Alaska Department of
Transportation
and Public Facilities

Alaska Flexible Pavement Design Manual

DOT&PF Research Report FHWA-AK-RD-03-01, Effective April 1, 2004

Preface

This manual guides the designer through a comprehensive computerized method for thickness design of asphalt concrete pavements in Alaska. The Alaska Flexible Pavement Design method (AKFPD), a computer program, replaces a collection of pavement design tools previously used by DOT&PF engineers and is intended to be applied to all but the most complicated designs. The manual also replaces most of the information that was formerly contained in the Alaska DOT&PF *Preconstruction Manual*, Chapter 11, Section 1180.

The purpose of this manual is to help the pavement designer produce good pavement design recommendations.

- The manual contains general engineering background to help the designer understand basic principles of the AKFPD design process and how the program itself works.
- The manual describes all functional capabilities of the AKFPD program and provides step-by-step design examples.
- The manual provides specific guidance on input variables and other decision criteria required to run AKFPD.

Finally, the manual also presents some of the broader aspects and policies bearing on the general pavement design process.

This work was funded by the U.S. Department of Transportation, Federal Highway Administration. It is being published under report no. FHWA-AK-RD-03-01.

Prepared for the Alaska Department of Transportation and Public Facilities

Robert L. McHattie, P.E.
Inkworks
2324 Waterford Road
Fairbanks, AK 99709

Table of Contents

Figures and Tables

1. Introduction

1.1. Pavement Design Focus

The pavement design process as it is presented in this manual is narrowly defined. It consists of determining whether a proposed layered assemblage of materials (the pavement structure) will adequately perform if subjected to a specified number and intensity of vehicle load cycles. This process is often termed pavement thickness design because the designer usually starts by defining each layer of a candidate pavement structure using known material properties and an assumed layer thickness. 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 pavement designs, asphalt concrete will serve as only the topmost material layer of the pavement structure. In more complex designs, asphalt concrete will often be used as an overlay layer for existing pavements and/or in the form of an asphalt-treated base course.

As a stand-alone tool, this manual and computer program combination will not turn the neophyte engineer into a pavement design expert. Other engineering skills are needed as well, and many aspects of the general pavement design process are covered minimally or not at all here. The expert pavement 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 problems can profoundly affect the performance of pavement, regardless of the quality of the pavement thickness design—and often to a far greater extent than the thickness design itself. The pavement designer must therefore actively seek help from technical specialists. Design measures that tackle drainage problems, foundation problems, sloping stability, and erosion usually require consultation with the Regional Materials Section. Regional Materials personnel will also help with designs that must address special Alaska problems such as ice-rich permafrost, muskeg, and with the associated use of special materials such as insulation and geotextiles.

1.2. Background

Before creating the AKFPD computer program covered in this manual, Alaska DOT&PF used three separate computer programs for designing pavement layer thicknesses for asphalt pavement structures. One of the older programs (AKPAVE98) covered layer thickness design by Alaska’s empirically developed “excess fines” method. The two other computerized methods, PAVEINFO and AKOD98, were used for calculating pavement design thickness using what are considered the more advanced methods of mechanistic design (based on layered elastic theory). As two of the program titles indicate, the last significant program updates were in 1998.

Until the AKFPD program and manual became available, the most complete and continually updated source of pavement thickness design information was contained in the *Alaska Preconstruction Manual,* Chapter 11, Section 1180 (Pavement Design). **This manual contains most items of pavement design technology and policy previously covered in the *Preconstruction Manual*.**

During the late 1970s and early 1980s, the State of Alaska began almost simultaneous development of two quite different methods of doing thickness design for asphalt concrete pavements. Today the two design methods are commonly referred to as

- the excess fines design method and
- the mechanistic design method.

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 since its 1983 adoption by the department. Limitations are inherent because the excess fines method was empirically derived using only highway data. Therefore, the excess fines method cannot be used for designing aircraft runway pavement structures (or any other pavement structures for that matter) that will be subjected to 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 similar to those that characterized the original database.

On the other hand, the mechanistic method is capable of easily handling a huge variety of material types and vehicle load configurations and is the method of choice for designing overlays of existing pavements. 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. For some time DOT&PF has required that designs using the excess fines method be checked using mechanistic methods whenever the design traffic loadings are very high (see Sections 2.2. and 2.3 for policies regarding selection of design method).

