Influence OF Aggregate Source On The Properties Off WMA Mixturers In South Dakota

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Introduction

The Study

In 2008, the South Dakota Department of Transportation initiated an extensive study to evaluate various types of warm-mix technologies relative to HMA mixtures in attempt to determine their suitability for use in South Dakota. The study included multiple aggregate sources commonly used in asphalt paving in South Dakota to assess whether the performance of the WMA mixtures is aggregate dependent.

This study evaluated the impact of three aggregate sources (Limestone, Quartzite and Natural Gravel) and three different WMA processes (Advera, Evotherm, and plant Foaming) on the properties of asphalt mixtures from South Dakota.

What is WMA?
What are its advantages?

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- Worm Mix Asphalt (WMA) is produced at temperatures that are 30 to 100F lower than those that is used for making HMA.
- Because WMA is produced at a lower temperature than HMA, a primary benefit to using WMA is a reduction in fuel consumption when compared to the amount of energy needed to heat traditionalHMA.
- Lowered temperatures during asphalt production allow for reduced emissions at the plant and around the paving site, but the resultant decreased fuel usage would also have the potential to reduce the construction costs for asphalt paving projects.
- WMA lowers the viscosity of asphalt concrete. By lowering the viscosity, several resultant benefits might include better compaction, slower cooling rates, reduced mixture aging and more options for maintenance activities in colder weather like patching.
- These conditions may result in better capabilities to pave and compact at cooler temperatures, and thus provide more options for paving operations during less than ideal weather conditions.

Methodology

- **Materials**

A total of three aggregate sources with different mineralogy from South Dakota were evaluated: Quartzite, Limestone, and Natural Gravel. The aggregate water absorptions for the Quartzite, Limestone and Natural Gravel were found to be 0.45, 0.21 and 0.91%, respectively.

All aggregates were mixed with the same PG64-28 asphalt binder commonly used in South Dakota.

Limestone

Gravel

Quartzite

Mix designs

- A total of four mix designs were established for each aggregate source; one for the control HMA and three for the WMA mixtures.
- For each aggregate source, a conventional HMA mixture was designed to be the control mixture. WMA mix designs were based on the current SDDOT gyratory controlled QC/QA mix design requirements and specifications for hot asphalt mixtures and the WMA mix design procedure proposed by the NCHRP Project 9-43, Mix Design Practices for Warm Mix Asphalts.
- As recommended by NCHRP Project 9-43, the aging index of the used binder was used to indicate the minimum mixing and compaction temperatures for the WMA mixtures without increasing the performance grade of the used asphalt binder.

Mix designs

- All three aggregate sources resulted in asphalt mixtures with different design binder contents.
- In summary, by following NCHRP 9-43 guidelines, a satisfactory mix design that meets SDDOT specifications for Superpave mixes was achieved for the various WMA mixtures and aggregate sources

Laboratory Performance Evaluation

The laboratory evaluations that were conducted in this research effort:

- Moisture Damage: Indirect tensile strength (ITS) and tensile strength ratio (TSR) in accordance with AASHTO T283.
- Mechanical Property, E*: Dynamic Modulus Master Curve in accordance with AASHTO TP79.
- Rutting: Asphalt Pavement Analyzer (APA) and Flow Number (FN) in accordance with AASHTO T340 and T79, respectively.
- Fatigue Cracking: Flexural Beam Fatigue in accordance with AASHTO T321

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TSR test basically compares the indirect tensile strength test results of a dry sample and a sample exposed to water/freezing/thawing.

ITS The indirect tensile test applies a constant rate of vertical deformation until failure.

Stiffness tests are used to determine a HMA’s elastic or resilient modulus.

The thermal cracking test determines the tensile strength and temperature at fracture of an HMA sample by measuring the tensile load in a specimen which is cooled at a constant rate while being restrained from contraction. The test is terminated when the sample fails by cracking.

