1 Introduction

1.1 Pavement Design Focus

The pavement structural design process consists of determining whether a proposed assemblage of layered materials will perform as expected when subjected to a specified number and intensity of vehicle load cycles. This process is often termed layer thickness design because the designer starts by defining each layer of a pavement structure using known material properties and assumed layer thicknesses. The designer then calculates whether the pavement structure will withstand the required vehicle loadings (design loadings).

This manual addresses the design of flexible pavements, i.e., those having an asphalt concrete surface. These methods cannot be used for designing pavement structures surfaced with rigid Portland cement concrete. In the simplest designs, asphalt concrete will serve only as the topmost layer of the pavement structure. In more complex designs, asphalt concrete will often be used as an overlay on existing pavements and/or in the form of an asphalt-treated base course.

Two methods for pavement structural design are presented here. The Excess Fines method and the Mechanistic-Empirical method. The Excess Fines method is useful for designing low volume roadways while the mechanistic method is appropriate for roadways with higher traffic volumes.

This manual and computer program combination will not turn the neophyte engineer into a pavement structural design expert. Other engineering skills are needed, many of which are covered minimally or not at all here. The expert pavement structure designer will have accumulated expertise in economic analysis; construction methods; materials science, including laboratory test procedures and test-data interpretation; hydrology; geological and engineering evaluation of aggregate sources; and asphalt concrete and asphalt cement technology.

The designer must realize that poor foundation conditions and other geotechnical or drainage problems profoundly affect the performance of pavement structure, regardless of the quality of the pavement design. The designer must therefore actively seek help from technical specialists. Design measures that tackle drainage problems, foundation problems, slope stability, and erosion usually require consultation with the Regional subject matter experts. Regional Materials personnel will also help with designs that must address special Alaska problems such as ice-rich permafrost and muskeg with the associated use of special materials such as insulation and geotextiles.

1.2 Background

The *Alaska Highway Preconstruction Manual,* Chapter 11(1), Section 1180 (Pavement Design) is found at:

http://www.dot.state.ak.us/stwddes/dcsprecon/assets/pdf/preconhwy/chapters/chapter11.pdf

This chapter refers designers to AKFPD as the Department’s pavement structure design procedure. AKFPD has its root base on the Excess Fines Method developed in the 1980’s and adopted by DOT&PF in 1983 and the Mechanistic Design method first proposed in the late 1980’s. Shortly, thereafter, the mechanistic design method became the method of choice for DOT&PF.

Although it is now considered to have limited usefulness, the excess fines method’s easily understood concepts and simple computations made it the favorite tool for designing highway pavements on low volume roads. Limitations are inherent because the excess fines method was empirically derived using only highway data.

Therefore, the excess fines method cannot be used for any pavement structures that will be subjected to anything other than normal highway vehicle loadings. Because of its empirical origin, the excess fines method cannot be applied to designing pavement structures that will contain unusual materials. This includes any materials other than the standard road-building types like those that characterized the original database.

On the other hand, the mechanistic method easily handles a variety of material types and vehicle load configurations. DOT&PF officially recognizes mechanistic design as not only the more comprehensively useful tool but as the more defensibly "correct" of the two analytical methods. The term *mechanistic design* is a generic one, implying that the pavement structure is objectively analyzed as a mechanical system of elastic layers. Be aware that the mechanistic pavement design process could be done in a variety of ways, only one of which has been developed for use in Alaska.

Chapters 3 and 4 cover, in detail, the basics of the excess fines method and mechanistic method, respectively.

Regardless of which design method you use, economics will remain a chief concern. As in any engineering discipline, the design engineer must design a pavement structure that cost-effectively meets the intended need. To do this, the designer must consider life-cycle costs. Life-cycle costs include all costs associated with constructing, maintaining, and rehabilitating the pavement structure through a defined period of service (the analysis period). Chapter 8 provides a complete description of the life-cycle cost analysis procedures preferred by DOT&PF.

