road map:

- Identify existing best practices to mitigate moisture damage.
- Determine gaps in knowledge, both short and long term.
- Identify research needs in the following areas:
  - Fundamental material properties,
  - Testing and treatment procedures,
  - Design (pavement and mix) and specifications, and
  - Construction and field performance.
- Identify a process and timeline to accomplish these tasks.

Goals

The steps that have been used to accomplish these objectives include the following:

- Conduct a national seminar of leading experts to focus on the issue. The seminar was held in San Diego on February 4–6, 2003. The California Department of Transportation initiated the seminar to bring about a better understanding of how to deal with a moisture sensitivity issue (or problem) that had developed in northern parts of the state in the early 1990s.
- Present papers on various subjects to stimulate discussion on the important issues and their solution. Peer-reviewed papers were presented at the seminar.
- Develop reports on best practices, gaps in knowledge, and research needs in the following areas:
  - Fundamentals,
  - Testing and treatments,
  - Design and specifications, and
  - Construction and field performance.

A summary of the results of these reports is included in this road map.

Tasks Remaining

Tasks that remain to be completed include the following:

- Prioritize research needs
  - Short-term
  - Long-term
- Prepare research problem statements
- Identify funding sources
- Obtain funding and conduct the research

It is expected that the committees in the Bituminous Section of the Transportation Research Board will be able to prioritize the identified research needs and develop the appropriate research problem statements. In the meantime, it will be necessary to identify appropriate funding sources to accomplish the needed work.

MAJOR FINDINGS OF THE SEMINAR

The major findings from the seminar came partly from the papers and the subsequent discussion, but they were more fully developed in the breakout sessions. Findings are presented in terms of best practices, gaps in knowledge, and research needs.

Best Practices

For each of the breakout sessions, best practices were identified and summarized. Table 1 summarizes the best practices for the fundamentals breakout group. The best practices are presented in two broad categories: testing/specification and prevention. In terms of testing and specifications, the following were developed:

- Use test methods (as designed) to verify acceptable resistance to moisture damage.
- Use the Hamburg test to screen HMA mixtures because it addresses the major mechanisms of moisture damage. AASHTO T283 still needs work to quantify its relationship to field performance.
- Use improved aggregate tests to screen good from bad performers. These include tests such as the cleanness value to indicate the type of claylike materials clinging to the aggregate, the sand equivalent test to indicate the amount of claylike material on the fine aggregate, and the plasticity index or methylene blue tests to determine the sensitivity of clay to moisture. In addition, a wash and sieve analysis should be performed during design and construction, and natural sands should be limited in their use.
- Verify the effect of the liquid antistrip agent on the grading of the asphalt after it has been added and mixed.

In terms of prevention, the following good construction practices were identified:

- Treat mixtures as necessary to mitigate moisture damage when identified by mix testing.
- Achieve good compaction and provide adequate drainage.
- Avoid marginal material combinations.

TABLE 1 Summary of Best Practices: Fundamentals

TESTING AND SPECIFICATIONS	PREVENTION
• Use Hamburg device	• Achieve good density and drainage
• Include aggregate tests ○ Methylene blue ○ Hydrometer	• Avoid marginal materials
○ Soundness ○ Sand equivalent	• Include additives in mix design
• Grade binder after additives	• Practice good QC/QA, including sampling behind paver

- Use sound mix design practices, including volumetrics and additives in the mix design process.
- Practice good quality control/quality assurance (QC/QA) for mixture production, placement, and compaction.

Table 2 summarizes the best practices resulting from the breakout group on testing and treatments. They include the following areas:

- Testing: Three test procedures could be used to mitigate moisture damage. The tests included AASHTO T283, the Hamburg wheel-tracking test, and a loose mix test. However, issues such as sample preparation, repeatability and reproducibility, relationship to field performance, and the need for standardized test procedures were all expressed as concerns that need to be addressed.
- Treatments: Several items were identified as important:
  - Verify that the antistrip material is in the mix.
  - Identify any incompatibility between the binder and the additive.
  - Ensure that the additive was included in the mix design process.
  - Acceptance of the mix should be based on mix production data.

