A Concept Paper by

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ASPHALT PAVEMENT ALLIANCE

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 of the structure. Both are advantages to perpetual pavements. Thus, when surficial distress reaches a critical level, an economical solution is to remove the very top layer and replace it to the same level.

Recent efforts in materials selection, mixture design, performance testing, and pavement design offer a methodology to 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 top structural layer with a rut resistant and durable intermediate layer and a fatigue resistant and durable base layer as shown in *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 is discussed below.

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 single axle load (ESAL)/day or greater. California uses such designs when the truck traffic exceeds 15,000 vehicles/day or the average daily traffic is greater than 150,000 vehicles/day.

Thus, it is conceivable, that with the right design approach, the use of perpetual pavements could become common on medium- and low-volume roads as well.

Mechanistic-Based Design

Currently, most pavement design procedures do not consider each pavement

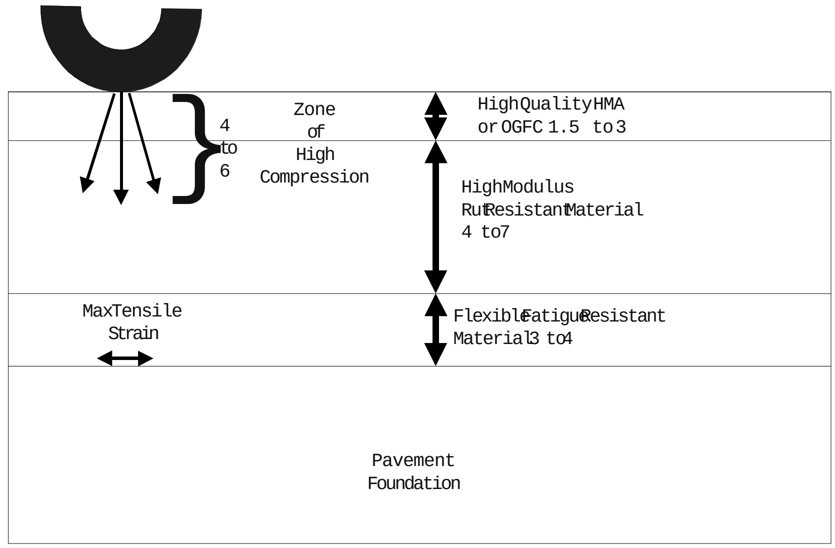

Figure1. PerpetualPavement DesignConcept.

layer to explain its characteristics 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, and a research project under the National Cooperative Highway Research Council is proceeding on the development of a new mechanistically-based AASHTO pavement design guide.

Mechanistic design is much the same as other engineering approaches used for bridges, buildings, and dams. Essentially, 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 the perpetual pavement, it would consist of providing enough stiffness in the upper pavement layers to preclude 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 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 mixtures' stiffnesses need to be optimized to resist rutting or fatigue cracking, depending upon which layer is being considered. Durability is a primary concern for all layers.

HMA Base Layer

The asphalt base layer must resist the tendency to fatigue crack from bending under traffic loads. One mixture characteristic that can help guard against fatigue cracking is a higher asphalt content *(Figure 2a)*.