Resistance of Asphalt Mixtures to Moisture Damage

As can be seen from the figure-c, the WMA mixtures exhibited lower ITS values than those obtained for HMA and HMA-2hrs STA mixtures. Mixtures prepared using Quartzite aggregate exhibited slightly higher TS values than those prepared using Limestone and Natural Gravel. This is probably due to the greater interlock within the Quartzite aggregate structure and its higher asphalt binder content than the other two aggregates. However, all the mixtures met the minimum TSR requirement of 80% specified by the SDDOT gyratory controlled QC/QA mix design specifications for hot asphalt mixtures. As mentioned earlier, all mixtures had a 1.0% hydrated lime by dry weight of aggregate.

TRB

Resistance of Asphalt Mixtures to Moisture Damage

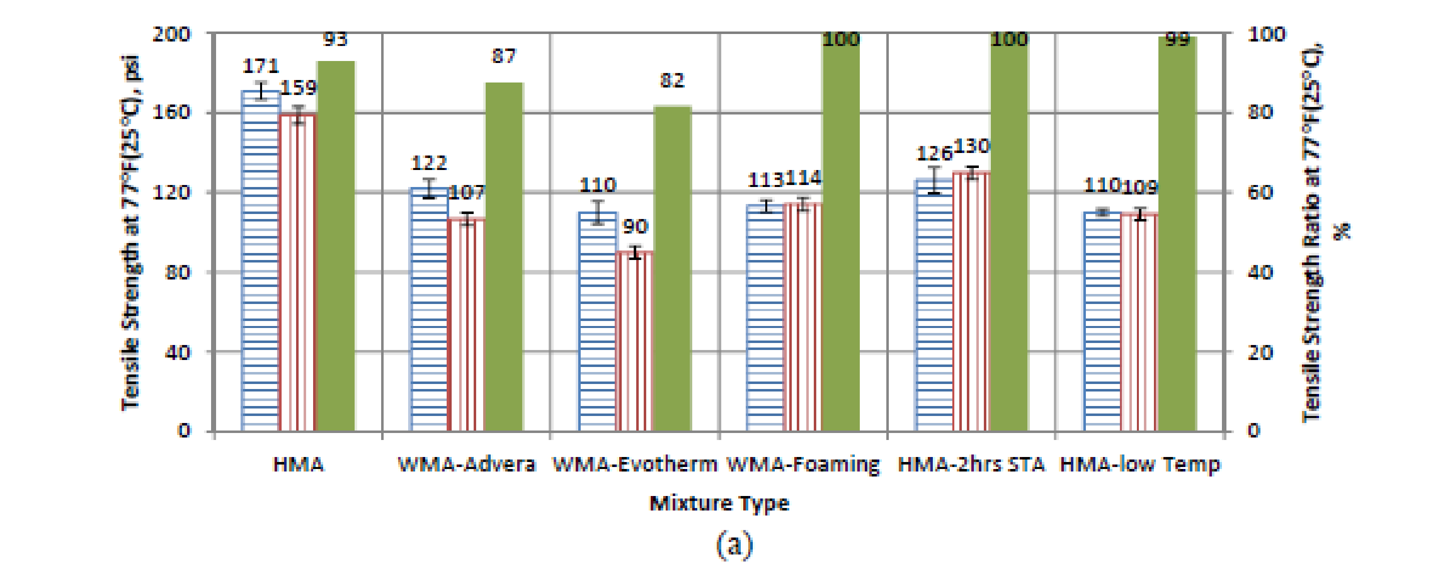

Figure-a
Indirect tensile strength values and tensile strength ratios for Quartzite aggregates

