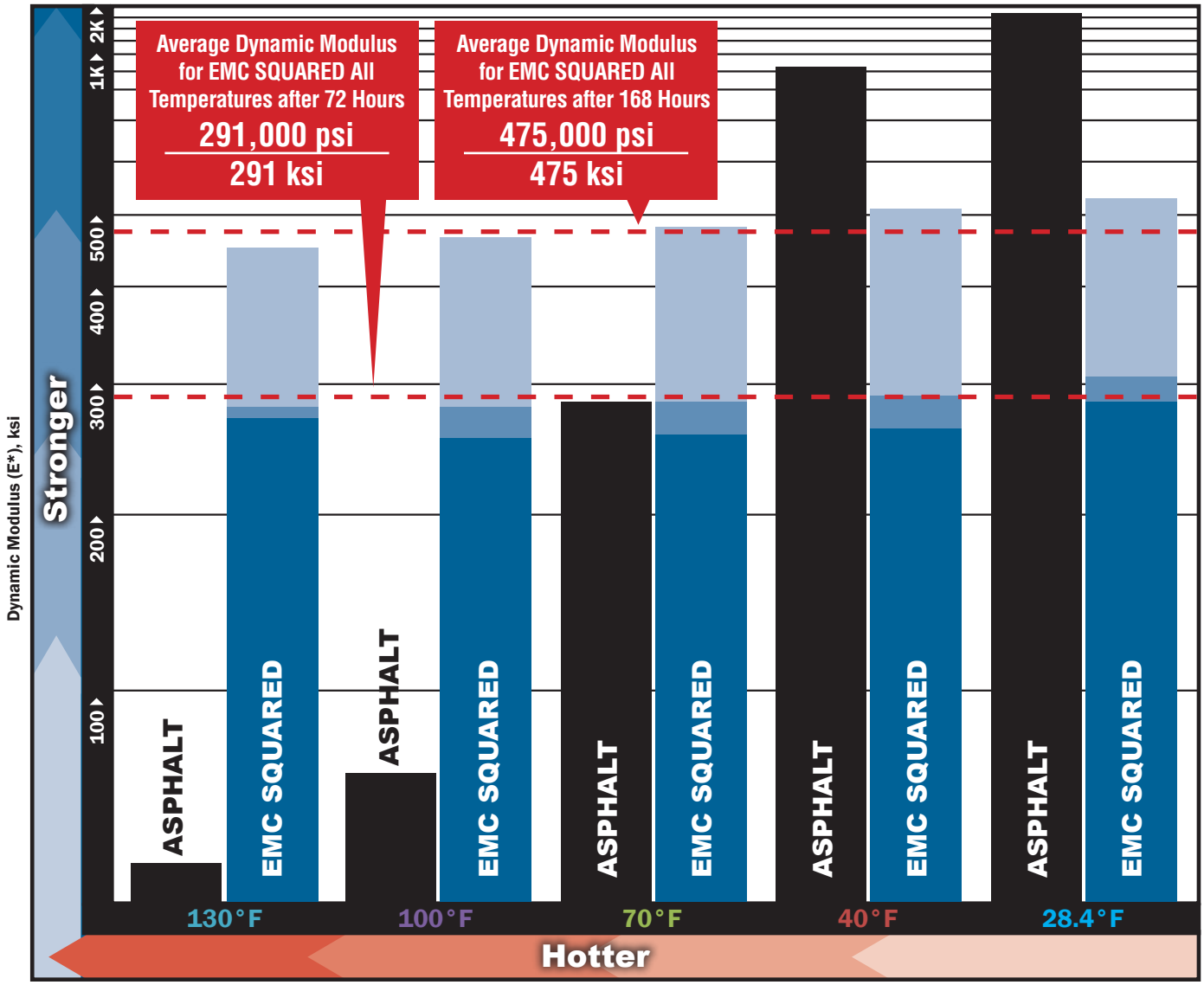
COMPARISON OF TYPICAL DYNAMIC MODULUS AND REPEATED LOAD TRIAXIAL TEST RESULTS FOR HOT MIX ASPHALT (HMA) MIXTURE AND EMC SQUARED® STABILIZED AGGREGATE

Dynamic modulus is the main input required for design of Hot Mix Asphalt (HMA) pavements using the nationally recognized AASHTO Mechanistic-Emperical Pavement Design Guide (MEPDG). HMA pavement materials are viscoelastic in nature and their dynamic modulus values vary dramatically in response to changes in loading rate and temperature. For example, HMA materials exhibit much lower modulus values (significant strength loss) as pavement temperatures increase. In contrast, dynamic modulus testing shows that EMC SQUARED Stabilized Aggregate materials retain a relatively consistent dynamic modulus (consistent strength) through the full range of loading rates and temperature changes, indicating elastic rather than viscoelastic behavior. Cold-mixed EMC SQUARED Stabilized Aggregate materials have the further advantage of gaining strength with additional curing time.

