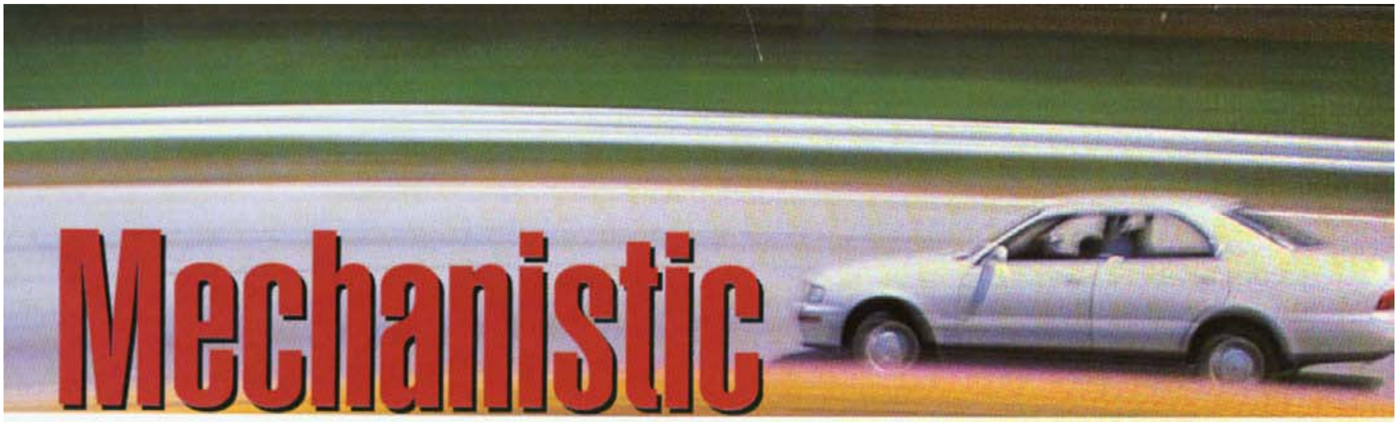


Mechanistic Pavement Design:

The Next Wave

By David E. Newcomb and Dr. David H. Timm

Hot Mix Asphalt (HMA) technology has changed dramatically in the last two decades. The advent of QC/QA procedures brought a recognition that control of product variation resulted in product improvement. The development and implementation of the Superpave binder specifications and mixture design system have provided the industry with a more uniform and, generally, a more thorough materials selection and proportioning method. The next change in HMA technology will be the introduction of an improved method for designing the pavement structure.

An effort is underway by the National Cooperative Highway Research Program to develop a new pavement design guide by 2002. It is anticipated that this new design procedure will replace the 1993 version of the AASHTO pavement design guide. It is mandated that the new 2002 guide be based upon mechanistic principles, meaning that the performance equations from the AASHTO Road Test of the late 1950s will not dictate the pavement design as they have in the past. Layer coefficients will no longer be assigned to determine the structural number of an asphalt pavement. The new design guide is being developed for both asphalt and concrete pavements.

This article and ones to follow in subsequent editions of *HMAT* are intended to introduce the concepts of mechanistic pavement design and to discuss its features. It is important for the Hot Mix Asphalt industry to become acquainted with this technology to understand how it will impact decisions concerning the design and construction of flexible pavements.

Background

Mechanistic pavement design simply means that a model is used to calculate the reaction of the pavement to traffic loads. This is the same principle used in designing buildings and bridges. Equations are used to determine the deflections and strains resulting from loads imposed on columns and beams. In pavements, the equations used are a little more complicated but the concepts are the same.

The analysis methods employed in mechanistic pavement design date back to the 1920s. Charts and tables for computing stresses and strains in asphalt pavements were developed in the 1950s. Computer programs became available in the 1960s, but it wasn't until the widespread use of personal computers in the late 1980s that mechanistic design of pavements began to be implemented by agencies. States such as Washington and Illinois use mechanistic pavement design on a regular basis, and many other states use it to check the reasonableness of their standard design procedures.

The biggest advantage to mechanistic design is not that it will result in radically different pavement sections, but that it will allow a rapid analysis of the impact of changes in such items as materials and traffic.

Figure 1 shows the basic idea of mechanistic pavement design. In order to simplify the discussion, the sections of this article will correspond to the numbered areas in the flow diagram.