Resistance of Asphalt Mixtures to Moisture Damage

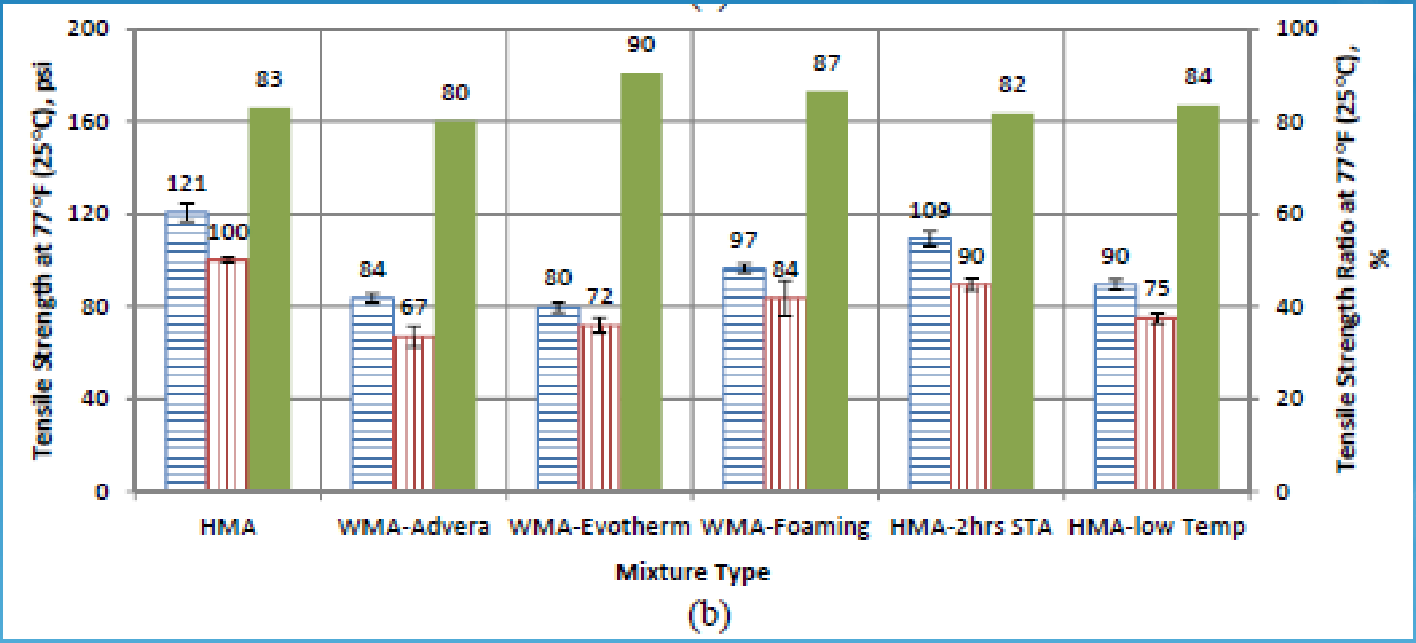

Figure-b
Indirect tensile strength values and tensile strength ratios for Limestone aggregates