Typical Dynamic Modulus Data for HMA Mixture and EMC SQUARED Stabilized Aggregate Mixture



The above chart references data from a report by Peter Sebaaly, Ph.D., P.E. University of Nevada, Reno, Director of the Western Regional Superpave Center. The original charts are provided on the following pages of this document.

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COMPARISON OF TYPICAL DYNAMIC MODULUS AND REPEATED LOAD TRIAXIAL TEST RESULTS FOR HOT MIX ASPHALT (HMA) MIXTURE AND EMC SQUARED® STABILIZED AGGREGATE

The viscoelastic behavior of Hot Mix Asphalt (HMA) pavement materials is again illustrated in the two Figures below, as the modulus of the HMA material drops from a strength of over 1,000,000 psi when evaluated at a temperature just below freezing to a modulus value of less than 10,000 psi when tested under slow loading conditions at a temperature of 130°F. For the purpose of pavement design using the AASHTO (MEPDG) method, the variations in the behavior of a viscoelastic pavement material related to various combinations of loading frequency and temperature are presented as a Dynamic Modulus (E*) Master Curve.

Typical Dynamic Modulus Data for HMA Mixture

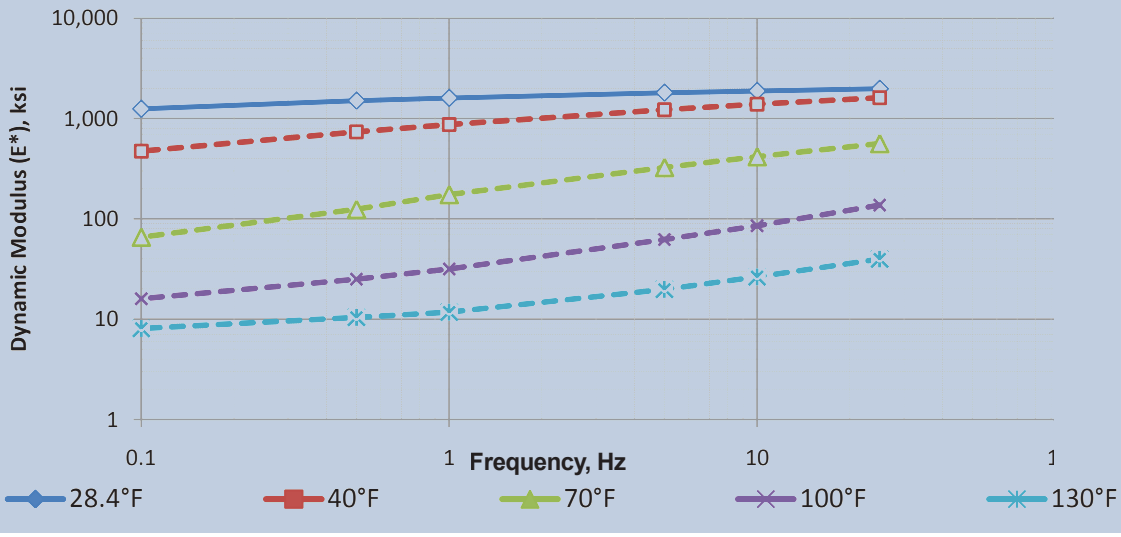

Figure 8

Dynamic Modulus E* Master Curve for HMA Mixture

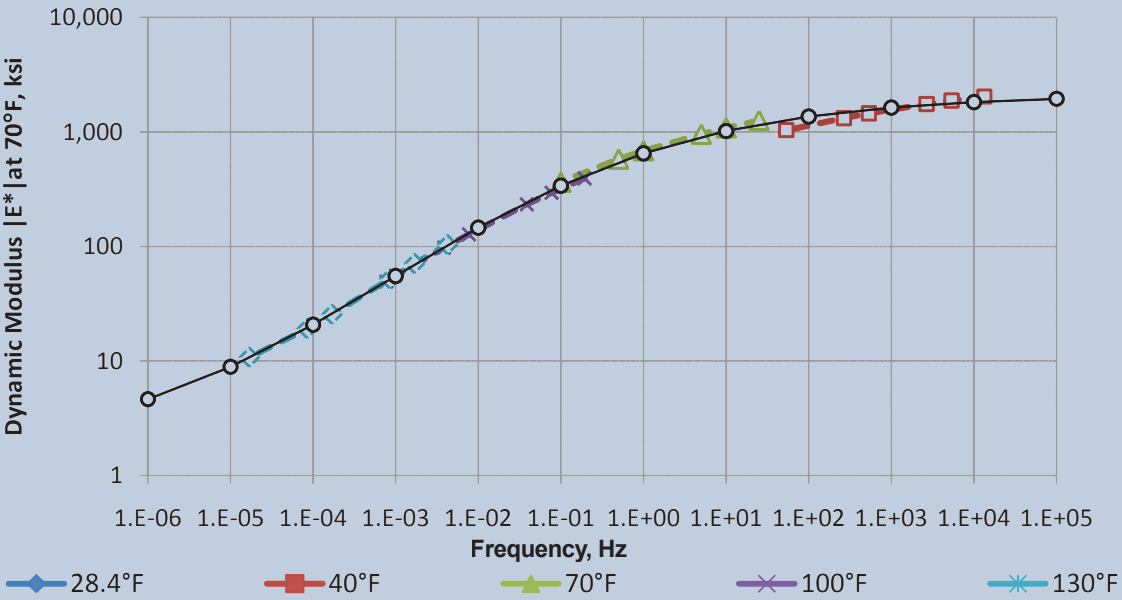

Figure 4

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Dynamic Modulus of EMC SQUARED Stabilized Aggregate Cured for 24 Hours @ 140°F

