Extended-Life Asphalt Pavement

New Approaches To Increase Durability

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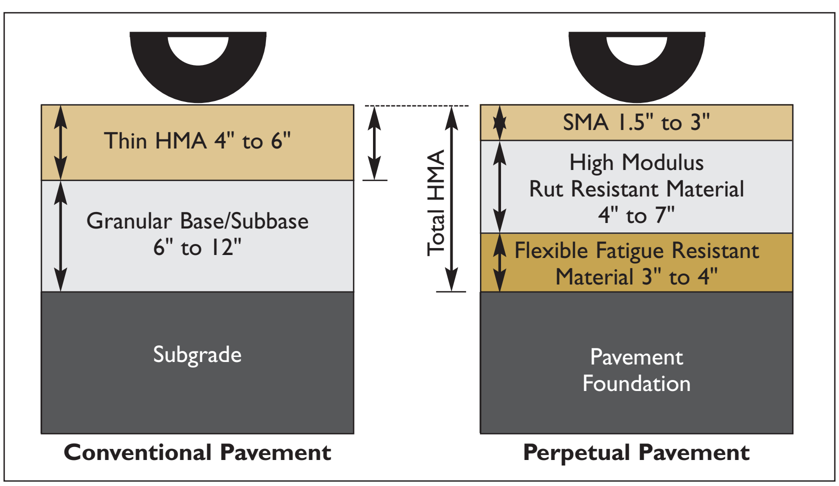
Imagine constructing asphalt pavements that could last for 50 years or more—that is, 30 years longer than typical asphalt pavements. The asphalt industry calls the concept "perpetual pavement," and recent research reports indicate the name may be appropriate.

The reports come from Britain, France, and various parts of the United States, but offer a common perspective—asphalt pavements can be designed to last almost indefinitely. The premise is that an asphalt pavement constructed on a good-quality base with sufficient thickness will not develop the classic fatigue cracking that leads to failure of the pavement. With only periodic renewal of the surface, the asphalt pavement could last a long time. Figure 1 compares typical cross sections of conventional and perpetual pavements.

FIGURE 1 Comparison of structures of conventional pavement and perpetual pavement. (HMA = hot-mix asphalt; SMA = stone matrix asphalt)



Several nations—including the United Kingdom, France, Germany, and the Netherlands—have formed the European Long-Life Pavement Group (ELLPAG)[1], to develop optimal strategies for designing and maintaining long-life pavements. ELLPAG is coordinating research as well as promoting understanding and application of the approach throughout Europe.

U.S. transportation agencies also are looking for longer-lasting pavements. With traffic density always increasing, minimizing delays has become a priority for most transportation agencies. The use of warranties and design-build contracts by agencies in the last decade was an attempt to increase service life and reduce closures on newly designed roadways; perpetual pavement would achieve the same goal.

United Kingdom: "Curing Curve"

Researchers in the United Kingdom began looking into the perpetual pavement phenomenon more than six years ago. They found that thick asphalt pavements had no cracking in the asphalt base course; the cracking started at the surface and progressed downward into the top lifts only. Further evaluation of the in situ strength with falling-weight deflectometer (FWD)-type testing confirmed that the pavement structure was sound and serviceable.

The theory is that as the asphalt mix ages, the surface hardens more than the base lift, initiating cracks at the surface. However, as the thick base course stiff-

[1] For more information about ELLPAG, contact David Gershkoff, Group Secretary, dgershkoff@trl.co.uk, or Brian Ferne, Chair, bferne@trl.co.uk.

ens, its qualities actually improve. The increased stiffness of the base course reduces the deflection of the pavement structure caused by traffic and therefore increases the fatigue life of the roadway.

As the work progressed, researchers proposed the concept of a "curing curve" for asphalt pavements. The asphalt base stiffens fairly quickly within the first 20 years of service life, but then levels off. This suggests a different design and maintenance strategy: at an appropriate time, mill off the cracked surface layer and replace it with a new, high-quality wearing layer.

After extensive evaluation of different roadway types, the U.K. researchers have concluded that the asphalt pavement must be at least 8 inches thick to achieve extended life. The researchers recognize that the minimum thickness of any pavement must relate to the traffic loading and the strength of the subgrade; however, a minimum threshold limit of pavement thickness and strength must be established, either in a new design or in a functioning roadway.

France: Stiffening the Binder

France began to develop extended-life asphalt pavements as a secondary result of the 1980s oil embargo. Development began with the use of very stiff (10/20 pen) asphalt binders in an attempt to reduce layer thickness but maintain overall pavement stiffness, decreasing the demand for asphalt cement.

The result was high modulus asphalt concrete (HMAC). Designed with the stiff asphalt binder and a relatively high binder content, the HMAC has half the air voids and 35 percent more stiffness than conventional mix. Laboratory and full-scale accelerated testing have confirmed that HMAC would provide greater resistance to rutting and to fatigue cracking.

Since France has a relatively moderate climate, thermal cracking has not been a problem; however, in the one area where the temperature drops to –10°C, a very hard asphalt cement showed cracking in the first winter. Pavement designs currently use this material in the base courses; the wearing surface may contain modified asphalt for protection against thermal cracking.