Combined with an appropriate total

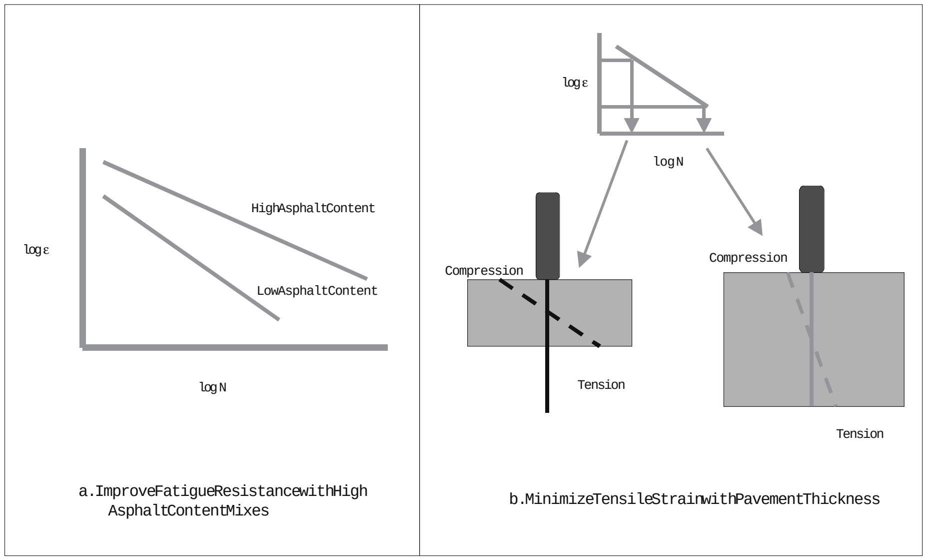

Figure2.FatigueResistantAsphaltBase.

asphalt thickness, this ensures against fatigue cracking from the bottom layer *(Figure 2b)*.

Another approach to ensuring the fatigue life would be to design a thickness for a stiff structure such that the tensile strain at the bottom of the asphalt layers would be insignificant. This would allow for a single mix design to be used in the base and intermediate layers, precluding the need to switch mix types in the lower pavement structure.

The asphalt content in the base should be defined as that which results in a density of 96 percent to 98 percent of maximum density in place. 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 to be opened to traffic during construction, provisions should be made 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 and ensuring an aggregate skeleton. One option would be to use a large nominal maximum size aggregate (1.5 inches), but the same effect could 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 would not be as severe as the surface *(Figure 3)*.

The mix design should be a standard Superpave approach, and the design asphalt content should be the optimum. Performance testing should include rut testing and moisture susceptibility.

Wearing Surface

The wearing surface requirements would depend on local experience and economics. In some cases the need for rutting resistance, durability, impermeability, and wear resistance would dictate the use of SMA. This might be

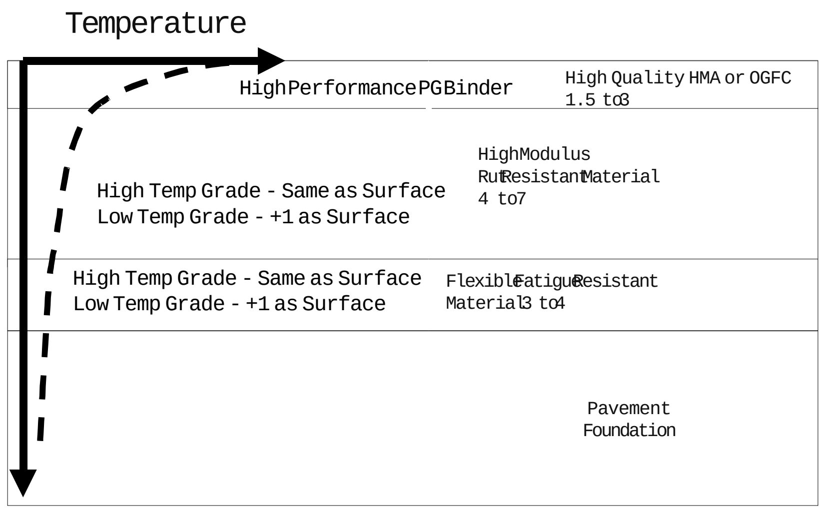

Figure 3. Impact of Temperature Gradient on Asphalt Grade.

especially true in urban areas with high truck traffic volumes. Properly designed and constructed, an SMA 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 mixture. Maryland reports that in-place voids for this type of mixture 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 mixture might be more appropriate. As with the SMA, it will be necessary to design against rutting, permeability, weathering, and wear. It is recommended that a performance test be done during mixture design; at a minimum, this should consist of rut testing.