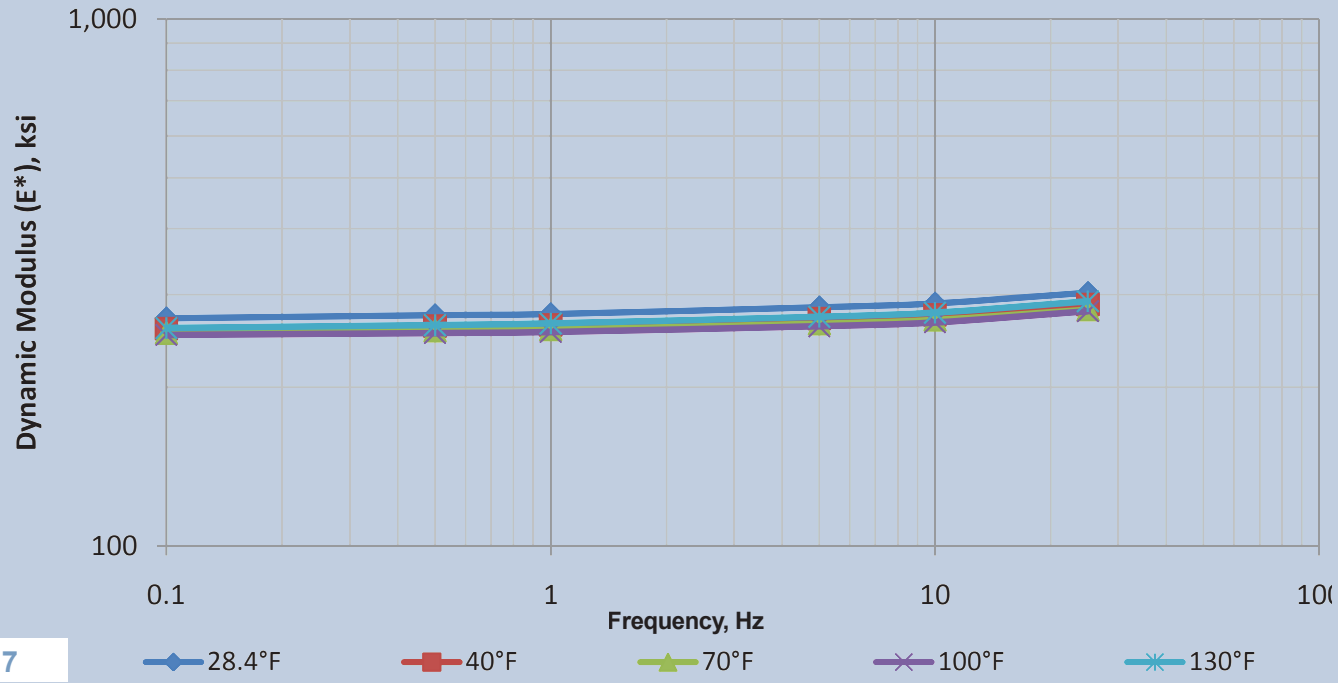

Figure 7

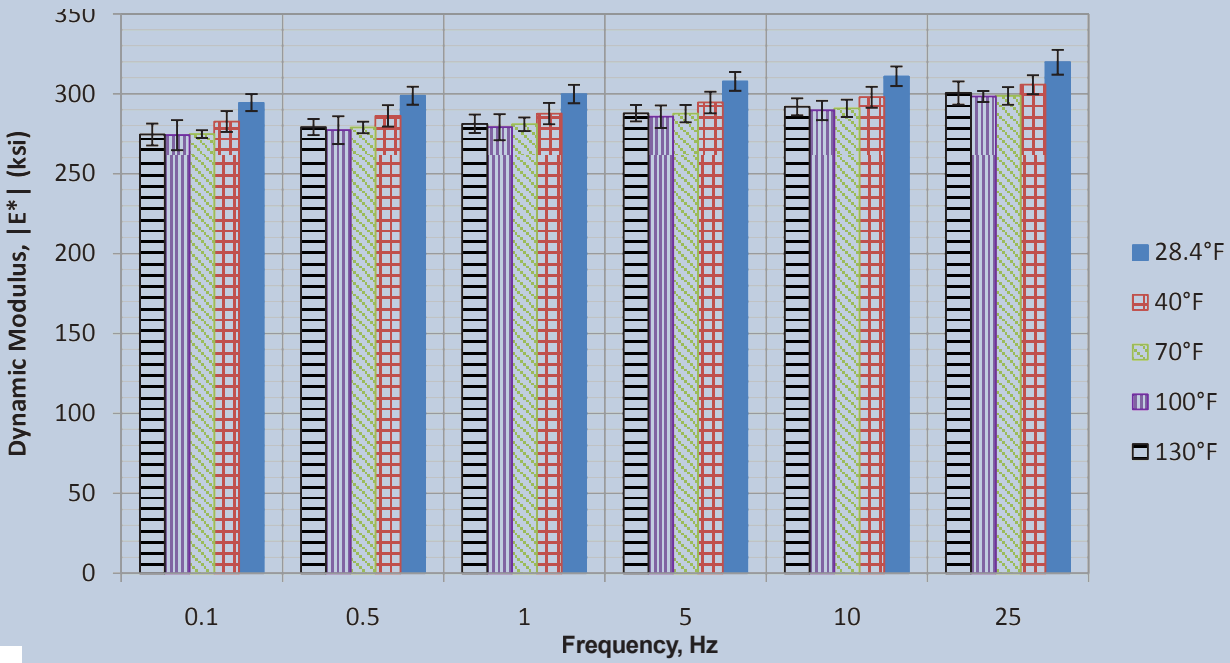

Figure 10

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Dynamic Modulus of EMC SQUARED Stabilized Aggregate Cured for 72 Hours @ 104°F