California: Elastic Analysis

A California project, the I-710 Freeway, offers one U.S. approach to designing a long-life pavement. The project used the same concepts for the new full-depth asphalt pavement sections as well as for the rehabilitated (or crack-and-seat) portland cement concrete section. A mix design and analysis procedure developed under the Strategic Highway Research Program was validated with a full-scale heavy-vehicle simulator. In its 30-year design life, the I-710 pavement is expected to carry more than 200 million equivalent single-axle loads (ESALs).

The full-depth asphalt concrete pavement design relied on multilayer elastic analysis. To mitigate bottom-up fatigue cracking, the principal tensile strain on the underside of the asphalt layer was determined; the vertical compressive strain at the top of the subgrade also was determined, to minimize the rutting in the asphalt layer that results from deformation in the unbound layers.

The lower lift of the asphalt base course in the new asphalt concrete section used a "rich bottom" design. This is essentially the same mix used for the base course but with an additional 0.5 percent asphalt binder. The intent is to increase the compactibility and density of the mix, which is placed directly on the subgrade. The mix should be more resistant to fatigue cracking and to moisture penetration.

The entire base course will have a relatively stiff asphalt binder (AR8000 grade) to enhance the stiffness of the mix. The top lift, made with modified asphalt (PBA 6-A grade), will provide optimal resistance to rutting and top-down cracking. A thin, open-graded friction course will serve as the wearing surface. This course will reduce tire spray and hydroplaning in wet weather and will decrease tire noise. Because the lift is thin (less than 1 inch) it also can act as the "sacrificial" course that protects the structural layers—yet it will be economical to mill and replace periodically.

In 1993, after 26 years of service, New Jersey I-287 (*above*) appeared to be in terminal condition.

After 7 years of service with the top 4 inches of surface replaced, New Jersey I-287 remains in good condition today.

Texas: Mechanistic Approach

Like California and many other states, Texas is experiencing the pressures of ever-increasing traffic density and public demand to minimize roadway disruptions. The Texas effort to develop extended-life pavements relies on more conventional materials and a mechanistic design approach.

Core sample from I-287, showing top-down cracking.

The project has designed pavement materials and thickness to limit the tensile strain at the bottom of the hot-mix asphalt (HMA), so that the critical vertical compressive strain on the top of the subgrade would not be exceeded for the extended pavement life. The indirect tensile strength at failure and the resilient modulus were used to determine the design criteria. This approach applied the same concepts as the California project—namely the use of a rich-bottom first lift, a stiff base course, and a high-performance, renewable surface.

New Jersey: Infrastructure Uses

Extended-life pavement concepts also have applications to existing infrastructures. The New Jersey Department of Transportation (DOT) has developed this approach after investigating an interstate highway. The surface of the 26-year-old, 10-inch asphalt pavement, which had received minimal maintenance, appeared to be in terminal condition (see photograph, page 13). The slow and middle lanes of the six-lane roadway had severe fatigue cracking, wheel-path longitudinal cracking, and rutting deeper than 1 inch.

Cores taken from the roadway during the design evaluation showed that the cracks were top-down, with none extending more than 3 inches downward from the surface (see photograph above). Subsequent FWD analysis confirmed that the pavement was structurally adequate. Recovered binder from the cores showed age-hardening to a 20 penetration (similar to the French HMAC). As a result, the New Jersey DOT replaced only the top 4 inches of the pavement, milling 3 inches off the surface and replacing it with 2 inches of a conventional HMA base course and 2 inches of a polymer modified surface course.

The estimated rehabilitated structural capacity was determined to be 69 million ESALs. The 20-year design life was estimated at 50 million ESALs. The rehabilitation is now seven years old and shows no signs of cracking or rutting.

Florida: Promising Research

Most industry experts agree that thick or stiff asphalt pavements will develop top-down cracking. Preliminary findings from ongoing research in Florida suggest a new concept, "time of low crack growth," which models a phenomenon many have observed in the field—cracks start in the pavement surface but grow extremely slowly. The model explains pavements 26 years old with cracks that only penetrate 3 inches from the surface.

Validating this model may provide pavement designers with critical input for determining when a crack may speed up. The findings also may have implications for new approaches to rehabilitation and may provide insight for developing crack-resistant surfacing materials. This ongoing work and other similar projects offer the potential for a better understanding of the phenomenon of top-down cracking and for improved approaches to mitigate the problem.

Adding Years

In summary, an extended-life asphalt pavement has a minimum of 8 inches of HMA; typically the pavements are 12 to 14 inches thick. The pavement components are a sound or improved subbase and base with good drainage, a fairly high modulus HMA base course, and a relatively thin (1.5 to 3 inches) high-performance wearing surface.

The essential concept is that a thicker, stiffer pavement section will reduce traffic-caused deflections of the asphalt layer so that classic bottom-up fatigue cracking will not occur. With a high-performance, thin surfacing material and a "mill and fill" of the surface every 15 to 20 years, the roadway theoretically could last for 50 years or more.

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