1. Pavement Structure and Material Properties

The pavement is comprised of one or more layers of material placed on the prepared soil or subgrade. Each layer is defined in the model by its thickness and its modulus or stiffness as shown in *Figure 2*. The pavement model most commonly used is called a layered elastic model, meaning that the layers are comprised of different materials, such as clay for the subgrade, crushed rock for the base, and one or more layers of HMA for the surface. The term elastic means that once a pavement has been loaded and it deforms, it then regains its original shape when the load is removed.

2. Material Properties

The modulus of elasticity of each layer will vary according to the climatic conditions. In the summer, the HMA modulus due to the asphalt binder will be lower than in the winter, since its stiffness decreases as temperature increases. The subgrade and aggregate base moduli will change with moisture content and whether or not it is frozen or thawed. *Figure 3* shows how the layer moduli would change according to the weather conditions in certain times of the year. The combination of layer thicknesses and moduli dictates the pavement's reaction to vehicle loading.

3. Traffic Loading

The load of any given set of tires is expressed in terms of the tire contact pressure, the weight each tire supports, and the number of tires. *Figure 2* shows half of an axle with dual tires, each tire supports 5,000 lbs. and has a pressure of 100 psi. Along with the loads imposed by individual vehicles, the number of loads must be considered. One load or vehicle by itself rarely causes the pavement to fail. Rather, damage in the pavement is usually accumulated over hundreds of thousands or millions of load repetitions. Thus, the traffic

Figure 1

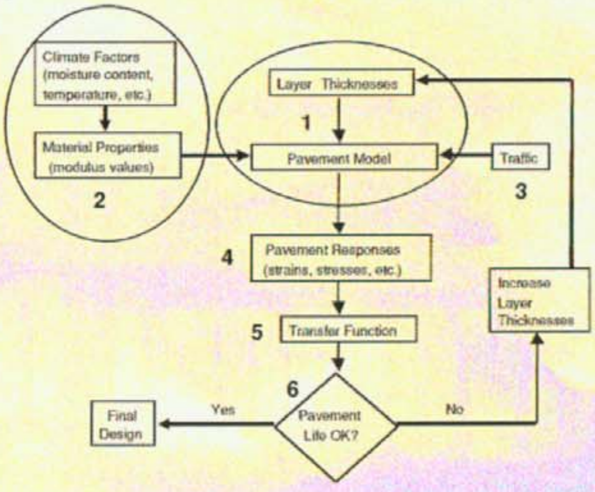


Figure 1. Flowchart of mechanistic design process.

Figure 2

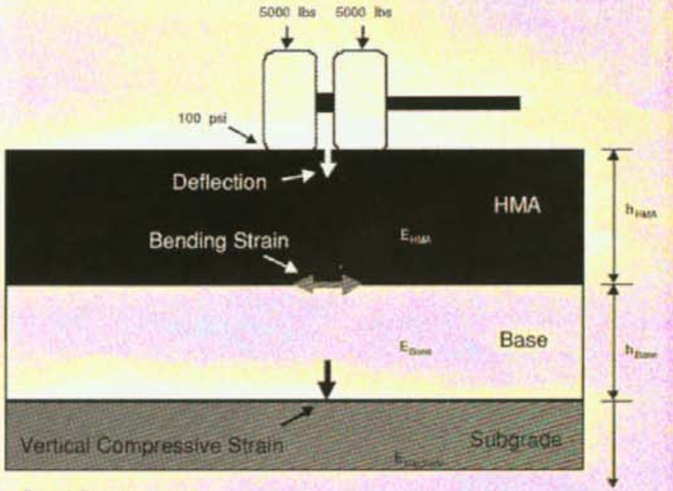


Figure 2. Pavement structure.