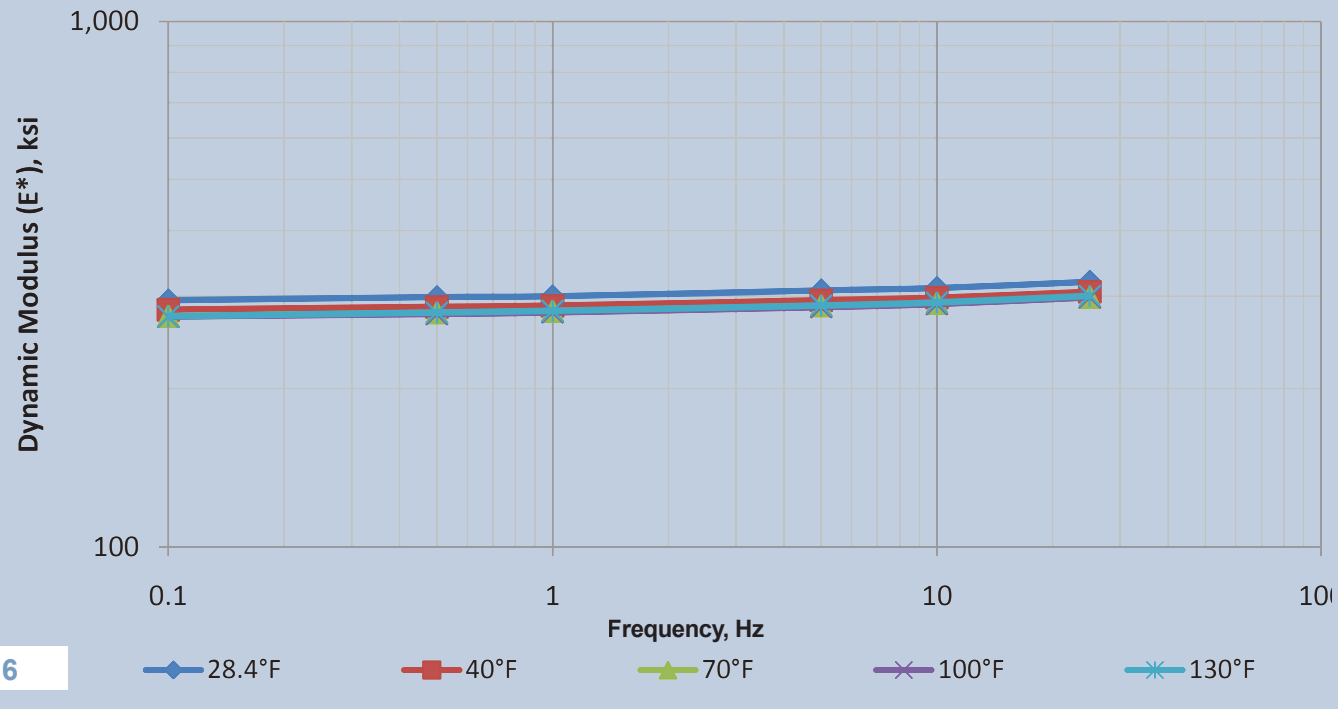

Figure 6

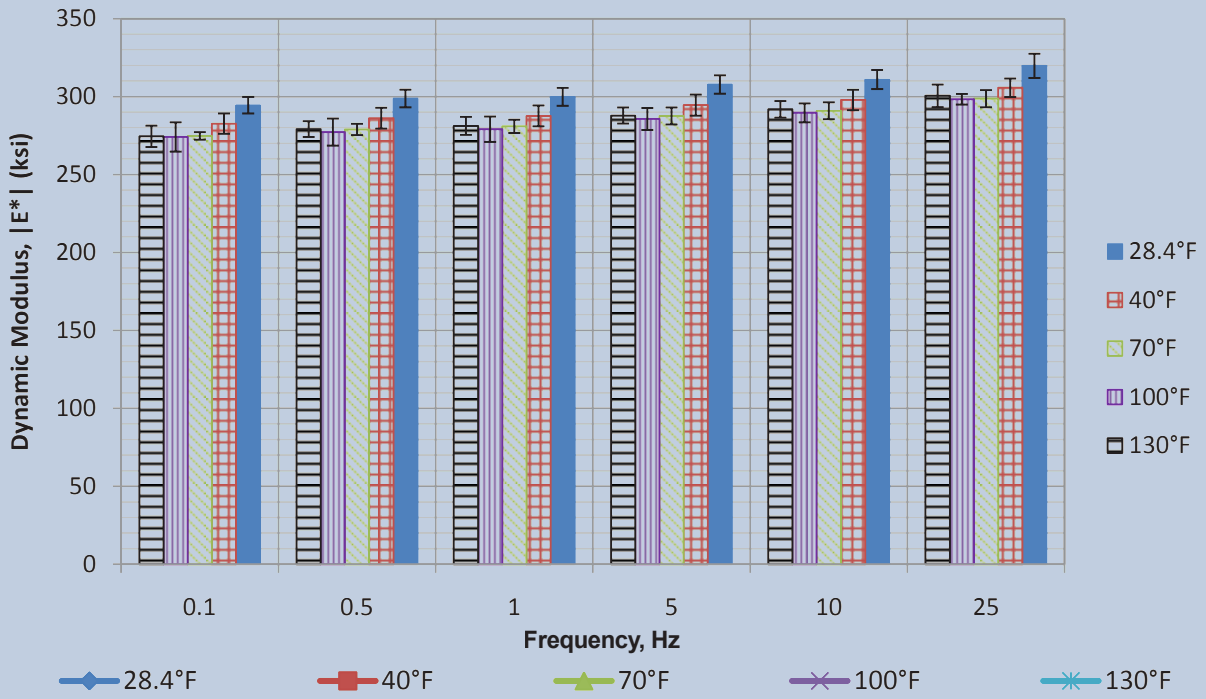

Figure 9

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Dynamic Modulus of EMC SQUARED Stabilized Aggregate Cured for 168 Hours @ 104°F

