Perpetual Pavements

The concept of perpetual pavements, or long-lasting asphalt pavements, is not new. Actually, Full-Depth® and Deep-Strength® asphalt pavement structures have been constructed since the 1960s.

Full-Depth pavements are constructed directly on subgrade soils and Deep-Strength sections are placed on relatively thin granular base courses. One of the chief advantages of these pavements is that the overall section of the pavement is thinner than those employing thick granular base courses.

As a result, the potential for traditional fatigue cracking may be reduced, and pavement distress may be confined to the upper layer or surface of the structure. Thus, when surface distress reaches a critical level, an economical solution is to remove the top layer or surface course and replace it.

Combination of Layers

Recent efforts in materials selection, mix design, performance testing and pavement design offer a method of obtaining long-lasting performance from asphalt pavement structures (greater than 50 years) while periodically replacing the pavement surface.

The thrust is to combine a rut-resistant, impermeable, and wear-resistant surface course with a rut-resistant and durable base layer (Figure 1). Though the use of a perpetual pavement is focused at high-volume traffic, the justification may be made for medium- and low-volume roads as well. The criteria used in Maryland and California for high-volume traffic provide examples.

Maryland incorporates a thick asphalt structure surfaced with a stone matrix asphalt (SMA) on roads where the posted speed limit is 55 mph or greater, and the traffic is at 2000 equivalent axle loads (ESALs)/day or greater. California uses this design when the truck traffic exceeds 15,000 vehicles/day or the average daily traffic is greater than 150,000 vehicles/day.
**Mechanistic Design**

With the right design approach, the use of perpetual pavements can be used effectively on medium- or low-volume roads as well. Currently, most pavement design procedures do not consider the characteristics of each pavement layer relating to fatigue, rutting and temperature cracking. Since each pavement layer has its own part to play in performance, a new structural design method is needed to analyze each pavement layer. The mechanistic-empirical approach meets this need.

Mechanistic techniques for asphalt pavement design have been around since the 1960s, although wider development and implementation started in the 1980s and 1990s. States such as Washington, Kentucky and Minnesota are currently adopting mechanistic design procedures. A research project under the National Cooperative Highway Research Council (NCHRC) is proceeding on the development of a new mechanistically-based American Association of State Highway and Transportation Officials (AASHTO) pavement design guide.

Mechanistic design is much the same as other engineering approaches used for bridges, buildings and dams. The principles of physics are used to determine a pavement's reaction to loading. Knowing the critical points in the pavement structure, one can design against certain types of failure or distress by choosing the right materials and layer thicknesses.

In the case of a perpetual pavement, this consists of providing enough stiffness in the upper pavement layers to prevent rutting and enough total pavement thickness and flexibility in the lowest layer to avoid fatigue cracking from the bottom of the pavement structure.

**Material Considerations**

Since the hot mix asphalt (HMA) pavement is tailored to resist specific distresses in each layer, the materials selection, mix design and performance testing need to be specialized for each material layer. The stiffness of each layer must be optimized to resist rutting or fatigue cracking, depending upon which layer is being considered. Durability is a primary concern for all layers.

The asphalt base layer must resist the tendency to crack from bending under traffic loads. One mix characteristic that can guard against fatigue cracking is a higher asphalt content. Combined with an appropriate total asphalt thickness, this ensures against fatigue cracking from the bottom layer (Figure 2).

![Fig.2: Fatigue Resistant Asphalt Base](image-url)
Another approach to ensure long-term fatigue life is to design a thickness for a stiff structure so the tensile strain at the bottom of the asphalt layers is insignificant. This allows for the use of a single mix design in the base and intermediate layers, and precludes the need to change mix types in the lower pavement structure.

Asphalt content in the base should be defined as that which results in a density of 96 to 98 percent of maximum in-place density. The asphalt grade should have the same high temperature characteristics of the overlying layers. The low-temperature characteristics should be the same as those of the intermediate layer. If this layer is opened to traffic during construction, the contractor should make provisions for rut-testing the material.

**Intermediate Layer**
The intermediate or binder layer must combine the qualities of stability and durability. Stability in this layer can be obtained by achieving stone-on-stone contact in the coarse aggregate and using a binder with an appropriate high-temperature grading. The internal friction provided by the aggregate can be obtained by using crushed stone or gravel, which ensures a strong aggregate skeleton. One option is to use a large nominal maximum-size (1.5-inch) aggregate, but the same effect can be achieved with smaller aggregate sizes so long as stone-on-stone contact is maintained.

The high-temperature grade of the asphalt should be the same as the surface. However, the low-temperature grade could probably be relaxed one grade, since the temperature gradient in the pavement is relatively steep and the low temperature in this layer is not as severe as the surface layer (Figure 3). The mix design should be a standard Superpave mix, and the design asphalt content should be the optimum. Performance testing should include rut-testing and moisture susceptibility.

