Oregon DOT uses Superpave mix designs for perpetual pavement project.

The Oregon Department of Transportation (ODOT) is actively pursuing the use of long-life pavement, otherwise known as perpetual pavement, when designing new pavement structures. The concept behind perpetual pavement design is to provide a section that is rut-resistant, durable and fatigue-resistant, with future preservation needs limited to surface restoration.

ODOT has applied perpetual pavement concepts through the use of a rut-resistant wearing and top base course (top 4 in. of pavement) and a rich binder base course (RBBC) using Superpave mix designs. Durability and fatigue resistance are provided at the base of the asphalt pavement utilizing a mix design based on 3% laboratory air voids. The 3% air-void content results in as much as a 0.5% increase in asphalt content as compared to the standard 4% laboratory air-void mix. The increased asphalt improves the durability of the mixture, aids in compaction for the contractor and allows for higher in-place density of the RBBC layer. The lower in-place air voids lead to better fatigue resistance and longer pavement life.
The early application of perpetual pavement design concepts in Oregon has been limited to the interstate highways in the Willamette Valley. Over the next few years, ODOT will apply perpetual pavement design concepts to projects in southern Oregon as well as east of the Cascade Mountains.

**Loaded answer**

Perpetual pavements certainly benefit from the thickness design motto “the more, the better.” The challenge for the engineer is to find the best combination of asphalt pavement thickness and material properties to minimize life-cycle costs including future maintenance activities. In most cases, a perpetual pavement will have a higher initial cost than a conventional pavement designed for a shorter life, but fewer costly repairs in the future, since any cracking that may appear would initiate at the top of the pavement rather than propagate from the bottom up.

The design of a perpetual pavement is based on principles from the mechanics of materials. When a load is applied to a pavement structure, the asphalt behaves like a beam and compresses near the surface and produces tension at the bottom. Each passing traffic load produces a loading and unloading condition. The thicker the asphalt structure, the smaller the tensile stress is at the bottom. The cyclic loading can lead to fatigue, which produces the characteristic cracking pattern in the wheel tracks.

The cyclic loading and resulting tensile stress is the basis for most empirical pavement design methods. Each load produces a stress for which there is a corresponding strain (displacement) based on the modulus (stiffness) of the asphalt mixture. However, a threshold strain exists such that strain values below the threshold result in no damage to the bottom of the asphalt pavement.

The other principle of importance for a given thickness of asphalt pavement is that a heavier traffic wheel load produces a greater tensile strain. The significance of this principle is that an unloaded five-axle semi-truck and trailer can produce a lower tensile strain than a three-axle bus. Therefore, for a perpetual pavement design, the magnitude of a wheel load can be more significant than the number of standard wheel-load applications.

The design of a perpetual pavement requires leaving behind the concept of equivalent single-axle loads and utilizing the principles of mechanistic-empirical design. Mechanistic design, or layered elastic theory, uses the actual wheel loads to calculate stresses and strains within the asphalt mix, specifically at the bottom of the asphalt pavement. Using programs such as PerRoad, Weslea, MnPave or EverStress, the designer can...
calculate the theoretical strain at the bottom of the asphalt pavement for a specified traffic load spectrum. Some major questions still remain regarding application of the methodology. What maximum wheel load should the design be based on and for how many applications? What are the impacts of overloads? What kind of wheel loads might exist in the next 50 years?
To help provide some answers to the questions of design parameters, ODOT pavement engineers have teamed with the ODOT Research Unit and Dr. Todd Scholz of Oregon State University (OSU) to monitor asphalt pavements designed and built using perpetual pavement concepts. The research is currently under way with one instrumented site on I-5, 70 miles south of Portland, Ore.

**An Oregon original**
ODOT’s instrumented site is located on a four-lane stretch of interstate between Salem and Albany within the outside lane of the southbound direction. The site consists of strain gauges at the bottom of the asphalt pavement, temperature thermistors within the pavement, a traffic weigh-in-motion device and a monitoring plan for determining traffic wander within the lane. The mean maximum temperature at the site is approximately 80°F.

One unique feature of this site is that instrumentation was placed within two types of pavement structure: (a) traditional hot-mix asphalt (HMA) over aggregate base, and (b) HMA over rubblized jointed reinforced concrete pavement (JRCP). The two instrumentation setups allow a unique opportunity to compare the effects of stiffness in the base materials used directly beneath an asphalt pavement.

For the immediate future, ODOT and OSU have planned five additional instrumented sites. Planned sites include perpetual pavement designs of interstate pavement with stop-and-go conditions, interstate pavement with mean-maximum temperatures at or above 90°F and an interstate or major arterial with winter freeze conditions. There will likely be a site or two chosen based on traditional design methodology.

Initial data collection at the I-5 instrumented site has provided no major surprises. As expected, strains at the bottom of the asphalt pavement are greater over the aggregate base course than the rubblized concrete. The tensile strain at the bottom of the asphalt pavement is greater in summer than in winter, due to the response of the asphalt binder (temperature-viscosity relationship).

The instrumentation also provided a few interesting observations. In one instance, the tensile strain produced by a bus exceeded the tensile strain produced by a loaded semi-truck. Lane wander measurements indicate approximately 5% of trucks wander...
across the fog stripe. For the same nominal thickness of asphalt pavement, the design sections on aggregate base or rubblized JRCP indicate strains well within the currently accepted threshold for perpetual pavement of 70 microstrain.

A stiff upper surface

The current experience in Oregon with perpetual pavement design has been positive and encouraging. For the most part, perpetual pavement design thicknesses on the interstate as determined by a mechanistic-empirical approach have been well within the thickness calculations based on AASHTO empirical design methods.

The instrumentation has shown that stiffer base-course materials under the asphalt pavement result in lower strains at the bottom of the asphalt material. The lower measured strains provide incentive to further investigate stiffer base-course materials such as asphalt- or cement-stabilized bases.

Not all pavements need to be designed as perpetual, but the concepts gleaned from Oregon’s analyses and instrumentation can be applied to any pavement, including:

- The first lift of HMA paving over base course is critical to the long-term life of the pavement. Through discussions with industry, ODOT is specifying a 3-in.-thick first HMA base layer. The 3-in. thickness provides adequate heat retention for compaction to meet a minimum requirement of 92% of maximum density. The use of a rich binder base course layer provides an even better opportunity to reduce in-place air voids and improve fatigue resistance through specification of a minimum compaction at 94% of maximum density;
- A general understanding of the actual traffic wheel loads anticipated can provide for a more cost-effective design. Design programs such as the new “Mechanistic-Empirical Pavement Design Guide” provide for a risk-based analysis of traffic, climate and material properties;
- The concept of truck traffic wander recognizes that the same point in a wheel track may not receive the full wheel load stress with each passing vehicle. Wander accounts for the drifting within a lane, thus allowing a design that accounts for more vehicle passes than actual point loading; and
- Each asphalt pavement is a little different. Fatigue damage to an asphalt pavement is the result of accumulated strains, but the strain is a function of pavement thickness, material properties, climatic season, underlying support, wheel load stress and age.

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