Resistance of Asphalt Mixtures to Moisture Damage

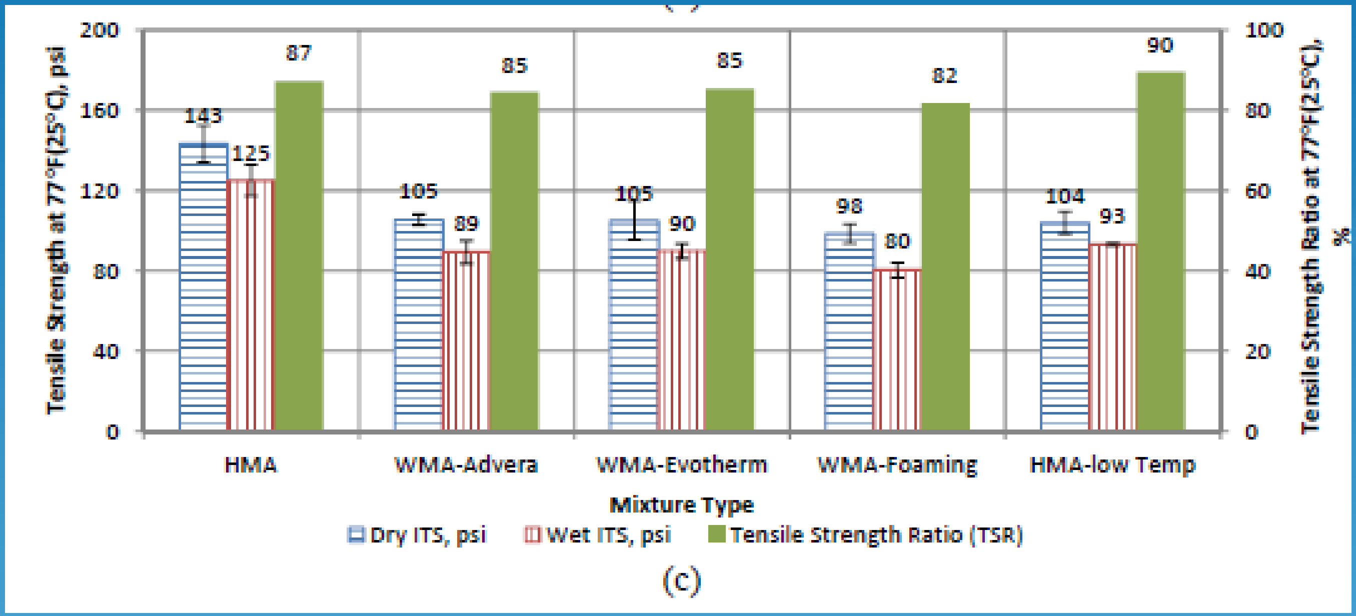

Figure-c
Indirect tensile strength values and tensile strength ratios for Natural Gravel aggregates

Mechanical Property of Asphalt Mixtures

- The dynamic modulus (E*) properties for the various mixtures were evaluated under various combinations of loading frequency and temperature.
- The dynamic modulus was measured according to "AASHTO TP 79: Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)."
- Figure e shows the dynamic modulus master curves at 70°F (21°C) for the HMA and WMA mixtures.