1.3 The "Pavement Structure"

Vehicles are not supported by the hot asphalt concrete surfacing material alone. Much of the support comes from the bound layer (asphalt cemented) and unbound material below. This brings up a few questions: (1) What total thickness of material supports the load? (2) What quality of material is required within this thickness? (3) What happens if poor quality materials are used within this thickness?

The asphalt concrete layer is the top layer or wearing course of a pavement structure. Pavement structure is an important concept, defined for our purpose as the total thickness of material that "feels" significant compression stresses (and therefore strain) under the design vehicle's wheel loading, i.e., the material that must support that load. Material at the surface (asphalt concrete surfacing) and material close to the surface (base course) will be subjected to relatively high compression stresses and therefore high levels of strain. Stresses and strains due to vehicle loadings are distributed laterally within the pavement structure and attenuate quickly with depth. The influence of a standard vehicle loading is attenuated to such a degree that at about 10 feet below the surface, stresses and strains are about zero. A good discussion of stress distribution through uniform and layered soil structures can be found in almost any soils engineering textbook.

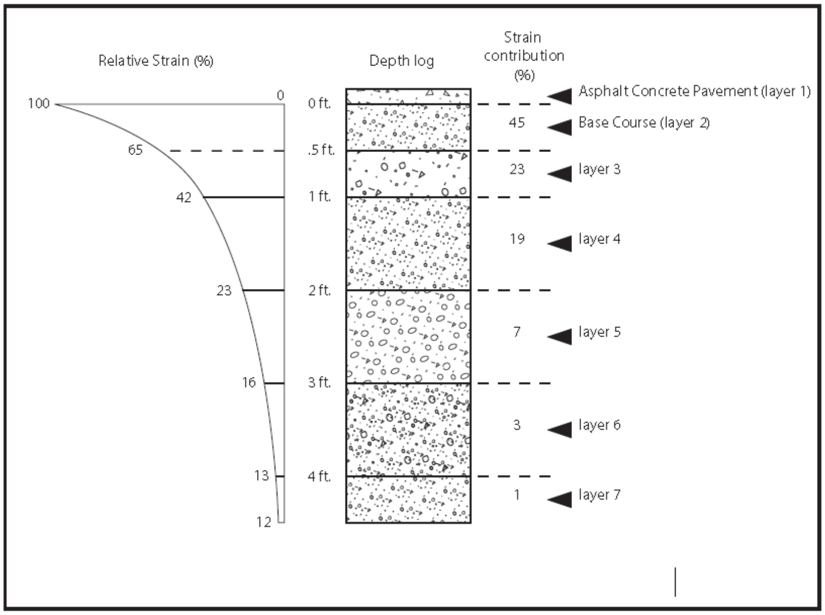

Figure 1-1 Strain Distribution with Depth

The empirically derived rule-of-thumb adopted for use in Alaska is that normal highway loads are carried by the hot asphalt concrete plus an additional 3.5 feet of layered structural materials. Alaska's excess fines design method specifically defines the pavement structure based on this rule-of-thumb.

The excess fines method therefore requires that all material to a depth of 3.5 feet below the bottom of the asphalt concrete layer be accounted for in every pavement design analysis.

Figure 1-1 illustrates how strains are distributed within a typical pavement structure. The required load-carrying capacity of each layer is directly related to the strain contribution of that layer. Layers having the largest strain contributions must therefore be of highest quality (stiffest) to minimize pavement bending and resultant damage. Both the Excess Fines design method and the Mechanistic Design method recognize this, but they handle the integration of this relationship in different ways.

1.4 Excess Fines Design Method

Alaska research strongly suggests that the quality of unbound aggregate materials within the pavement structure is mostly controlled by the percentage of fines (weight percent of particles finer than the #200 sieve, also known as P_{200}, minus 75 micron, or $P_{0.075\ mm}$). The P_{200} content correlates with the aggregate's ability to support vehicular load, especially during the springtime thaw period. The general relationship is low P_{200} content = good support and high P_{200} content = poor support. The P_{200} content matters less as depth below the asphalt concrete pavement surface increases. At a depth greater than 3.5 feet, a high P_{200} content is acceptable (assuming standard highway-type loadings).

