ASTM STANDARDIZATION NEWS

FEBRUARY 1991

Traveled Surfaces

Highway Monitoring Standards ■ Pavement Texture
Weigh-in-Motion Systems ■ Asphalt Chemistry
Are Pavements Built for the User?

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Asphalt Chemistry and its Effect on Roadway Surface Conditions

Poor surface conditions on asphaltic pavements can be both unpleasant and unsafe when environmental conditions are right. As an example, surfaces that are excessively smooth or that trap water can obscure lane markings or lead to hydroplaning when it rains.

The major problem facing researchers is that the causes for pavement problems are so complex. The materials used in construction, the way in which the pavement is put down, the traffic loads it carries, and the environment in which it functions all have a role in the pavement's performance. But, like eating an elephant, the way to solve big problems is to take them one bite at a time. So this article's first focus will be the ongoing research on these problems; the next "bite" will focus on some specific causes and possible solutions.

Highway Research

Certainly the most noticeable and important highway research to come along in many years is the Strategic Highway Research Program (SHRP). SHRP is a five-year, highly focused, product-oriented research effort divided into three major areas of interest: asphalt, concrete, and highway operations. The goal of the asphalt portion of the program is to issue new binder and mixture specifications to aid federal, state, and local specifying agencies in obtaining better performing, hot-mix asphalt concrete pavements. Of the $150 million pledged for SHRP, one-third ($50 million) is designated for the asphalt research program.

A novel feature of the new specifications to be developed by the SHRP program is that they will be performance-based, which will enable highway engineers to accurately estimate the present and future performance of pavements under the traffic loads and environmental conditions in which they function. While both a binder and a mixture specification will be issued by SHRP, this article will focus primarily on the research affecting the binder specification, although it is acknowledged that the combination of binder, aggregate, construction practices, and service environment will control the ultimate performance of the pavement (Figure 1).

The SHRP Program

When the SHRP program was organized in 1986, six areas of pavement distress were identified as the focus of its Asphalt Research Program. They are:

- Low-temperature cracking;
- Fatigue cracking;
- Aging;
- Permanent deformation;
- Moisture damage; and
- Adhesion.

The Problem

Understanding the relationships between the chemical species in the asphalt and their effects on pavement performance in these targeted distress areas is a daunting task (Figure 2). As stated earlier, many variables besides the asphalt chemistry can affect the performance of the pavement. Perhaps the only clear case of a distress mode which is directly affected by the binder is low-temperature cracking of the pavement. In this area, there is overwhelming evidence of a direct link between chemistry and performance. As the temperature drops, the pavement will try to contract. If the binder becomes too stiff (viscous) at these low temperatures, the pavement will not be able to absorb the stress of the contraction and will crack.

Unfortunately for both the user (the public) and the supplier, it is much harder to accurately assign a cause to all distress areas; the causes of one type of distress often are interrelated to other distress modes. For example, an easy way to cure low-temperature cracking of pavements is to use a less viscous asphalt. However, if summertime temperatures get high, the asphalt will get too soft, and the pavement will rut in the wheel paths, or the asphalt will "flush" to the surface, and the roadway will become slick and dangerous.

The proper design then of a pavement surface is somewhat like squeezing a balloon filled with water; when you press in one place, the balloon pops out somewhere else, and if you squeeze too hard...

