Effects of Hot Plant Fuel Characteristics and Combustion on Asphalt Concrete Quality
SD2001-13
Final Progress Report

Overview

This research was initiated to investigate the effects of differing fuel types and combustion conditions on hot mix asphalt. In early October 2001, eleven fuels were used to fire a plant under optimum, insufficient oxygen and excess oxygen conditions. Samples of heated aggregates, mixtures and raw materials (fuels, binder and aggregates) were obtained and transported to Purdue University at West Lafayette, Indiana, for testing.

The heated aggregate and hot mix asphalt (HMA) samples for this project were produced during the week of October 5, 2003. The HMA samples were produced with the hot mix plant of W. Hodgman and Sons. The HMA plant was setup in the Fisher Sand and Gravel quarry South of Mitchell, SD. Brian Prigge, with Electromatics, was hired to do determine when the HMA plant damper was set to produce combustion conditions of excess oxygen, optimum, and insufficient oxygen.

Task Report

The following summarizes the status of the research task by task.

1. Meet with project's technical panel to review project scope and work plan.

Dr. John Haddock and Rebecca McDaniel met with the technical panel in Pierre, SD, on November 15, 2001. This task is 100% complete.

2. Review previous and ongoing research, conduct a survey of other states' experiences and present findings to the technical panel.

A literature review was conducted during the proposal development phase of this project. The literature review is 100% complete. Survey responses have been received from about 30 states, two industry representatives and one academic laboratory. This task is 100% complete.

3. Evaluate the current practices used by the HMA plant manufacturers to determine combustion efficiency, and recommend methods for use in tasks 4 and 5.

Contacts were made with technical representatives from Astec, Cedarapids and Hauck. Results were reported in the May 14th status report. The NAPA report also has good information on burners and operating conditions as well. Sources for exhaust gas monitors have been identified. The exhaust gas data and variations in the gases for various fuel-burner combinations have been reviewed. This data has also been discussed with Mr. T. J. Young, as recommended by the SDDOT. The analysis and Mr. Young's suggestions are currently being summarized for the final report. This task is 100% complete.

4. Using solvent extraction or other appropriate methods, determine the combustion residue content on aggregates heated in an operating HMA plant under conditions of insufficient, optimum and excess oxygen. The aggregates will be heated with no asphalt cement added and fired with propane (if feasible, to establish base line combustion conditions), No. 2, No. 5L, No. 5H, No. 6, (as defined by ASTM D-396) and recycled motor oils RFO4, RFO5L and RFO5H (as defined by ASTM D-6448) and a minimum of four samples of non-specification waste motor oil, which will be identified by the technical panel. Test non-specification waste motor oil to determine deleterious ingredients and quantities.

All aggregates heated under insufficient oxygen conditions plus the No. 2 and No. 6 fuels at excess and optimum conditions were analyzed gravimetrically to determine the percent residue. The soluble organic residue, insoluble organic content and inorganic carbon contents were also determined. As requested by the SDDOT, additional gravimetric analyses are being performed to test the assumption that insufficient oxygen conditions are the worst case. The exhaust gas data was analyzed to suggest which additional fuels to evaluate and Mr. Young was contacted for his recommendations. The decision was ultimately made to test three additional fuels at excess oxygen conditions, the No. 5H, RFO5L and Non-spec #4. Samples have been provided to Heritage Research Group and testing is underway. Results are expected by mid-October.

Standard fuel quality tests were performed on all 11 fuels. Results were summarized in the May 14th status report. This task is 100% complete.

5. Using Gel Permeation Chromatography or other appropriate tests for molecular weight distribution as well as chemical testing for trace elements, test asphalt cement before it is combined with aggregates and when it is extracted from asphalt concrete produced from an operating HMA plant. The plant is to be fired with propane (if feasible), No. 5L, No. 5H, No. 6, (as defined by ASTM D-396) and recycled motor oils RFO4, RFO5L and RFO5H (as defined by ASTM D-6448) and a minimum of four samples of non-specification waste motor oil, which will be identified by the technical panel. Extracted asphalt cement will be obtained for each of the fuels at combustion conditions of insufficient, optimum and excess oxygen.

Chromatographic analysis techniques including gas chromatography with flame ionization device (GC FID) and GC with mass spectrometer (GC MS), plus FTIR analysis were used to examine the residue washed from the heated aggregates as well as binder extracted from the hot mix. These efforts concentrated on the No. 2 fuel at optimum and No. 6 at insufficient oxygen conditions. The results were summarized in the May 14th status report. More detailed information is being prepared for the draft final report.

As requested by the SDDOT, arrangements were made to test residue from aggregates heated with the No. 2 at optimum conditions and the No. 6 at insufficient oxygen conditions using gel permeation chromatography to determine if that test method is better able to detect and/or identify any contaminant from the fuel. Ray Robertson at Western Research Institute has agreed to do the testing under their contract with FHWA. Robertson indicates that the GC MS that Heritage performed is extremely sensitive for materials with up to about 30 Carbon atoms in the molecular chain. The GC FID, he indicates, gives better resolution than GPC. Robertson will run GPC, which may be able to detect larger chain molecules, if present, but may not be able to identify what it is. Robertson will also run the No. 2 and No. 6 fuels to see if he can detect their presence in the residue. Results of the GPC testing are expected in mid-October.