The Excess Fines design method combines the relationship of P_{200} to performace at depth and the strain distribution at depth to estimate the surface deflection under a standard 18kip single axle loading. Using the estimated deflection, the fatigue life of the asphalt concrete surface can be estimated. This procedure works well as long as the underlying assumptions of the procedure are met. The Excess Fines methodology is discussed in more detail in Chapter 3.

1.5 Mechanistic Design Method

The pavement structure is made of up elastic layers with a known thickness, stiffness or modulus and Poisons ratio. Knowing these three parameters, it is possible to compute the stress, strain and deflection at any point below and at any offset from vertical for any surface loading. Using the stresses and/or strain at strategic points in the pavement structure in conjuction with emperically derived equations, the number of cycles to failure can be estimated for each layer. If the estimated number of cycles to failure for each layer are greather than the number of cycles imposed on that layer, then the pavement structure can be expected to perform as designed. By varying the material and the thickness of those materials, the designer has an infinite number of possibilities to choose from. The goal is to select the most cost effective combination. It it important to realize that the most cost effective design may not be the design with the lowest first cost.

As the designer gains experience, finding the best combination becomes easier. The mechanistic procedures are fully described in Chapter 4. The AKFPD software makes complex computations simple. With a little practice, the designer will be able to find a cost effective solution in short order.

1.6 Pavement Drainage

It is often said that the first dollar spent in the construction of a roadway should be spent on drainage. Water has a greater impact on the performance than the materials selected or their thickness. Too much water reduces soil strength, increases the thaw rate of permafrost under the roadway and may increase the chances of spring thaw weakening. Even asphalt pavement itself will be damaged by standing water.

Avoid premature pavement failures by providing proper drainage. Refer to the *Alaska Highway Preconstruction Manual,* Chapter 11, Section 1120.5. Drainage, for basic guidelines:

http://www.dot.state.ak.us/stwddes/dcsprecon/assets/pdf/preconhwy/chapters/chapter11.pdf

DOT&PF's *Highway Drainage Manual*(2) is also available at a

http://dot.alaska.gov/stwddes/desbridge/pop_hwydrnman.shtml

Pavement designs must provide for surface and subsurface drainage of moisture away from the pavement surface and supporting layers.

For driver safety, the less water on the road surface the better. The pavement design engineer must be able to identify any points on the pavement where standing water or sheet flow is enough to cause hydroplaning and skidding. This requires strategies for eliminating standing water and minimizing the film thickness of moving water on the pavement surface. Typical strategies include increasing cross slope, adding drainage inlets, adding culverts, increasing ditch depth, or grooving the pavement. Paved shoulders help move water away from the pavement structure.

For structural reasons, the less free water in the pavement structure the better. Drainage ditches must be large enough to store the annual snow accumulation as well as move the water away when the snow melts. Ditches must keep water moving away from the pavement structure during rainstorms. This requires careful attention to ditch grades and cross drainage, especially in areas of sag curves.

Additional pavement drainage design references and information can be found at:

- Subsurface Water and Drainage Requirements (Section 7.2 of "Geotechnical Aspects of Pavements" Reference Manual FHWA-NHI-05-037)(3):
  https://www.fhwa.dot.gov/engineering/geotech/pubs/05037/05037.pdf

- Improved Surface Drainage of Pavements, NCHRP Web Document 16(4)
  https://www.nap.edu/read/6357/chapter/1

- Pavement Subsurface Drainage Systems, NCHRP Synthesis 239(5)
  http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_syn_239.pdf

- Drainage Requirements in Pavements(6)
  http://onlinepubs.trb.org/onlinepubs/archive/mepdg/Part3_Chapter1_Subdrainage.pdf
  http://onlinepubs.trb.org/onlinepubs/archive/mepdg/2appendices_TT.pdf
  https://www.fhwa.dot.gov/pavement/pubs/010942.pdf

- Effects of Subsurface Drainage on Pavement Performance, NCHRP Report 583(7)
  http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_583.pdf