Mechanical Property of Asphalt Mixtures

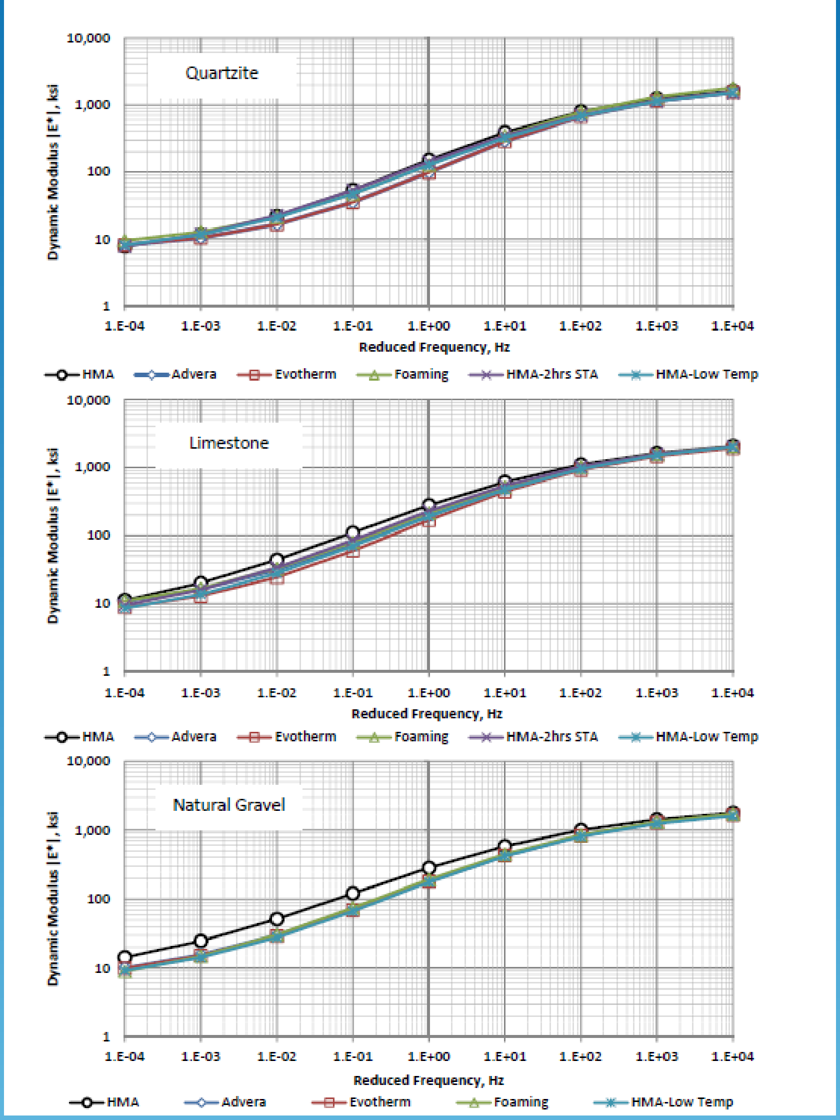

Figure
The dynamic modulus master curves at 70°F (21°C) for the HMA and WMA mixtures.

Mechanical Property of Asphalt Mixtures

- As can be seen from the figures, HMA mixtures exhibited higher E* values than the other mixtures.
- The Quartzite mixtures exhibited lower E* values than those obtained for the Limestone and Natural Gravel mixtures.
- The reduction in the E* property of the Quartzite mixtures can be partially attributed to its higher design binder content.

Resistance of Asphalt Mixtures to Rutting

- The rutting resistance of the various mixtures was evaluated using the Asphalt Pavement Analyzer (APA) test and the Flow Number (FN) test. The mixtures were tested at the short-term aged stage because rutting is a short-term distress mode.

Resistance of Asphalt Mixtures to Rutting

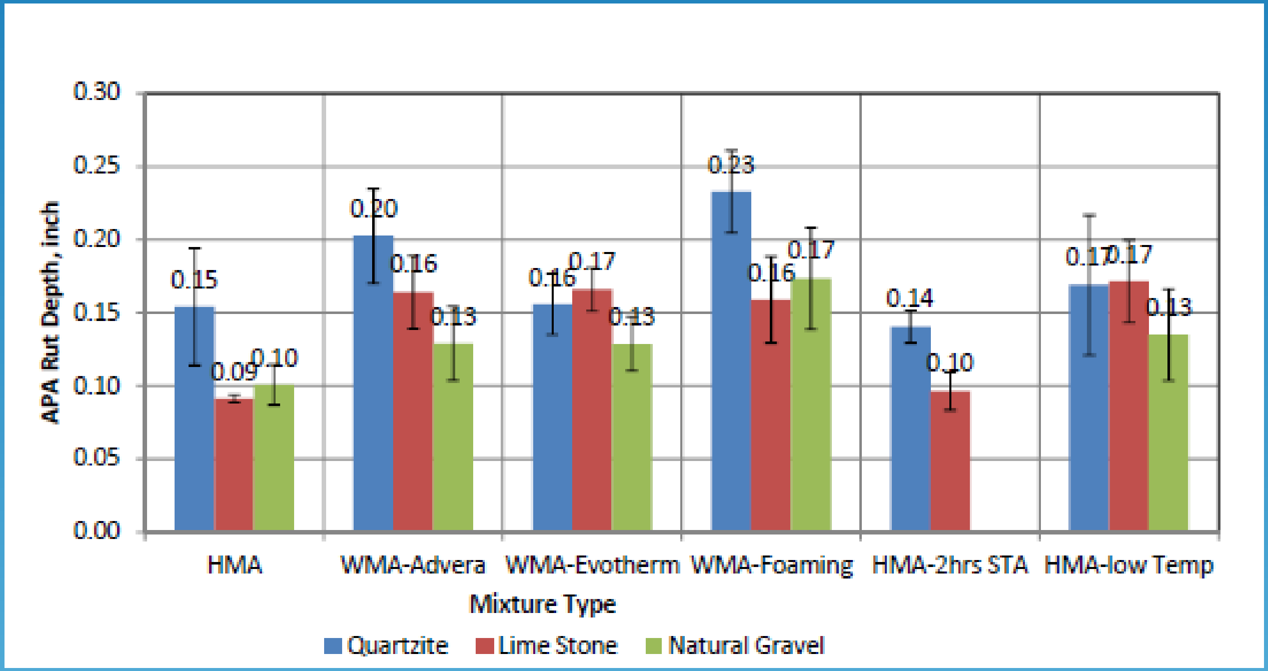

Figure .D1
Comparisons of APA rut depth at 147 F for all Aggregate Sources.