TABLE 2 Summary of Best Practices: Testing and Treatments

CURRENT TESTING PRACTICES	TREATMENTS	APPLICATION OF ANTISTRIP AGENTS
AASHTO T283	Mix design should include additives	Use dry lime on wet aggregate or add liquids to the binder at the job site
Hamburg wheel-tracking device	Test binder with additives	Accept on the basis of production data
Loose mix—consider screening tests such as static boiling, rolling bottle, or ultrasonic	Certification that correct product is used and of product quality	Use method specification for incorporating lime

- Incorporating additive into the mix: With respect to a method of adding lime, the use of dry lime on wet aggregate was identified as the best practice. Lime slurry is also good, but it costs more because of the additional handling of the materials. For liquid antistrip agents, the additive should be mixed with the asphalt on the construction site.

Table 3 summarizes the best practices identified by the group on design and specifications. They include the following:

- Materials issues: Use clean aggregates and improved aggregate tests to identify problem aggregates. Limit the natural sands to about 15% and use angular aggregates. Use additives such as lime or liquid antistrip agents to mitigate moisture damage problems.
- Mix design: It is essential that a test be performed on the mix to identify its potential for moisture damage, and the test should be performed as a part of the mix design process. The use of voids in the mineral aggregate in the mix design process is considered critical. All additives, including any baghouse fines, should be included in the mix design process.
- Structural design: Use of permeability to evaluate the compaction of the finished product is considered an important step to minimize moisture damage. Practice good drainage design in all pavements, both at the surface and in the underlying layers. Do not overlay open-graded mixes; they should be removed prior to an overlay.
- Construction specifications: Emphasis was placed on the use of clean aggregates. Tests such as the sand equivalent, plasticity index, or methylene blue can be used to identify dirty aggregates. Both modified binders and antistrip agents help reduce the potential for moisture damage. The use of good compaction, improved joint designs, and testing of plant-mixed products for moisture sensitivity are all good practices.

Table 4 summarizes the best practices identified by the construction and field performance group. They include the following:

- Training: Training of agency and contractor personnel should be a high priority in mitigating moisture damage.
- Materials handling: Aggregate moisture content and segregation from aggregate handling or from temperature variations need to be controlled.
- Production balance and control: If the hot-mix production is not in balance with the paving or the compaction equipment, it is difficult to achieve uniform mixes and uniform densities.
- Improved mat and joint density: If only this were accomplished, most of the moisture problems could be eliminated.
- Good surface and subsurface drainage: Emphasize the need to follow good practices to restore drainage during maintenance and rehabilitation operations.

TABLE 3 Summary of Best Practices: Design and Specifications

MIX DESIGN	STRUCTURAL DESIGN	SPECIFICATIONS
▪ Include moisture test ▪ Include volumetrics in mix design process ▪ Include all additives in design—replicate production process ▪ Use baghouse fines in design	▪ Permeability test ▪ Good drainage practices	▪ Material aggregates (baghouse fines, binders, etc.) ▪ Construction including joint density ▪ Verify presence of additives by mix verification moisture test

TABLE 4 Summary of Best Practices: Construction and Field Performance

TRAINING	MATERIAL HANDLING	UNIFORM MAT AND JOINT DENSITY
▪ Joint training with agency and contractor personnel ▪ Need to develop cooperative spirit in solving problems	▪ Control aggregate moisture content ▪ Minimize aggregate segregation ▪ Minimize temperature segregation	▪ Need for improved compaction ▪ Control permeability for mix ▪ Control drainage characteristics of mix

Gaps in Knowledge

A number of gaps in the knowledge were identified. The major gaps are summarized in Table 5. For example, the fundamentals group identified the following gaps in knowledge that need to be addressed:

- Standardize existing test procedures. Many test methods, including the Hamburg wheel-tracking device, do not have standard procedures. There is a need to optimize the procedure and then standardize it as an AASHTO/ASTM test procedure.
- Identify new test methods for mixes and screening tests for components.
- Develop tests to evaluate the emulsifiability of the asphalt binder.
- Develop a better understanding of the mechanisms of failure, including both adhesive and cohesive failures.