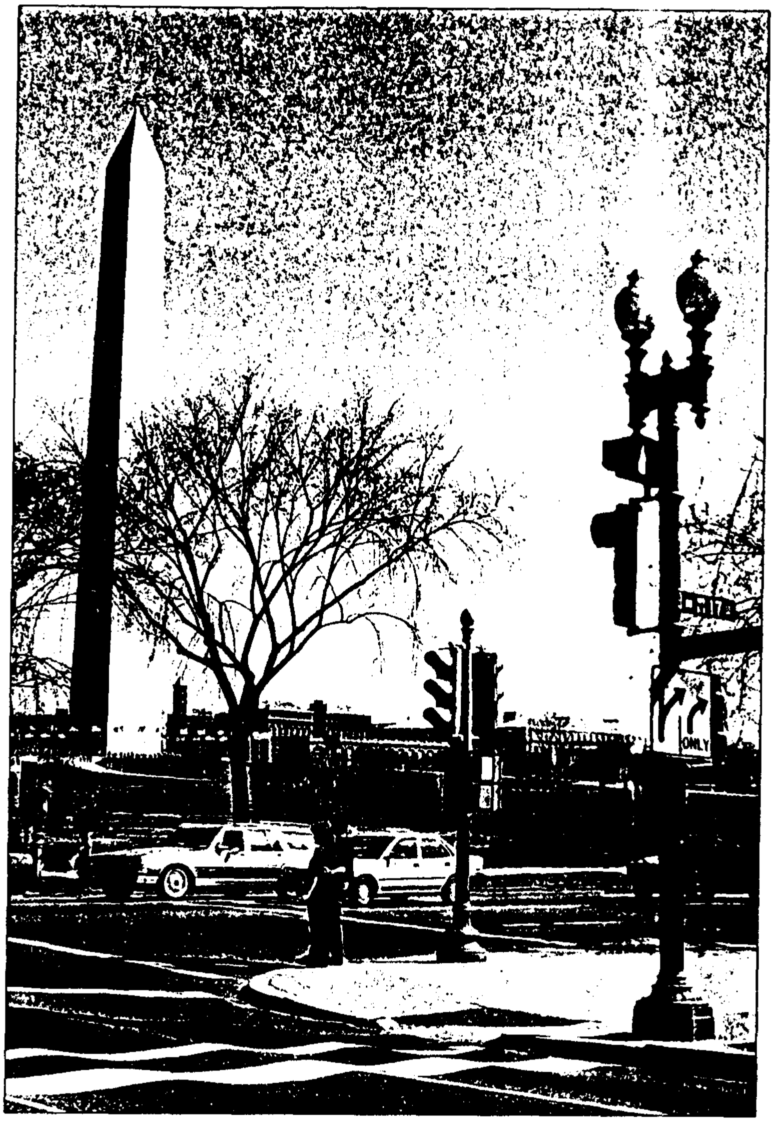


Figure I--This badly rutted and deformed asphalt pavement ***in*** **Washington, DC, is likely the result of traffic loads in excess of the pavement design.**

The Solution

By the time this paper is published, the Asphalt Research Program will have been under way for more than three years, and will be well on its way toward delivery of the end-product specifications. A number of tentative specifications will have been issued and reviewed, and regional groups of users and producers will have been formed to allow input about the materials covered under the new specifications. As our understanding of the relationships between asphalt chemistry and pavement performance expands over the life of the SHRP program, the specifications will be modified to reflect the new relationships, and once again, input will be sought from the users and producers. Through the use of this iterative process, the SHRP Asphalt Research Program will end its work with specifications that have been well thought out and thoroughly reviewed by both the users and producers of the materials, and have an excellent chance of adoption and use.