Resistance of Asphalt Mixtures to Rutting

- Figure.D1 presents the rut depth data obtained using the APA test for the HMA and WMA mixtures.
- As can be seen from the figure, the WMA mixtures exhibited higher rut depth values than the HMA and HMA-2hrs STA mixtures, but similar to those obtained for the HMA-Low Temp mixtures. However, all the rut depths obtained for all mixtures were less than the specified maximum rut depth, of 0.27 inch (7.0 mm).
- The Quartzite mixtures exhibited significantly higher rut depths than the Limestone and Natural Gravel mixtures except for the
- WMA-Evotherm mix where the Quartzite mix showed similar rut depth to the Natural Gravel and lower rut depth than the Limestone. The increase in the APA rut depth of the Quartzite mixtures can be attributed to its higher design binder content.

Resistance of Asphalt Mixtures to Rutting

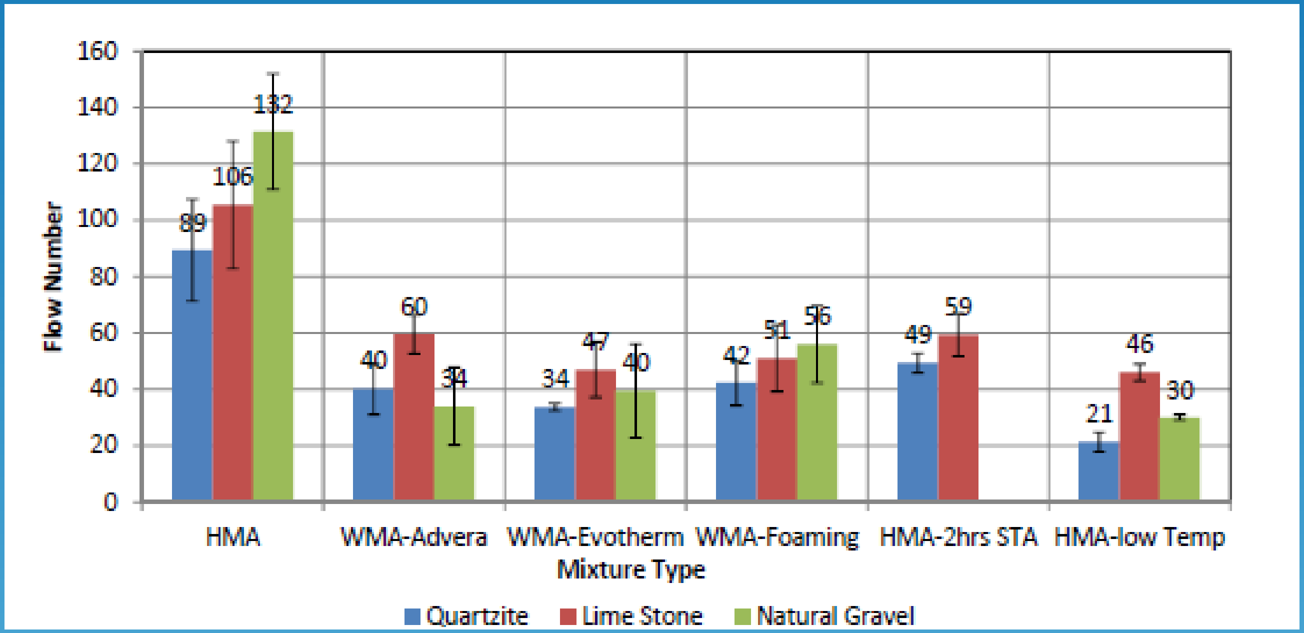

Figure.D2
Comparisons of Flow Number Values for all Aggregate Sources.

A higher FN indicates higher resistance to rutting. As can be seen from the figure.D2, the WMA mixtures exhibited lower flow number values than HMA mixtures but similar or higher than those values obtained for the HMA-2hrs STA and HMA-Low Temp mixtures.