The group on testing and treatments identified the following gaps:

- Lack of criteria and procedures for calibration of test methods,
- Correlation of the test with a specific failure mode,
- Lack of well-documented field performance data,
- Need to verify that an additive is present, and

- Need to establish the compatibility of the additive with the binder.

All of these gaps are important if a test method is to be developed that correlates with field performance. At present, none of the test methods relate well to field performance.

The group on design and specifications identified the following gaps in knowledge:

- Laboratory tests that correlate with field performance,
- Identification of moisture damage in the field and the mechanisms causing the damage,
- Documentation of information on successful projects and the sharing of this information, and
- Diagnostic tools to identify moisture damage.

The group on construction and field performance identified the following gaps:

- Joint training with agency and contractor personnel to cope with personnel turnover.
- Timely test results: Lack of continuous test results means lapses in process control.
- Coping with complex project logistics: Some contractors are good at this and others are not.
- Achieving good density continuously in the mat and at the joints. It is important to achieve density in a cost-effective manner.
- Equipment constraints: These can contribute to project delays, change orders, and overruns due to rejected work.
- Project control by funding: The practice of downsizing a project in final design or after it goes to construction is a recipe for disaster.

Research Needs

The last item solicited from the breakout sessions was the identification of research needs. Table 6 summarizes the needs identified by the various groups. As can be seen, there is redundancy in the recommended research needs. Although needs were identified, research needs statements were not developed. This task remains to be completed by research and materials committees in the transportation community.

GENERAL DISCUSSION OF THE ROAD MAP

The findings from the breakout session suggested that the following items be included as part of the road map:

- Develop a presentation for the AASHTO Subcommittee on Materials on the findings from the seminar.
- Circulate the proceedings of the seminar for comments and suggestions.
- Establish technical working groups to address research needs and develop problem statements.
- Initiate an NCHRP synthesis on moisture sensitivity as soon as possible. The last one was done in the early 1990s.
- Conduct a follow-up TRB/ASTM symposium on moisture sensitivity.

- Provide additional technology transfer or training on the subject. This could include
  - Basic materials understanding,
  - Self-directed training, and
  - Virtual training.
- Develop guidelines for preconstruction partnering that would include
  - Roles defined,

TABLE 5 Gaps in Knowledge

<table>
<tr><td>FUNDAMENTALS</td><td>• Standardization of Hamburg device
• Testing protocol for aggregates
• Need to identify emulsifiability of binder
• Need to understand the mechanisms for adhesion and cohesive failures
• Aggregate properties that contribute to failure mechanisms</td></tr>
<tr><td>TESTING AND TREATMENTS</td><td>• Testing
– AASHTO T283
– Update precision and bias
– Specimen preparation-compaction and degree of saturation
– Air void determination
– Calibrate for local conditions
– Need for repeated load
– Porosity/permeability
– Standardization and certification
– Hamburg device
▪ No standard procedure
• Test conditions for environment and mixture
• Sample preparation and compaction
▪ Equipment improvements
▪ No precision and bias
– Loose mix
▪ Criteria/protocols for local calibration
▪ Data collection that relates to field performance
• Treatments
– Verify quantity of additive in mixture
– Field performance of various additives over time
– Compatibility of additives with bitumen, polymers, and so forth</td></tr>
<tr><td>DESIGN AND SPECIFICATIONS</td><td>• Develop tests that correlate to field performance
• Identify the real failure mechanisms
• Document field performance</td></tr>
<tr><td>CONSTRUCTION AND FIELD PERFORMANCE</td><td>• Need for training
• Time lag of process control/lack of continuous test results
• Complexity of project logistics
• Inaccurate density measurements
• Equipment constraints
• Project control by funding</td></tr>
</table>

TABLE 6 Research Needs

FUNDAMENTALS

- Standardize Hamburg device and test method.
- Identify needed test methods for mixes and for components.
- Develop tests to identify the emulsifiability of a binder.
- Adhesion failures: Evaluate surface energy measurement method and molecular orientation at the asphalt–aggregate interface.
- Cohesive failures—for both the bitumen and mastic. This could include an evaluation of the Hiethaus procedure, pull-off tests, and water absorption and diffusion tests.
- Develop improved aggregate tests such as the environmental conditioning system (ECS) or inductively coupled plasma procedures to evaluate solubility.