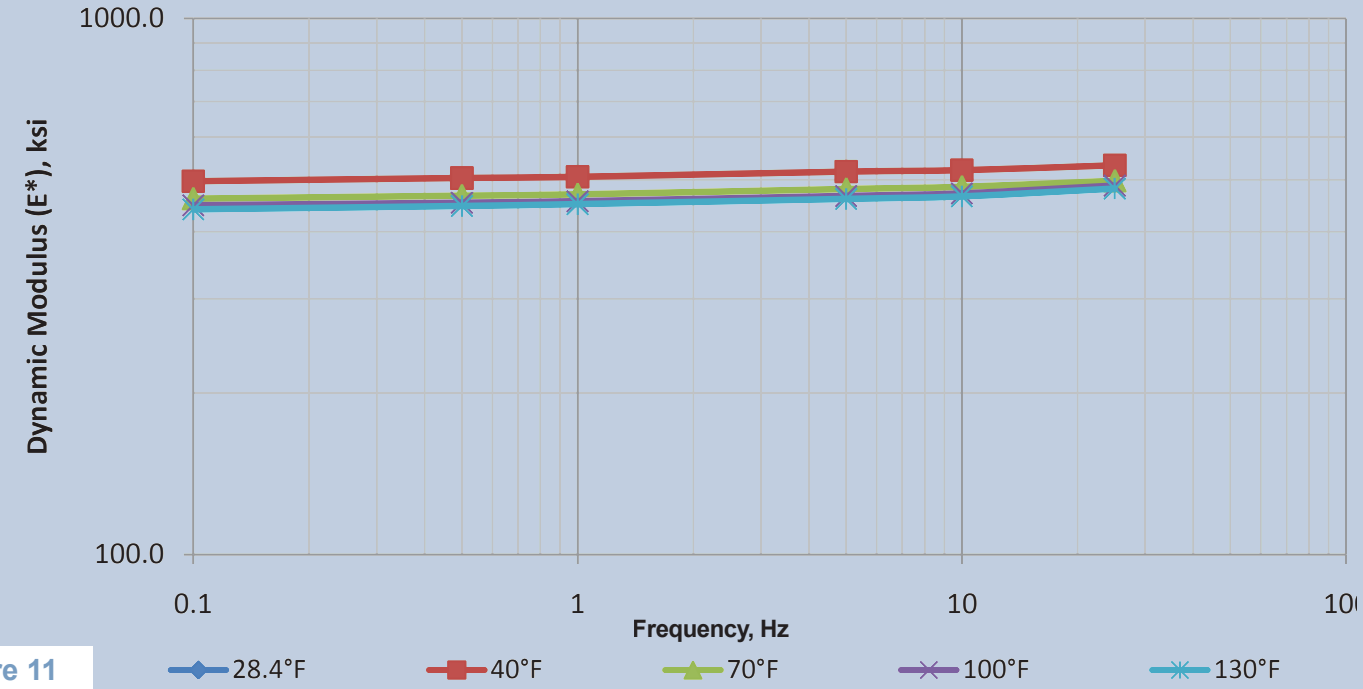

Figure 11

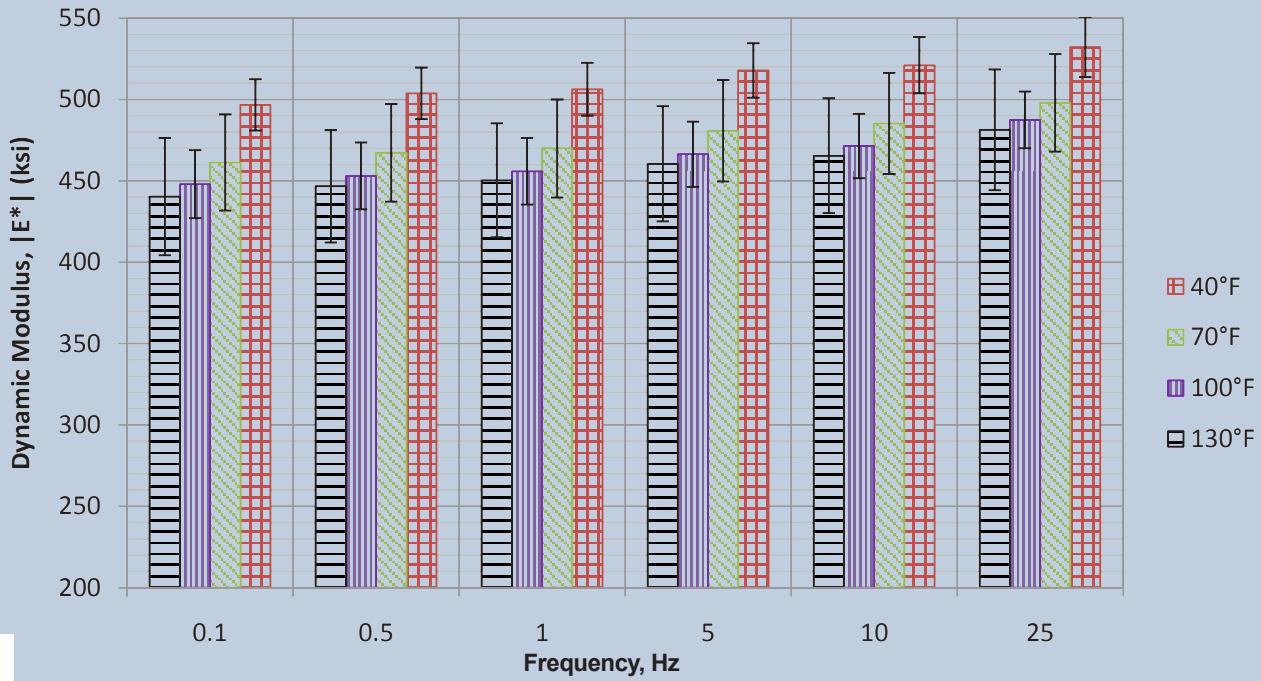

Figure 12

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The Typical Deformation Curve for HMA Mix and the Permanent Deformation Characteristics of the EMC SQUARED Stabilized Aggregate, as shown below, are developed from the results of Repeated Load Triaxial (RLT) testing. RLT testing measures the resistance of a material to rutting and permanent deformation. In comparison to the HMA Mix, the EMC SQUARED Stabilized Aggregate Mix showed only 0.1% permanent axial strain. The report on the testing indicates that the deformation characteristics of the stabilized aggregate are expected to remain constant at all temperatures used in the related Dynamic Modulus testing and that the stabilized aggregate is not anticipated to generate any permanent deformation under a wide range of loading conditions.