This task is 100% complete.

6. Evaluate asphalt concrete produced from the fuel combustion conditions of insufficient, optimum and excess oxygen using wheel rutting tests, Tensile Shear Rheometer with freeze thaw, film thickness, Marshall stability, Marshall mix parameters, or other tests as appropriate to determine what impact fuels and combustion residue have on physical and chemical properties of in-place asphalt concrete.

A proposed testing plan was presented in the May 14th status report and revised based on a conference call with the South Dakota DOT to include AASHTO T283 testing. The testing plan calls for Superpave shear testing (SST) (repeated shear at constant height) of the No. 2 fuel at optimum conditions and all other fuels at insufficient oxygen conditions.

All samples are prepared for testing and testing has been completed. The SST testing was originally delayed until calibration had been completed to ensure the accuracy of the tests. Since calibration was completed in June, the SST has been experiencing extreme and uncontrollable temperature fluctuations that make testing almost impossible. Repeated efforts to work with the SST and controller manufacturers were largely unsuccessful. The controller was replaced and similar problems occurred. The controller was then returned to its manufacturer for diagnostics and no problems were found. Finally the computer and controller were returned to Interlaken (the SST manufacturer) for diagnostics. They believe they identified and repaired a problem with the arc suppressors. Larger external arc suppressors were placed in front of the controller that they say will solve the problem. The computer and controller have been shipped back and the SST is expected to be operational again by September 25. After shakedown testing, the SST testing for this project can begin in earnest. This problem with the SST has put us about three months behind schedule on completing this testing. Sample preparation is the most time consuming part of this testing, and that is essentially complete now, but the delay in testing still impacts the final completion schedule. If the machine is in fact fixed, approximately 30-40 days of testing remains to complete the SST work.

Loaded wheel testing is in progress on the samples of mixture produced with No. 2 fuel at optimum and No. 6 at insufficient oxygen conditions to determine if these tests are sensitive to any differences in the mixtures. Samples have been prepared for dynamic modulus testing of the same two mixes and testing will be completed by the end September. The dynamic modulus devise is very new, and it took some time to do the shakedown testing and develop the skill to run the test properly.

In the May conference call, the research team agreed to conduct AASHTO T283 testing on the No. 2 at optimum and No. 6 at insufficient oxygen conditions. This testing has been completed for the mixes produced under those conditions. The testing on both the No. 2 and No. 6 fuels showed a tensile strength ratio in excess of 90%.

The gyratory compaction data for the No. 2 and No. 6 fuels at all burner conditions was analyzed to determine if the early compaction data (small numbers of gyrations) indicated any mixture differences. Tender mixes sometimes show rapid compaction in only a few gyrations (high $\%G_{mm}$ at low gyrations). The compaction data for the two fuels at all the burner conditions is virtually identical in every case.

This task is 100% complete. The significant problems with the SST created the need to extend the contract.

7. Evaluate asphalt cement extracted from the same sample lots to determine what affects the different fuels and combustion conditions have on ductility, viscosity, penetration and other significant physical properties of the asphalt cement.

The May 14th plan calls for high temperature dynamic shear rheometer testing of the extracted/recovered binder. The extraction of binder from the mixes produced with the No. 2 fuel at optimum and the other fuels at insufficient oxygen conditions were completed this quarter, as was the binder testing.

This task is 100% complete. Data analysis is nearly complete. No significant differences in the test results have been noted so far.

8. Based on analysis of test results determine what implications, with respect to pavement performance and life cycle costs, that the different fuels and combustion conditions have on asphalt concrete.

This task is 90% complete

9. Develop specifications for fuels and combustion conditions that will ensure production of acceptable asphalt concrete.

This task is not scheduled to begin until the majority of the test results are available for analysis. Information gathered during the earlier tasks, including task 2, will be used in the development of specifications. We have been giving thought to and searching the literature for potential specifications. Again, this task will be relatively easy to complete once all of the data is available and we see what the potential problems with contamination may be. This task is 90% complete.

10. Determine test method(s) and frequency of tests necessary for field personnel to easily determine when HMA combustion conditions are in compliance with the recommended specifications.

Again, this task is not scheduled to begin until the majority of the test results are available for analysis. Some ideas have been generated based on information gathered during the earlier tasks, including task 2, such as the use of exhaust gas monitors. The researchers are fully aware of the importance of this task and the two preceding tasks, but it is still too early to define the products of these tasks. We are experimenting with a simple boiling water test to see if an oily film can be detected when contamination is present. We are testing plant materials (aggregates and mix) heated with the No. 2 at optimum and No. 6 at insufficient. We are comparing these to unheated aggregate as a control and laboratory doped specimens to ensure there is contamination with fuel (though admittedly not combustion by-products). This task is 85% complete.

11. Prepare a final report and executive summary of the research methodology, findings, conclusions and recommendations.

SDDOT has received the draft copy of the final report. The report needs to be refined and the final results tasks 8, 9, and 10 need to be incorporated into the final report.

12. Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

The executive presentation was completed in February, 2003.