TESTING AND TREATMENTS

- Testing
  - Develop fundamental property tests
  - Evaluate effects of long-term aging on moisture susceptibility of mixes
  - Develop a rapid QC test
  - Complete the ECS research initiated under SHRP
    - Dynamic modulus/fundamental properties
    - Traffic impacts on pore pressure
    - pH of water
- Treatments
  - Develop a field test to determine uniform distribution of additive to mix
  - Document field performance of additives over time
  - Evaluate aging of aggregates in the stockpile
  - Evaluate the potential of placing the lime directly into the bitumen
  - Evaluate whether there is diminished performance with the various treatments over time

DESIGN AND SPECIFICATIONS

- Develop diagnostic tools for identifying moisture damage
  - Standardization of terms
  - Evaluation techniques
  - Testing data format
  - Forensic procedures
- Evaluate long-term effects of treatments on aging, moisture, and pavement performance
- Evaluate the side effects of additive use on mix properties (fatigue, rutting, and the like)
- Develop a synthesis of test procedures
  - What mechanisms are measured per test?
  - Variations used for each test
  - Pros and cons of each test
  - Standardization of terms

CONSTRUCTION AND FIELD PERFORMANCE

- Develop continuous density/stiffness measurement equipment.
- Develop real-time automated plant control and automated paver control/feedback.
- Evaluate the effects of temperature on adhesion.
- Develop a relationship between permeability and performance.

  - Responsibility assigned, and
  - Authority delegated.
- Develop improved mixture and construction guides for mitigating moisture sensitivity problems in the following areas:
  - Identification/mitigation of moisture-sensitive mixes
    - Laboratory testing
    - Correct treatment to address the problem
  - Minimization of segregation
    - Implementation of standard definition of segregation (NCHRP)
    - Development of an accurate measurement tool
    - Development of incentive/disincentive payments standards
  - Implement best practices in construction
    - Submit and implement a productivity plan
    - Optimize joint density
    - Use accurate density measurement tools
    - Use improved incentive/disincentive payments for density
- Construct field sections for validation of any new theories.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Conclusions of the authors of this paper from the seminar are summarized briefly below; details are discussed in the text of the paper.

- Current test methods for assessing moisture susceptibility of HMA mixes do not relate well to documented field performance and are not standardized.
- The industry does not currently have a clear understanding of the fundamental mechanisms that affect moisture damage in HMA.
- There is a deficiency of well-documented field performance data for pavements that experience moisture damage.
- Training of agency and contractor personnel is essential and should be given high priority. It is felt that many of the moisture-related problems could be eliminated through understanding of good construction practices.
- Current construction specifications should be enforced or modified (and enforced) to ensure adequate mat and joint density. If only this were accomplished, moisture-related problems in HMA would likely be greatly reduced.
- Proper surface and subsurface drainage practices need to be implemented during pavement construction, rehabilitation, and maintenance operations.
- Significant research needs were identified. Needs statements should be prepared by research and materials committees and submitted to appropriate agencies.

Recommendations

Following are the authors' recommendations resulting from the seminar:

- Present the findings of this seminar to the AASHTO Subcommittee on Materials at its August 2003 meeting and request its support in initiating and promoting research needs related to moisture susceptibility in HMA.
- Prioritize a list of research needs and develop an accompanying estimated budget and timeline.
- Initiate development of an NCHRP synthesis on moisture susceptibility of HMA paving mixtures.
- Develop improved guidelines for identifying moisture-sensitive mixes as well as for mixture design and construction to mitigate moisture sensitivity problems.
- Set a realistic timetable to accomplish the items identified above.
- Conduct a follow-up symposium on moisture susceptibility in HMA pavements at a future TRB-, ASTM-, or AASHTO-sponsored event.

RESOURCES

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