Figure 3

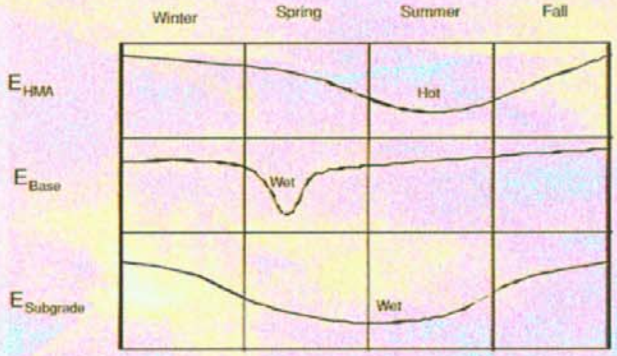
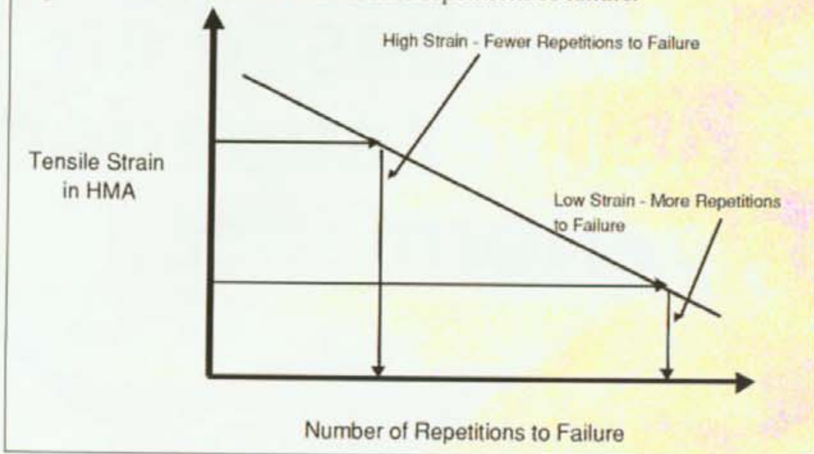


Figure 3. Modulus values changing with climatic conditions.

Figure 4 Strain versus number of load repetitions to failure.



must be described by the variety of loads and by the number of repetitions of those loads over the design life of the pavement.

4. Critical Points in the Pavement

There are a few points and pavement responses that are considered "critical" in mechanistic pavement design. In *Figure 2*, for example, the critical locations are at the top of the pavement, bottom of the HMA layer and at the top of the subgrade. The surface deflection is related to the overall strength of the pavement section. The tensile strain at the bottom of the HMA layer is related to fatigue cracking that starts there and grows upward to the surface. The vertical strain at the top of the subgrade is related to rutting due to an overall weak pavement structure, which is different from rutting that occurs near the pavement surface.

Fatigue cracking and deep structural rutting are considered the most significant forms of pavement distress since they may require very expensive rehabilitation processes including removal of a significant portion of the pavement structure. Thus, in mechanistic design, the idea is to preclude these modes of pavement failure during the design life. This is a little different than the Perpetual Pavement (*HMAT*, November/December 2000) concept where the idea is to avoid these distresses altogether.

5. Transfer Functions

Whether the pavement will last its design life without fatigue or structural rutting is determined by the "Transfer Functions." The transfer functions are simply equations that relate the pavement responses (like strains) to the number of load repetitions to failure. Failure being some pre-selected level of distress such as rut depth or area of fatigue cracking. *Figure 4* shows how the tensile strain at the bottom of the HMA layer may be related to the number of loads to failure. The lower the strain, the greater the number of allowable loads before fatigue cracking reaches an unacceptable level. While the idea of a transfer function is simple, trying to define it from the performance of in-service pavements is difficult. It is frequently viewed as the "weakest link" in the mechanistic design system.

6. Obtaining the Pavement Design

If the pavement structure is found to be sufficient to last for the design life according to the transfer function, then the design is considered final. If it is not adequate, then one or more pavement layers must be thickened and the analysis in *Figure 1* is repeated until a suitable structure is found.

Summary

This article has presented an overview of the mechanistic pavement design process. In coming editions of *HMAT*, the components of mechanistic design will be discussed, along with actions needed by the industry to prepare for the introduction and implementation of mechanistic design.

Next Month: A Homogenized, Icey-tropic Half-what?

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Why use mechanistic pavement design?

The argument can be made that the current pavement design procedures, based on the AASHO Road Test, have served satisfactorily in providing pavement structures that have lasted their design lives and longer. Why, then, is there an interest in changing to a new procedure? The following advantages are some of the reasons for using mechanistic pavement design:

- It allows an evaluation of changes in vehicle loading on pavement performance;
- New materials can be evaluated through their design properties;
- The impact of variability in construction can be assessed;
- Actual engineering properties are assigned to materials, rather than nebulous layer coefficients or gravel equivalencies;
- Pavement responses related to actual modes of pavement failure are used, rather than one generic model based solely on pavement roughness; and
- Material databases for updating pavement design input values can be developed and built as information becomes available.