

## Predict the Service Life of Pavement: Evaluate Moisture Sensitivity and Oxidative Aging of Asphalt

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Pavements are subject to different stresses during their service life. Correctly predicting the service life provides decisive information to pavement design and rehabilitation. A properly designed pavement material will perform adequately during its design life, and normally the distresses will not exceed the allowable limits. However, premature pavement failure may often appear due to several degradation factors. Moisture sensitivity and asphalt aging properties are two main factors that contribute to the pavement service life reduction. In this editorial, the author will give some comments on the current research status about these two phenomena.

Moisture damage of asphalt concrete is a common distress located in asphalt pavement. It is characterized by the loss of adhesive bond between the asphalt-aggregate interfaces or by a softening of the cohesive bonds within the asphalt binder. Both of the two damage modes are due to the external traffic loading with the presence of moisture. The mechanisms of moisture damage has been concerned that water gradually penetrates into the asphalt film and asphalt-aggregate interfaces. Several mechanisms have thus far been identified in the literature [1,2]. Researchers [3,4] in this field made experimental tests to handle this problem by using a proposed adhesion mechanism such as surface energy theory and chemical reaction between asphalt-aggregate interfaces. Surface energy theory suggested that the different amount of interfacial tension and work of separation between asphalt, water, and aggregate resulted in an adhesion failure between the asphalt-aggregate interfaces. With this theory, the reason that interface stripping was observed more in quartz than limestone is solved by the different physical interactions between the asphalt and aggregate. In addition to experimental studies, fundamental research (i.e. atomistic characterization and simulation) has also been carried out by leading researchers [5,6] in this field. The results reveal that there are certain hydrophilic/hydrophobic effects between different asphalt and mineral pairs. Water is a polar molecule and asphalt has non-polar or weakly polar property. At the same time silicates have high dipole moments (higher than water), and carbonate stones are also polar molecules. Thus, siliceous aggregates, e.g. quartz, absorb more water than asphalt due to the attraction between the polar mineral atoms and the polar water molecules. Furthermore, on a relatively non-polar surface, such as limestone which main component is calcite, the cohesive forces in the water are greater than the adhesive forces between water and limestone. Hence, a weak polar molecule such as asphalt does not have the potential to strip from limestone and is adhesive to the surface mainly by non-bonded forces.

Various mechanisms of moisture damage of asphalt pavement have been proposed and some promising results have been obtained, however individual concepts of these mechanisms cannot explain all of the moisture damage in asphalt concrete mixtures. In addition, it is difficult to determine the competing mechanisms when evaluating actual failure due to moisture damage. Based on long time research in asphalt concrete, the author proposes to employ combined computational and experimental testing methods to evaluate moisture damage in asphalt pavement. They are 3 systematic categories as following:

1. Develop a quantum-chemistry based moisturized asphalt force field to study the coupled chemical-physical-mechanical

moisture damage in fundamental level.

2. Conduct mechanical laboratory testing. Make comparison of the resilient modulus of the moisturized and dry samples to evaluate the moisture sensitivity of sample asphalt concrete.
3. Perform scalable loaded wheel test to simulate the pavement under traffic loading in laboratory. This testing is designed to accurately evaluate the moisture sensitivity in asphalt pavement under service conditions.

In addition to moisture damage, oxidative aging hardening contributes significantly to pavement embrittlement, eventually resulting in pavement cracking and failure. The performance of asphalt depends on its rheological properties under service conditions. However, being a natural end product of ancient living organisms, it is subject to chemical oxidation by reaction with atmospheric oxygen. Asphalt binders undergo important chemical changes of their molecular structure and composition through processes such as oxidation, formation/breaking of chemical bonds, agglomeration of similar molecules due to temperature, air, and other environmental factors. The oxidative aging has dramatic effects on binder and mixtures' mechanical properties such as stiffness, adhesion, and cohesion. Oxidative hardening of asphalt has thus far been studied on how asphalt physical properties changes, such as changes in viscosity. This physical observation approach meets the engineering needs. However physical observation does not deal with the fundamental driving mechanisms of asphalt oxidation, i.e., the detrimental chemical reactions appear to asphalt binder molecules under service conditions. The author of this editorial has an ongoing research which aims at exploring the chemical basis of asphalt oxidative hardening by establishing quantum chemistry based physic-chemical environment. The possible chemical reactions between asphalt ingredients and oxygen can be readily tested and simulated. Moreover, the study of these molecular interactions at the nanoscale level, and their effect of physical and chemical properties measured at the macro level, is by physic-chemical characterization. The physic-chemical consequences of oxidative aging and its effects are focused on the fundamental mechanical failure properties of the asphalt under moisture and oxidization. This leading chemical-oriented research is expected to alleviate the dependence on empirical and physical observations when asphalt durability is studied.

Through the up-to-date moisture sensitivity and aging mechanism study, we will reconstruct the elementary building block of asphalt

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concrete based on nanomechanics characterization and quantum-chemistry simulations, to restructure the molecular form of the asphalt concrete. The validated model will be used to relate mechanical properties to the molecular structure and composition of moisturized and aged asphalt binders using chemo-mechanics. Discoveries from asphalt moisture and aging research will provide useful guides for predicting and extending the service life of the pavement materials combination in asphalt concrete mixture design.

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