Resistance of Asphalt Mixtures to Thermal Cracking

- The Thermal Stress Restrained Specimen Test(TSRST) was used to determine the low-temperature cracking resistance of the various asphalt mixtures. The test was conducted in accordance with “AASHTO TP10: Standard Test Method for Thermal Stress Restrained Specimen Tensile Strength (TSRST)” with modifications to the mixture specimens size and shape.

Resistance of Asphalt Mixtures to Thermal Cracking

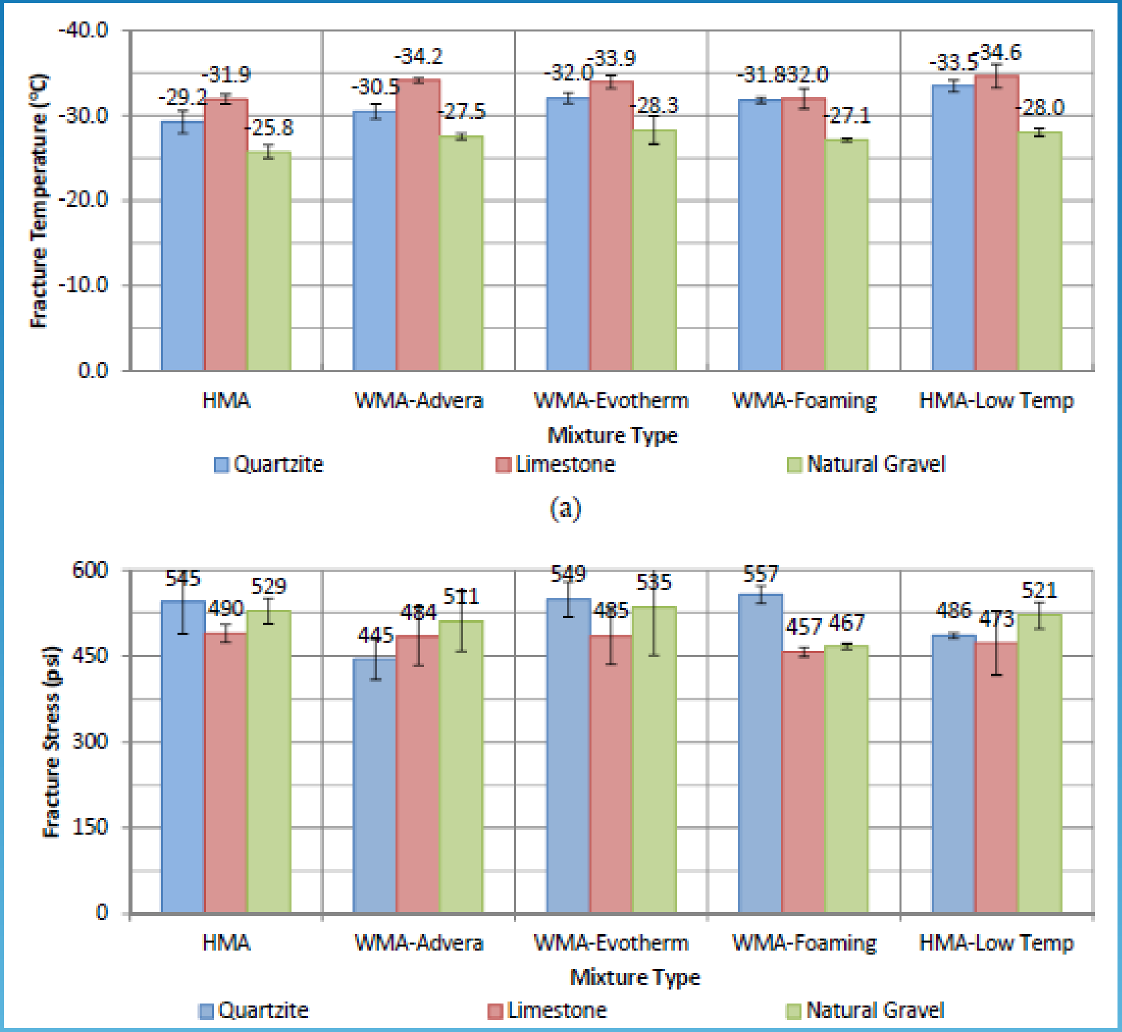

Figure.e

Comparisons of the TSRST a) fracture temperatures and b) fracture stresses for all aggregate sources.

