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Effects of Hot Plant Fuel Characteristics and Combustion on Asphalt Concrete Quality

Study SD2001-13
Executive Summary

Purdue University
School of Civil Engineering
West Lafayette, Indiana 47907

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DISCLAIMER

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This work was performed under the supervision of the SD2001-13 Technical Panel:

Mike Carlson .... Belle Fourche Area
Tom Grannes .... Materials and Surfacing
Tom Harman .... FHWA
Brett Hestdalen .... FHWA
Jason Humphrey .... Specification Engineer
Dan Johnston .... Research
Bruce Morgenstern1 .... Wyoming DOT
Paul Oien .... Research
Michael Remily .... Oregon DOT
Greg Rothschadl .... Yankton Area
Noel Schulz .... Jebro, Inc.
Ken Swedeen .... DAPA
Dan Thompson .... Border States Paving

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16. Abstract

This report summarizes the results of an extensive and comprehensive study to evaluate the possibility of contaminating hot mix asphalt due to the use of alternate fuel types and through poor combustion of the fuel. Eleven different fuels were used, and the plant burner was adjusted to optimum, insufficient oxygen and excess oxygen conditions.

Samples of aggregates and of hot mix produced under these combinations of fuel and combustion conditions were collected and tested using a variety of chemical and physical tests. Gravimetric analysis of the heated aggregates did reveal the presence of minute traces of residue at less than 35 ppb by weight of aggregate. This residue was then analyzed using gas chromatography and FTIR, and was shown to be composed of partially decomposed tars and fuel residues. The dynamic shear rheometer, bending beam rheometer and direct tension tests were used to assess whether the residue caused any changes in binder properties; none were detected. Samples of the hot mix produced in the plant were evaluated using gyratory compaction parameters, Superpave shear tests, dynamic modulus, loaded wheel and moisture sensitivity tests. Again, no significant changes in mix properties were observed.

Based on these findings, it was recommended that SDDOT expand the list of allowable fuels to include recycled fuel oils and fuels up to No. 6, allowing the use of economical alternates. No. 6 fuel should be evaluated in pilot field projects for possible inclusion in future specifications. Other specification changes and inspection techniques to ensure combustion adequacy and mix performance were recommended.

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EXECUTIVE SUMMARY

This report outlines the research approach and findings from a thorough and systematic examination of the possibility of hot mix contamination due to the use of various fuel types and varying burner conditions in a hot mix asphalt plant. This is the most complete examination of the potential for mix contamination to date. The study differs from some previous studies because the burner was deliberately misfired (fired with excess and insufficient oxygen) in order to evaluate what might happen if a hot mix plant is operated outside the normal ranges. This allowed looking at the "worst case" scenario to an extent never attempted before.

The study was conceived of and initiated by the South Dakota Department of Transportation in 2001. The research was conducted by Purdue University and the North Central Superpave Center in West Lafayette, Indiana, with the assistance of Heritage Research Group in Indianapolis and Western Research Institute in Laramie, Wyoming.

The study involved evaluation of the chemical and physical properties of a single hot mix asphalt produced in one hot mix plant using 11 different burner fuels and operating under three different burner conditions. The research approach and findings are summarized here.

Problem Description

Environmental and economic concerns have lead to many changes in the hot mix asphalt (HMA) industry over the past few decades. Beginning in the late 1960's, growing environmental concerns helped to encourage the use of pollution control devices (bag houses being among the most popular) and new plant designs (such as drum dryers) to reduce emissions from asphalt plants.

In recent years, high energy costs have prompted many contractors to investigate the possibilities of replacing their traditional fuel supplies with less expensive options, including recycled fuel oils. South Dakota reportedly started to allow the use of No. 5 grade fuels in about 1997. Prior to that they had used No. 2 fuel. Requests to use other grades of fuel increased after the requirement was initially loosened.

While there have been a few research projects evaluating the effects of plant type and burner fuel on emissions, binder properties and mixture properties, there has not been a definitive study establishing the effects of fuel type and burner efficiency. The research reported here addresses the need for a thorough and systematic evaluation of differing burner fuel types under varying combustion conditions to determine if there is any effect on binder or mixture properties and any resulting impact on pavement life and performance.

The question was addressed by producing asphalt concrete in one hot mix plant using 11 different burner fuels at three combustion conditions over a five-day period from October 1 to 5, 2001. The heated aggregates, asphalt binders and asphalt mixtures produced under these conditions were tested in a wide variety of ways to detect the presence of any contaminant and to assess the performance impacts due to that contamination. The underlying hypothesis tested in this project is whether the materials produced with different burner fuels and combustion conditions are the same or whether the fuel-burner combination changes the materials in some way.