Typical Permanent Deformation Curve for HMA Mix

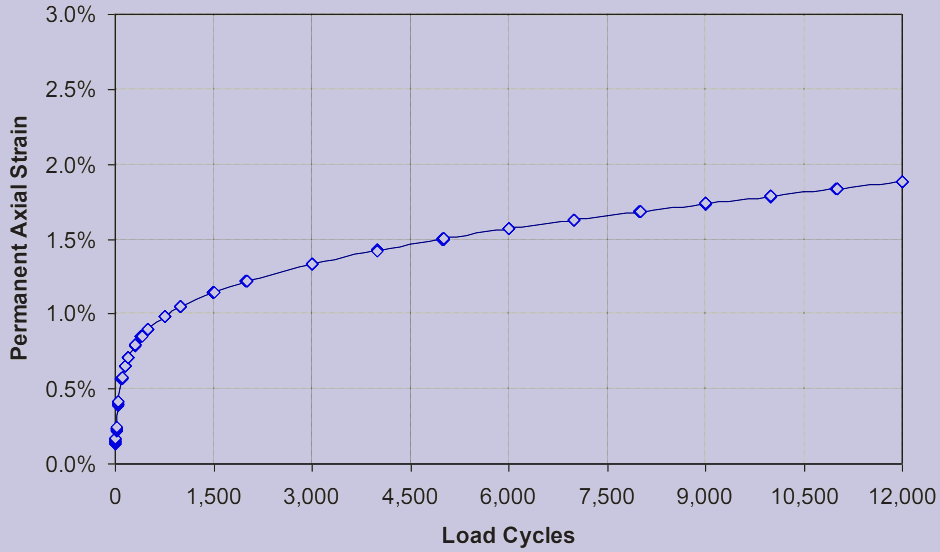

Figure 14

Permanent Deformation Characteristics of the EMC SQUARED Stabilized Aggregate Cured for 72 hrs @ 104°F

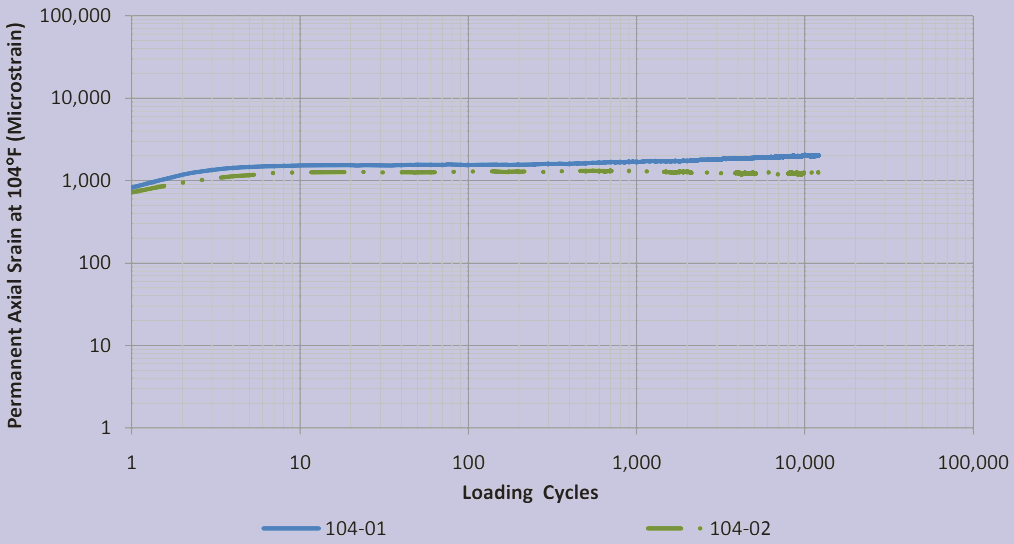

Figure 16

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Evaluation of EMC SQUARED Stabilized Aggregate in Pavements/Materials Laboratory

The laboratory evaluation under the direction of Dr. Sebaaly included both Dynamic Modulus (E*) and Repeated Load Triaxial (RLT) testing, the state of the art test methods for evaluating Hot Mix Asphalt (HMA) materials and providing input for AASHTO MEPDG pavement designs. EMC SQUARED Stabilized Aggregate materials exhibit flexible, or elastic behavior, and modulus values most similar to HMA materials. Consequently, those test methods are equally appropriate for evaluation of these stabilized aggregate materials and for pavement design purposes. The study found that the Dynamic Modulus property of the stabilized aggregate after one week of curing was in the range of 450,000 to 500,000 psi and that it was a very stable material that could be expected to resist permanent deformation very effectively and without excessive stiffening and risk of shrinkage cracking. "The combination of the elastic behavior of the EMC SQUARED stabilized aggregate material with its good level of long-term modulus makes it an appropriate choice for pavements serving heavy loads at slower speeds (worst case conditions) as well as for pavements subjected to standard loading conditions." Unlike HMA materials, which are weakened by increasing temperatures and slower loading conditions due to their highly viscoelastic nature, the study found that changes in loading frequency and temperature, from below freezing to 130^{O}F temperature, had minimal impact on the modulus of the EMC SQUARED Stabilized Aggregate, and that the EMC SQUARED Stabilized Aggregate can therefore be represented by an average constant Dynamic Modulus property of 475,000 psi (versus the Master Curve required for HMA).