Resistance of Asphalt Mixtures to Fatigue Cracking

The resistance of the various mixtures to fatigue cracking was evaluated using the flexural beam fatigue test following "AASHTO T321: Standard Method of Test for Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending". The beam specimen was subjected to a 4-point bending with free rotation and horizontal translation at all load and reaction points. This produced a constant bending moment over the center portion of the specimen. In this research, constant strain tests were conducted at different strain levels using a repeated haversine load at a frequency of 10 Hz and a test temperature of 70F (21C).

Conclusion

- The performance of the WMA mixtures was evaluated in terms of moisture damage, rutting, thermal; cracking, and fatigue cracking resistance. Aggregate source, WMA additive type, and the interaction between the two were shown to have moderate to significant effects on the performance of the asphalt mixtures for certain tests, while having no effect for other tests. Statistical differences were found when comparing indirect tensile strength and tensile strength ratios, Flow Number, Asphalt Pavement Analyzer rut depth, and fatigue cracking test results for the various mixtures.

Conclusion

Table 3 summarizes the relative ranking of the various mixtures based on their measured performance properties. The ranking are on a scale of 1 to 5 with the best mixture given a rank of 1. Two mixtures receiving the same rank indicates that their corresponding properties are similar for the given test.

In summary, the combination of aggregate type and WMA additive did not have significant effects for most of the tests, with the exception of small changes in the E* and fatigue tests. For the E* test, the Foaming worked the best with the Quartzite and Limestone, but not the Natural Gravel.

The Limestone worked the best with the Evotherm and Foaming for the fatigue test.

Conclusion

Property	Aggregate	WMA-Advera	WMA-Evotherm	WMA-Foaming	HMA-2hrs STA	HMA-Low Temp
Dry TS	Quartzite	1	2	2	1	2
	Limestone	4	4	2	1	3
	Nat. Gravel	1	1	1	--	1
Wet TS	Quartzite	3	4	2	1	3
	Limestone	3	2	1	1	2
	Nat. Gravel	1	1	2	--	1
E* Values	Quartzite	2	3	1	1	2
	Limestone	2	3	1	1	2
	Nat. Gravel	1	1	1	--	1
APA Rut Depth	Quartzite	2	1	2	1	1
	Limestone	2	2	2	1	2
	Nat. Gravel	1	1	2	--	1
FN Values	Quartzite	2	3	2	1	4
	Limestone	1	2	2	1	2
	Nat. Gravel	2	2	1	--	2
Fracture Temperature	Quartzite	2	2	2	--	1
	Limestone	1	1	2	--	1
	Nat. Gravel	1	1	1	--	1
Fracture Stress	Quartzite	4	2	1	--	3
	Limestone	1	1	3	--	2
	Nat. Gravel	3	1	4	--	2
Fatigue Characteristics	Quartzite	2	1	2	3	1
	Limestone	3	1	1	3	3

Table
Ranking of the Various Mixtures Based on Performance Properties.

Conclusion

- In summary, the combination of aggregate type and WMA additive did not have significant effects for most of the tests, with the exception of small changes in the E* and fatigue tests. For the E* test, the Foaming worked the best with the Quartzite and Limestone, but not the Natural Gravel. The Limestone worked the best with the Evotherm and Foaming for the fatigue test.

Reports Assessment

- Paper organization and title
- Results
- Conclusions
- Scientific value
- Contradictions (p2-p19)
- Problems and assessment

References

- **South Dakota Department of Transportation Research Project Statement/Project SD2008-03**
- INFLUENCE OF AGGREGATE SOURCE ON THE PROPERTIES OF WMA MIXTURES IN SOUTH DAKOTA