The PG grade should be bumped to at least one high-temperature grade greater than normally used in an area. To resist thermal cracking, the low-temperature grade should be that normally used for 95 percent 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.

In the process of building the roadway, modern methods of testing should be employed to give continuous feedback on the quality of materials and construction. The foundation must be able to support paving and compaction operations. This layer must be well-compacted, smooth, and stiff enough to support construction traffic and provide resistance to rollers.

In service, it is necessary to minimize volume changes in the foundation layer due to swelling soils or frost heave. Local experience best dictates how to handle these situations. Weakening during certain seasons of the year also need to be addressed. It might be necessary to provide drainage or a granular interlayer to ensure a consistent foundation during the service life. Michael Nunn, of the British Transport Research Laboratory, suggests a minimum design modulus of about 7000 psi for the foundation layer.

Typical of modern HMA pavements, good construction practices ensure good performance. With the possible use of polymer-modified asphalts, it will be critical 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 asphalt binders.

Segregation in coarse aggregate mixtures 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 HMA can be done by following the lessons learned during the implementation of Superpave and the successful applications of SMA.

Volumetric control of the mixtures by the contractor will be the key to consistency and quality in the final product. The contractor should have access to a fully equipped and

Monitoring Performance

staffed quality control laboratory. Periodic testing and data analysis with good quality control and inspection techniques will ensure that the desired characteristics will be imparted into the pavement.

To maintain the perpetual pavement concept, it is necessary to periodically monitor the pavement performance in order to keep all forms of distress in the top few inches of the pavement. Thus, distresses such as top-down fatigue cracking, thermal cracking, rutting, and surface wear must be confined to no deeper than the original thickness of the wearing course. Once the distresses have reached a predetermined level, the resurfacing would be programmed, and an evaluation of the pavement structure would be undertaken.

In the event that certain characteristics may have changed, such as a weakening of the underlying soil through increased moisture

Resurfacing

content, a slight additional thickness may be planned for the resurfacing to ensure the perpetual nature of the structure.

The first step in the resurfacing process is the removal of the existing surface to the depth of the distress. The milled material would then be replaced, and, if needed, a slight additional thickness would be placed. This new layer would have at least the same rut resistance, durability, thermal cracking resist-

Summary

ance, and wear resistance as the original surface.

New and more promising technology in asphalt surfacing materials could be employed as it becomes available. Pavement monitoring and the programming of future resurfacings would proceed as before.

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

The intermediate layer provides rutting resistance through stone-on-stone contact and the durability is imparted by the proper selection of materials.

The uppermost structural layer has the qualities of resistance to rutting, weathering, thermal cracking, and wear. SMAs or dense-graded Superpave mixtures provide these qualities.

The knowledge and engineering capa-

References

Brown, E.R., *Experience with Stone Mastic Asphalt in the United States, Report No. 93-4*, National Center for Asphalt Technology, Auburn University, Alabama, 1993.

Design and Construction of Stone Matrix Asphalt Mixtures, Report No. 425, National Cooperative Highway Research Program, Transportation Research Board, 1998.

Hughs, C., *Designing and Constructing SMA Mixtures - State-of-the-Practice, QIP 122*, National Asphalt Pavement Association, Lanham, Maryland, 1999.

Nunn, M.E., A. Brown, D. Weston and J.C. Nicholls, *Design of long-life flexible pavements for heavy traffic, Report No. 250*, Transportation Research Laboratory, Berkshire, United Kingdom, 1997.

Performance Graded Asphalt, SP-1, The Asphalt Institute, Lexington, Kentucky, 1996.

Superpave Mix Design, SP-2, The Asphalt Institute, Lexington, Kentucky, 1997.

Thickness Design - Asphalt Pavements for Highways and Streets, MS-1, The Asphalt Institute, Lexington, Kentucky, 1981.

Notes

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