The resistance of the EMC SQUARED Stabilized Aggregate material to permanent deformation was evaluated in RLT testing with a finding that under a wide range of loading conditions no permanent deformation is anticipated. Furthermore, even in the worst case conditions for a flexible pavement layer, which are slow moving loads in hot environments, the behavior of the stabilized aggregate "makes it a good candidate for pavements loaded under such severe conditions."

As an example of a severe service application, it should be noted that the EMC SQUARED Stabilized Aggregate materials for this laboratory evaluation were sampled during the construction of military heavy haul road projects designed by the U.S. Army Corps of Engineers (USACE). This high-strength stabilized aggregate material was plant-mixed and placed by asphalt paving machines as a surface course, or running surface, to be used by convoys of military battle tanks and other tracked military equipment as well as heavy haul trucks weighing over 120 tons when fully loaded. The EMC SQUARED Stabilizer product, manufactured by Soil Stabilization Products Company, Inc. (SSPCo), was specified by USACE for stabilization of subgrade soils as well as stabilization of aggregate surface course materials for over 100 miles of heavy haul road construction projects. Of additional interest, the stabilization of subgrade soils eliminated the need to manufacture and transport over 1 million tons of crushed aggregate subbase material that otherwise would have been required for these projects.

The engineering evaluation of the stabilized aggregate materials was conducted under the direction of Peter Sebaaly, Ph.D., P.E., Director of the Western Regional Superpave Center, one of five centers established by the Federal Highway Administration (FHWA) to support the implementation of the Superpave Technology for hot mix asphalt materials. Dr. Sebaaly is also the Director of the Nevada Technology Transfer Center (funded by FHWA and Nevada DOT), and Professor of Civil Engineering in the Civil and Environmental Engineering Department at University of Nevada Reno where the Pavement/Materials Program and materials testing laboratory are located.

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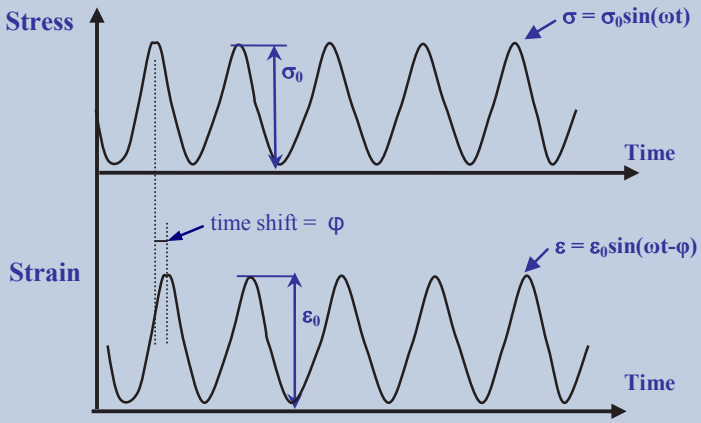
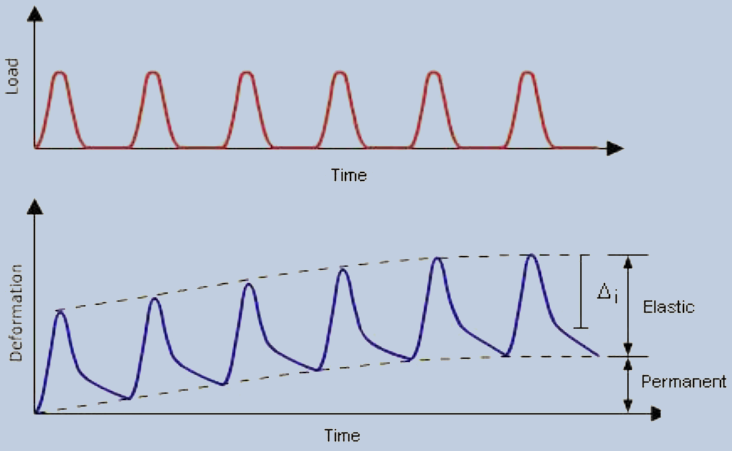
Dynamic Modulus Setup

Applied Stress and Measured Strain



Repeated Load Triaxial Setup

Loading and Response



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