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 pavement 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). The Federal Highway Administration (FHWA) recommends a minimum analysis period of 35 years. Economic impact on the public (user costs) must be included in life-cycle cost calculations whenever possible.

1.3. Introducing an Important Concept: The "Pavement Structure"

Vehicles are not supported by the asphalt concrete surfacing material alone. Much of the support comes from some thickness of bound (asphalt cemented) and/or unbound material under the asphalt concrete surface layer(s). 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 pavement is the top layer 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 strong 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.

The empirically derived rule-of-thumb adopted for use in Alaska is that normal highway loads are carried by the asphalt concrete pavement plus an additional 3.5 feet of layered pavement 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 pavement be accounted for in every pavement design analysis. For very heavy design loads, including heavy aircraft, the total thickness of materials influenced significantly by the live load can substantially exceed the 3.5-foot rule-of-thumb, and pavement designs should be done using the mechanistic method because it has no inherent limitations on materials thickness.

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) in order to minimize pavement bending and resultant damage.

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 usually controls 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 geotechnical purist may argue that the minus 0.02 mm (also known as minus 20 micron or $P_{0.02\ mm}$) size fraction, rather than the P_{200} size fraction, controls freeze/thaw-related seasonal aggregate strength characteristics. The relationship between frost susceptibility of materials (therefore thaw-weakening) and $P_{0.02\ mm}$ derives from A. Casagrande's early research into the frost heave phenomena[1] determined that soils containing less than 3% $P_{0.02\ mm}$ are usually non-frost-susceptible (NFS). Since the 1970s, DOT&PF engineers have adopted their own NFS criterion, and DOT&PF recognizes P_{200} content as a useful indicator of frost susceptibility for pavement design purposes. DOT&PF now classifies most natural soils and manufactured aggregates containing $\leq$6% P_{200} as NFS.

Interestingly, gradation data from many Alaska soils and aggregates indicates that the $P_{0.02mm}$ content usually runs approximately half the P_{200} content. It is therefore no surprise that material containing 6% or less P_{200} (therefore likely containing 3% or less $P_{0.02mm}$) should be classified as NFS. The question remains: If the original Casagrande criterion successfully defines the NFS condition, why has DOT&PF chosen to rely on the P_{200} content? The reason is that it is much easier to measure the P_{200} content of a sample (requires only sieve analysis) than it is to measure the $P_{0.02\ mm}$ content (requires hydrometer analysis).

Depending on traffic intensity, weather, and groundwater level, excess P_{200} will cause springtime softening in layers supporting the asphalt concrete pavement. If softening occurs, visualize the situation as a cracker (the asphalt concrete pavement) on a thick layer of cream cheese—the pavement is unsupported and highly vulnerable to imposed vehicle loads under these conditions.