![Figure 3. Impact of Temperature Gradient on Asphalt Grade.](image)

**Wearing Surface**
The wearing surface requirements depend on local experience and economics. In some cases the need for rutting resistance, durability, impermeability and wear resistance may dictate the use of SMA. This may be especially true in urban areas with a high percentage of truck traffic. Properly designed and constructed, an SMA mix will provide a stone skeleton for the primary load-carrying capacity and the matrix (combination of binder and filler) gives the mix additional stiffness.
The matrix can be obtained by using polymer-modified asphalt, relatively stiff unmodified binder with fibers, or an asphalt binder in conjunction with specific mineral fillers. Maryland, Georgia and Wisconsin have had great success in applying SMAs on high-volume roadways. Durability can be achieved by minimizing the voids in the in-place mix. Maryland DOT reports that in-place voids for this type of mix are generally six percent or less.

In instances where the overall traffic is not as high or in cases where the truck traffic is lower, the use of a well designed, dense-graded Superpave mix may be more appropriate. As with the SMA mix, the design engineer must design against rutting, permeability weathering and wear. Design engineers recommend that a performance test be done during mix design. At a minimum, this procedure should consist of rut testing.

The performance grade (PG) binder should be bumped to at least one high temperature grade greater than normally used in the geographic area. To resist thermal cracking, the low-temperature grade should be the one normally used for 95 or 99 percent reliability in the area.

**Construction**

Construction of a perpetual pavement requires great attention to detail and a commitment to build it with quality from the bottom up. Modern testing methods can supply continuous feedback on the quality of materials and construction. The foundation of the roadway must be able to support paving and compaction operations. This layer must also be well compacted, smooth, and stiff enough to support construction traffic, as well as provide resistance to rollers.

Due to swelling soils or frost heave, minimizing volume changes in the foundation layer are normally necessary. Local experience best dictates how to handle these situations. Design engineers must also address the weakening that occurs during certain seasons of the year. Installation of drainage or a granular interlayer may be necessary to ensure a consistent foundation during the service life of the road. Michael Nunn of the British Transport Research Laboratory (TRL) suggests a minimum design modulus of about 7000 psi for the foundation layer.

**Good Construction Practices = Good Performance**

With nearly all modern HMA pavements, good construction practices will ensure good performance. With the use of polymer-modified asphalts, contractors must be careful to avoid overheating the binder in the construction process. New industry guidelines have been developed to ensure the proper handling and application of polymer-modified binders.

Segregation in coarse aggregate mixes is another area of concern. But again, proper handling of the material during manufacture, transport and laydown can prevent the problem. Achieving density in the various layers of the HMA pavement can be done by following the lessons learned during the implementation of Superpave and successful SMA applications.

Volumetric control of the mixes by the contractor is the key to consistency and quality in the final product. The contractor should have access to a fully equipped and staffed quality control laboratory. Periodic testing and data analysis with good quality control and inspection techniques will ensure a properly designed road that will perform well.

**Monitoring and Resurfacing**

To maintain the perpetual pavement concept, state and local road agencies will find it necessary to periodically monitor pavement performance to keep all forms of distress in the top few inches of pavement. Distresses such as topdown fatigue cracking, thermal cracking, rutting and surface wear must be confined to the original thickness of the wearing course.
Once the distresses reach a predetermined level, the agency will resurface the road and evaluate the entire pavement structure. If certain structural characteristics have changed, such as weakening of the underlying soil through increased moisture content, an additional surface thickness may be planned to ensure the perpetual nature of the pavement structure.

The first step in the resurfacing process is the removal of the existing surface to the depth of the distress. The milled material is then replaced and, if needed, an additional thickness is placed. This new layer has the same rut resistance, durability, thermal cracking resistance and wear resistance as the original surface.

**Summary**

The perpetual pavement gives engineers the ability to design for specific modes of distress. Resistance to bottom-up fatigue cracking is provided by the lowest asphalt layer, which has a higher binder content, or by the total thickness of pavement reducing tensile strains in the base layer to an insignificant level.

The intermediate layer provides rutting resistance through stone-on-stone contact. Durability is imparted by the proper selection of materials. The uppermost structural layer contains qualities that resist rutting, weathering, thermal cracking and wear. SMAs or dense-graded Superpave mixes provide these qualities.

The knowledge and engineering capability to design and build perpetual pavements exist right now. Perpetual asphalt pavement, the long-lasting pavement, is a valid concept that is gaining national and international momentum.

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*The text and figures presented here came from* http://www.currancontracting.com/html/page11978.html#ChtC.