Contamination of the hot mix could lead to a variety of problems, depending on the nature and amount of contaminant, as discussed in Findings and Conclusions section. Unburned fuel could soften the binder and mix, which could in turn lead to instability, rutting, tenderness and asphalt drain down. Char, ash or other combustion byproducts could lead to stripping, excessive aging, stiffening of the binder and mix, or increased cracking.

While there have been some studies in the past evaluating the effects of different plant types and fuels on hot mix asphalt properties, this appears to be the first time the burner was deliberately misfired to evaluate the effects of excess or insufficient oxygen. A qualified burner technician was hired by the South Dakota Department of Transportation (SDDOT) to guide the plant operations and adjust the damper and pressure to produce optimum, insufficient oxygen and excess oxygen conditions. For each burner fuel-combustion condition combination, bare aggregates were heated in the plant (without the addition of asphalt binder) and hot mix was produced (with the addition of asphalt binder). Samples of the heated aggregates and hot mix were collected and stored in sealed cans for later testing. Some samples of the plant-produced hot mix were compacted in the plant laboratory in a Superpave Gyratory Compactor for later mixture testing. This was done to avoid the need to reheat the mixture before compacting, which could possibly change the mix properties. These samples were stored in sealed plastic bags. Retained samples of the fuels, asphalt binder, and mixtures were tested using a variety of physical and chemical analysis techniques to examine whether any contamination of the materials had occurred during production.

The tests included:

- Standard fuel quality tests for flash point, water content and solids content.
- Analysis of the residue extracted from heated aggregates to determine their nature, chemical composition and possible effects on binder and mix using gravimetric analysis (weight of residue), chromatography and binder testing of laboratory-contaminated specimens. Attempts were also made to analyze extracted asphalt binder using chromatography to detect the presence of any contaminant.
- Binder testing of recovered binders from plant produced mix using the 11 different burner fuels. The dynamic shear rheometer was used to assess high temperature stiffness and the bending beam rheometer and direct tension test were used to analyze low temperature cracking behavior of the binder; contamination could affect either stiffness or cracking resistance depending on the nature of the contaminant.
- Mixture testing of plant-produced mixes. The Superpave Shear tester was used to perform Frequency Sweep, Simple Shear and Repeated Shear at Constant Height testing on gyratory compacted specimens. These three tests involve different types of shear loading at specified frequencies and stresses. They essentially measure the stiffness of the mix and its resistance to rutting, which could be affected by mix contamination. The dynamic modulus test, which is another stiffness test under axial compressive loading rather than shear, was also performed. This test is one of the candidate Superpave performance tests under development by Dr. Matt Witczak and will be the basis for pavement structural design under the *Mechanistic-Empirical Pavement Design Guide*. Mixes were also analyzed for resistance to stripping, resistance to rutting in a loaded wheel test and compaction characteristics, which could all be influenced by contamination.

Objectives

The research objectives were to:

- Determine the effects of fuel type, fuel quality and combustion conditions on the physical and chemical properties of asphalt concrete produced in Hot Mix Asphalt (HMA) plant.
- Assess the potential effects of the physical and chemical properties induced by fuel type, fuel quality and combustion conditions on field performance and constructability of asphalt concrete.
- Recommend specifications for fuel type, fuel quality and combustion conditions that ensure acceptable asphalt concrete performance.
- Develop or recommend test methods that field personnel can easily use to ensure compliance with the recommended specifications.

Findings and Conclusions

The results of this research effort indicate the following specific findings:

- A survey of state practices showed that few states control the types of fuel that are burned in hot mix plants within their jurisdictions. Some states limit the fuel types, particularly disallowing waste fuels; others have indirect limits through emissions testing.
- Most states have not observed apparent mix contamination problems. Those that have observed occasional problems identified particular problem fuels or plants. Due to the relatively rare occurrence of contamination problems, there has been little research on the topic.
- Industry representatives also reported few instances of contamination. They identified ways to determine if the plant is properly firing and what might signal plant problems.
- Gravimetric analysis of aggregates heated in the plant without the addition of asphalt binder did detect the presence of a minute amount of residue from aggregates heated with the No. 6 fuel at insufficient oxygen conditions and even smaller amounts of residue from the other fuels.
- Chromatographic and FTIR analysis of the residue identified it as a high molecular weight material representative of partially decomposed tars and fuel residues. The residue concentration was found to be less than 35 parts per billion by weight of the aggregate.
- Extracted binders from the plant produced hot mix were analyzed using a variety of binder tests. Neither dynamic shear rheometer testing at high temperatures, nor bending beam rheometer and direct tension testing at low temperatures detected any effect of the residue.
- Binder samples deliberately contaminated with the residue from the heated aggregates were tested in the DSR and no changes in the binder properties were detected.
- Samples of the hot mix asphalt produced in the hot mix plant with different fuels under differing burner conditions were tested in a variety of ways, including Superpave shear tests, dynamic modulus, gyratory compaction parameters, stripping susceptibility and loaded wheel testing. No significant differences were noted in any of the mixture tests, adding more compelling evidence that no detrimental contamination occurred.
- Based on the chemical and physical tests conducted in this research, no performance differences would be expected due to the use of different fuel types or varying combustion conditions.

- Initial cost savings are possible through allowing the use of alternate fuels. The actual savings is highly dependent on fuel prices and availability, but could be in the range of one to two dollars per ton of hot mix.
- Specification changes were recommended to allow use of alternate fuel types and grades while still maintaining the quality of the hot mix and asphalt concrete pavements.
- Simple methods to ensure proper atomization and combustion of burner fuels and proper plant operations were suggested. A monitoring period at start up when fuels heavier than No. 2 are used was recommended. If problems are observed and are persistent, exhaust gas analysis should be required to continue using that particular fuel at that particular plant.
- The results of this research strongly suggest that mixture contamination is not a likely occurrence if burner fuels are properly preheated and the plant is operating reasonably well. This should give the DOT and industry confidence to use alternate fuels while implementing simple controls and checks to ascertain that the burner and plant are operating properly.

In light of these findings, the following specific recommendations are made.

- This research shows that SDDOT should relax its specifications regarding allowable fuel types to include fuels through No. 5 (L and H) and reprocessed fuel oils.
- Waste fuel oils should not be allowed.
- This research shows no detrimental effect of No. 6 fuel despite the observed discoloration of aggregates heated with that fuel. SDDOT should allow the use of No. 6 fuel on pilot projects and evaluate its performance to determine if it is reasonable to allow the widespread use of this fuel in the future.
- This research clearly shows no negative impact of using the alternate fuels, so elaborate and expensive test or monitoring procedures are not recommended for routine implementation.

The research findings support a staged implementation process including the following steps:

- Providing training to plant and field personnel to recognize signs of potential burner problems.
- Checking fuel viscosity for fuels heavier than No. 2.
- Implementing a monitoring period at start-up with a heavy fuel.
- Requiring flame eyes or combustion gas monitoring only for problem cases (plants or fuel types).
- Re-evaluating the changes after implementation.

As an overall summary, then, of the major findings of this study related to the primary objectives of the work:

- The fuel type, quality and burner combustion conditions evaluated in this study were found to have no detrimental effects on the physical or chemical properties of the hot mix produced.
- There was no evidence of any effects of fuel type, quality or combustion conditions on HMA performance or combustion.

- Based on the research testing results, supplemented with information from other states and industry, recommended specification changes were developed.
- Training and monitoring procedures were recommended for field and plant personnel to ensure adequate combustion is achieved.

Implementation Recommendations

The results of this research clearly show that hot mix asphalt contamination is unlikely to occur in a plant operating within normal parameters and is even unlikely if the plant is somewhat outside normal parameters. This does not mean that any and all fuels should be used or that it is not necessary to exercise care in operating a plant properly. Contamination could still result if fuels are not properly preheated, if the atomizer and other parts of the burner or exhaust system malfunction, or if other problems exist. It does show, however, that under reasonably normal conditions, contamination is not likely to be a problem and pavement performance will not be compromised.

Based on these findings, wholesale changes in the specifications and test procedures are not recommended, but relaxing of the specifications to allow more fuel types is possible. The use of alternate fuels, including recycled fuel oils and No. 5L and 5H fuels, may allow contractors to use an economical fuel with high BTU's without sacrificing hot mix or asphalt pavement performance. The use of No. 6 fuel may also be feasible, but should be evaluated further through pilot projects before implementing. Simple changes in the specifications and monitoring procedures are recommended for consideration by the DOT. Following changes in the specifications, the SDDOT should review hot mix production for at least one construction season to observe the effects of the specification changes. Based on this review, the specifications and monitoring procedures can be relaxed, strengthened or allowed to stand accordingly.