Asphalt Durability and Its Relation to Pavement Performance—Rheology, I

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ABRIDGMENT

•ASPHALT roads are two-phase systems—stones of various sizes and shapes held together by a viscoelastic binder. Road durability depends on, among other things, how well the binder resists changes in strength properties. Because roads are loaded dynamically under traffic, the dynamic mechanical properties of the binder were evaluated.

The four asphalts studied were selected from the current cooperative survey being conducted by the Bureau of Public Roads and The Asphalt Institute. They represented viscosity grades, AC-5, AC-10, AC-20, and AC-40. Routine tests and special tests for composition, wax, molecular weight, and glass transition temperature were run. Asphalts were aged in the thin film oven test (TFOT) for 5 and 24 hours and by weathering Marshall specimens. Instrument requirements were met by modifying a Farol rheogoniometer to permit accurate measurements of stress and strain and their phase relationship at low service temperatures (0 to 40 F).

Viscoelastic properties (storage modulus, loss modulus, and dynamic viscosity) of aged and unaged asphalts were measured at 0, 20, 40, 60, and 80 F over a 1000-fold range of stress frequencies. The data were combined into master curves for comparison of properties at 20 F. Storage and loss moduli increase with frequency and level off at high frequencies to ultimate values of about 5×10^9 and 8×10^8 dynes/cm^2, respectively. Dynamic viscosity depends on frequency in a manner similar to the dependence of steady shear viscosity on shear rate with limiting values at low frequencies and limiting slopes at high frequencies.

Comparison of unaged asphalts shows that the more viscous asphalts also have higher elastic moduli. Differences between grades are large at low frequencies but all have about the same modulus at high frequencies. Dynamic viscosities behave similarly.

Aging increases the elastic and loss moduli and the dynamic viscosity at low frequencies; however, the properties at high frequencies are the same as for the unaged asphalts. The moduli curves are shifted so that the ultimate values are reached at lower frequencies. In addition, relaxation times increase with age. These changes suggest that asphalts become more like solids and less like liquids and that the failure mechanism changes from ductile to brittle fracture. The viscoelastic properties of asphalts extracted from Marshall specimens are very similar to those of the 5-hr TFOT residues. Rheological properties do not appear to change significantly at the glass transition temperature.

Measurements of durability by relative changes in relaxation time with age showed that the four asphalts are equal in durability.

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Note: The complete paper is available from the Highway Research Board at $1.00 per copy (Supplement XS-8).