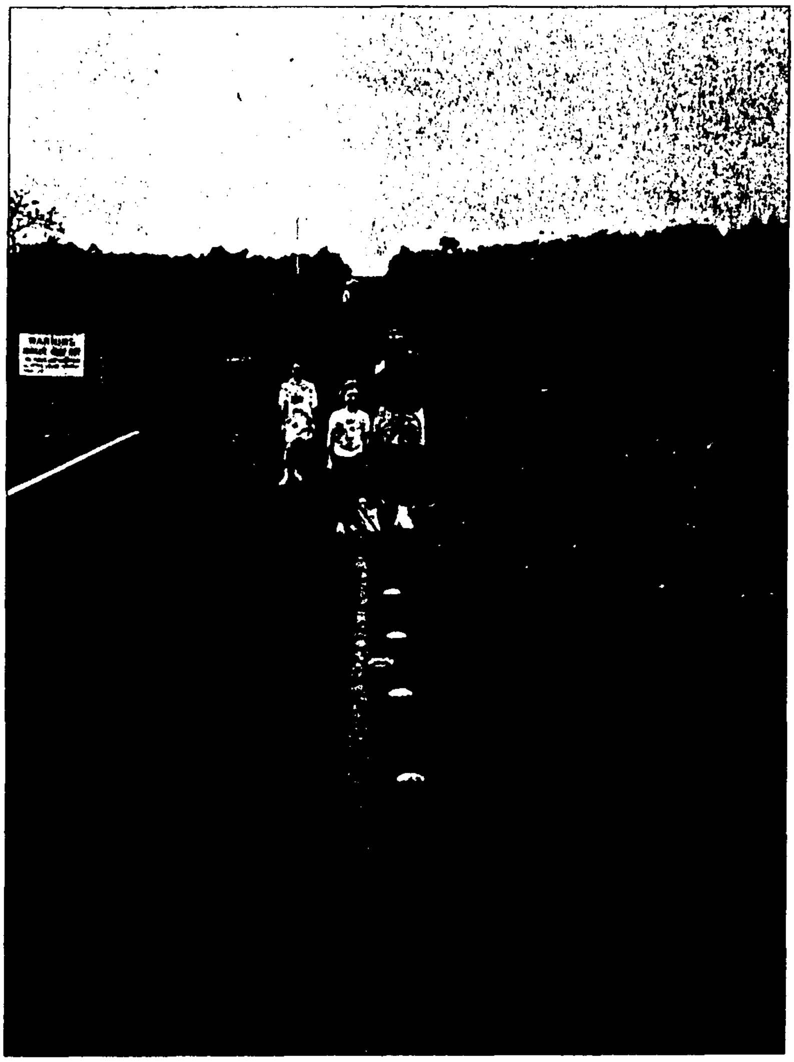
The Research

To this end, a number of major contracts have been awarded which address *the* need for improved binder and mixture specifications. A brief look at the titles and locations of these contracts will give the reader an appreciation of the diversity of the research being carried out under the SHRP Program. The asphalt research is being conducted at the following institutions:

- University of Texas at Austin-"Improved Asphaltic Materials"
- Western Research Institute, Laramie, WY-"Binder Characterization and Evaluation"
- Montana State University at Bozeman—"Binder Characterization and Evaluation by NMR Spectroscopy"
- University of California at Berkeley—"Performance-Related Testing and Measuring of Asphalt-Aggregate Interactions and Mixtures"
- Auburn University, Auburn, Al---"Fundamental Properties of Asphalt-Aggregate Interactions Including Adhesion and Absorption"
- Southwestern Laboratories, Houston, TX—"Asphalt Modification"

As can be seen by the titles of these contracts, the SHRP Asphalt Research Program encompasses a wide variety of experimental approaches. The goal is to increase the understanding of how the chemistry of the binder affects the properties of the mix, and the result-

Figure 2 — A lava flow in Hawaii is shown here. Highway engineers have been unable to design a pavement structure that will withstand this type of environmental distress.



ant performance of the flexible pavement.

The Findings

The two lists below compare the SHRP distress areas with the pavement factors influencing pavement surfaces:

Surface Condition	SHRP Distress Area
Skid Resistance	Low-Temperature Cracking
Smoothness	Fatigue Cracking
Rutting	Aging
Tire Noise	Permanent Deformation
	Moisture Damage
	Adhesion

At first glance there isn't much similarity, but SHRP's results will significantly improve the surface properties of asphalt pavements. Rutting is a form of permanent deformation, and is the most significant problem affecting today's highway system. Skid resistance is a function of both surface texture and water drainage, and since rutted pavements don't drain properly, they contribute to surface problems by allowing water buildup on surfaces and making lane changes more difficult for drivers (Figure 3). The other two surface problems, smoothness of pavements and tire noise, are functions of both construction practices and aggregate wear; the SHRP asphalt program is not going to address these areas directly in its work.

Binder Chemistry the Key

The role of binder chemistry in rutting is still not clear, although the work going on at Western Research Institute (WRI) has helped current understanding tremendously. The research at WRI has shown that the asphalt really exists in two phases. The first phase has historically been called the malthene phase. This part of the asphalt is relatively low in molecular weight, gives the asphalt its viscous properties, and acts as a solvent for the second part of the asphalt. Although scientists have agreed about the general character of this part of the asphalt for some time, researchers at WRI and Montana State University are discovering many new facts about the malthene phase, and have done much toward furthering our understanding of its role in the asphalt's performance.

Describing the other phase of the asphalt is not easy, nor is there much agreement among the SHRP researchers. There is no consensus yet as to the "right" name for this phase, so the authors will use the term "associated phase." This phase is made up of groups of molecules, which contain the bulk of the heteroatoms (N,O,S) in the asphalt. These associations contain ten to thirty asphalt molecules, loosely held together by interactions between the different species in the molecules. The associated phase contains much of the aromatic structure in the asphalt also, and gives the asphalt its elastic properties.

It is important to note that the asphalt has both viscous and elastic components, and behaves based on the combination of the two types. As if this weren't enough, we also are faced with the problem that each asphalt is chemically unique. There are about 75 refineries producing asphalt in the United States today, and each one is producing material from a particular blend or stock of crude oils. While there are ASTM specifications for asphalt (D 946, Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction; and D 3381, Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction, being the main ones), these specifications describe physical properties of the asphalt, and are not performance based. This results in wide variations in performance among materials meeting the specifications.

To return to the problem of rutting, both the viscous and elastic properties of the binder must be considered. A strong elastic character will be a benefit, since the pavement will be able *to* absorb stress, and rebound to its original shape, thus resisting rutting. As the SHRP research allows better understanding of the chemical interactions which control performance, scientists and engineers will be able to emphasize the elastic behavior of the binder, without making the material too stiff to handle, or too brittle at low temperatures.

What hope is there then, since the material is so complicated and variable? SHRP researchers believe the solution lies in the following three areas:

- A better understanding of the chemistry of asphalt and the relationships between chemistry and performance;
- Modification of the asphalt to enhance its properties; and
- Performance-based specifications.

The SHRP program is addressing all three areas. As stated above, the chemistry-performance link is under thorough investigation. In addition, other SHRP researchers are exploring the performance response of asphalt when it is modified. These data will allow the user agencies to formulate specifications which will permit construction of pavements that do not exhibit surface conditions which lead to unsafe pavements.

The Key

The key then, is performance-based specifications. The new binder and mixture specifications that will be issued by the SHRP program will allow groups such as ASTM to adopt a performance-based specification for pavements that will help eliminate the distress modes which lead to problems with the surfaces of asphalt pavements. Interested readers can help this process by becoming involved in the user producer groups mentioned earlier in this article. The authors will be happy to direct readers to the group in their area. SN

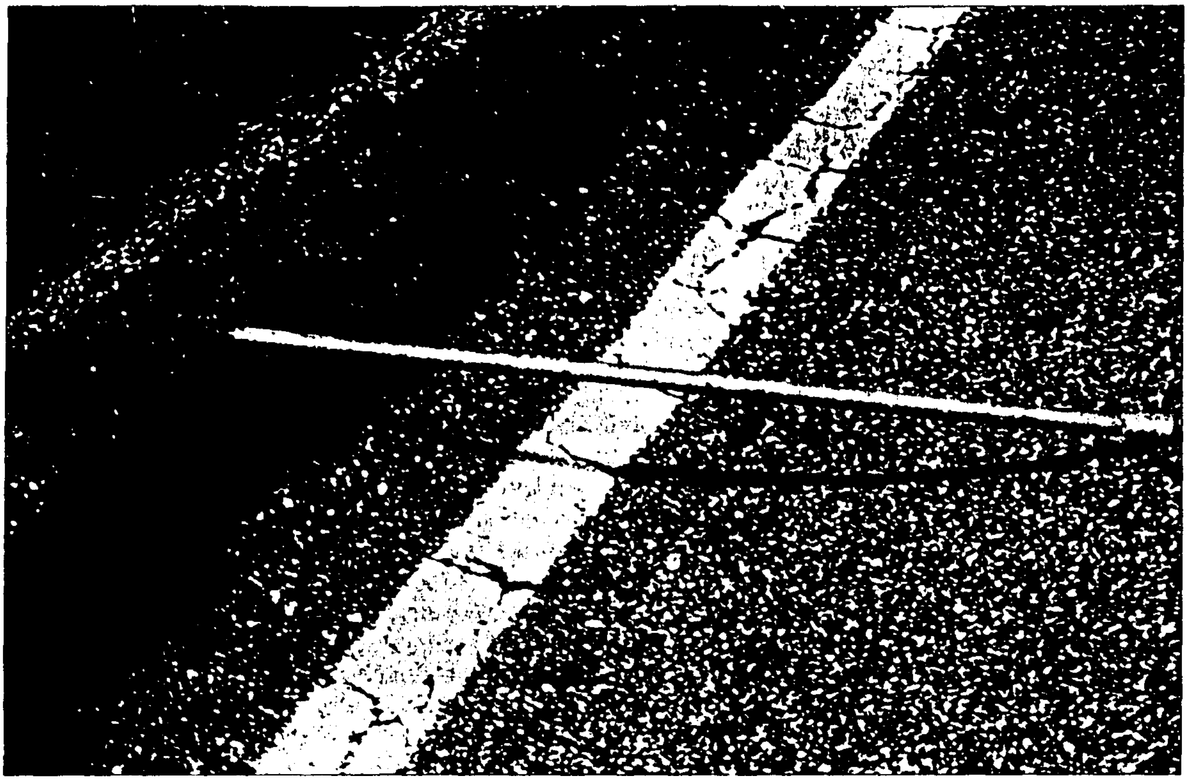


Figure 3 — A deep rut such as this can fill with rain and present a serious driving hazard. This pavement failure will need to be completely rebuilt.