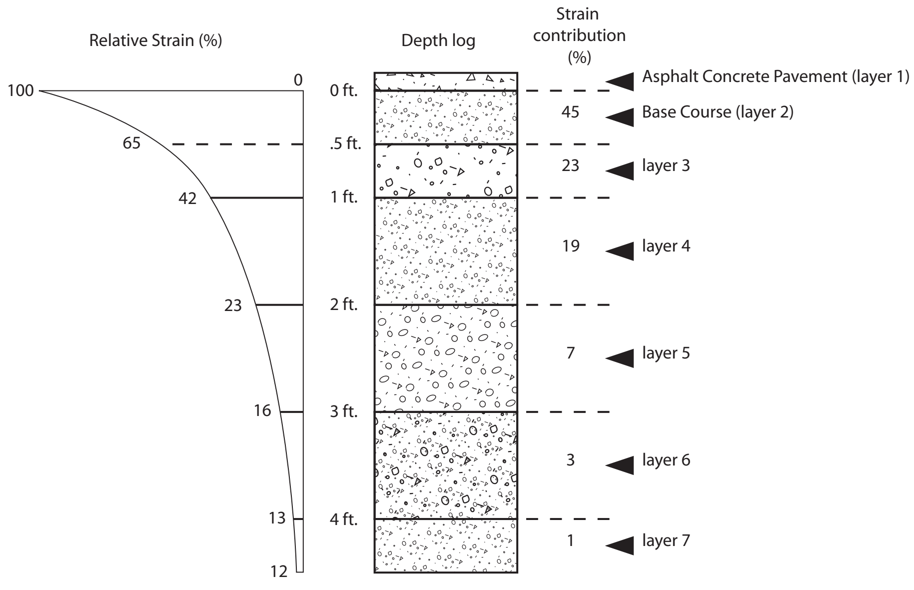


Figure 1-1. Strain Distribution With Depth

1.3.1 Characterizing Materials Within the Pavement Structure as Input for the AKFPD Program

This manual provides the designer with methods for determining the thickness of pavement structural layers in new construction projects and overlay for pavement rehabilitation projects. Design procedures presented here require design inputs that accurately represent real loadings and materials conditions. Considerable engineering judgment is required to properly select design inputs.

The excess fines design method handles P_{200} content in a very direct way. It uses the P_{200} content of each unbound aggregate layer as an item of input data.

The mechanistic method does not handle the P_{200} content of individual aggregate layers directly. Instead, aggregate layers are characterized in terms of their elastic properties. Specifically, these properties are repeated-load, i.e., "dynamic" elastic modulus (a measure of stiffness called resilient modulus and noted by the symbol "M_R") and Poisson's ratio (deformational characteristic, noted by the symbol "μ"). M_R is defined in Section 4.3.1 where program input values are discussed in detail.

For designing most new pavement structures, mechanistic properties of the various layers are often obtained from DOT&PF-approved tables. These tables provide reasonably accurate estimates of mechanistic properties for aggregate materials based on P_{200} content. These tables are presented with supplementary information in Chapter 5.

Values for M_R can also be obtained through laboratory testing or through the process of "backcalculation," using data collected in the field by deflection testing equipment. Derivation of mechanistic properties from laboratory tests and backcalculation is applicable mostly to the design of overlays for existing pavements. Laboratory test methods recommended for determining the M_R values of asphalt concrete and soil/aggregate materials are, respectively, ASTM D4123-82 and AASHTO T 292-97 (2000). Chapter 5 presents summaries of M_R test methods for asphalt concrete and soils/aggregates. Chapter 5 also presents an overview of the extensive field testing and other requirements associated with the process of backcalculating M_R values. Detailed explanation of the backcalculation process is far outside the scope of this manual.

2. Policies and Required Considerations in the Pavement Design Process

2.1. General Policy (GP) Statements

GP-1 Prepare a pavement design analysis for all highway projects requiring pavement construction, reconstruction, resurfacing, or rehabilitation. (See Section 2.2.4 for non-highway designs)

GP-2 The pavement design method presented in this manual is the standard for flexible highway pavement designs for the Alaska DOT&PF.

GP-3 The regional preconstruction engineer is responsible for the final pavement design. Alternate design methods may be approved by the preconstruction engineer provided rigorous analysis and hard data support those designs.

GP-4 Design pavement structures such that no seasonal load restrictions are needed.

GP-5, GP-6 and GP-7 refer to construction, reconstruction and rehabilitation projects.

GP-5 For projects with design average annual daily traffic (AADTs) volumes ≥ 10,000 without curb and gutter:

- Use Alaska Renewable Pavement (see Section 7.4.3).
- Use a 15-year design life for both the fatigue failure criterion and the functional failure criterion (see Section 4.3.2).

GP-6 For projects with AADTs < 10,000 without curb and gutter and for projects with AADTs < 5,000 with curb and gutter:

- Use no less than one layer of binder course, asphalt-treated base, or other stabilized base (see Section 7.4).
- Use a 15-year design life for both the fatigue failure criterion and the functional failure criterion (see Section 4.3.2).

GP-7 For projects with AADTs > 5,000 with curb and gutter:

- Use Alaska Renewable Pavement (see Section 7.4.3).
- Use a 30-year design life for the fatigue failure, (TAI equation, see Section 4.3.2).
- Use a 15-year analysis period for the functional failure analysis (Per Ullidtz equation, see Section 4.3.2).

GP-8 The minimum design life of resurfacing projects using the Alaska Renewable Pavement will be not less than 15 years for both fatigue life and functional failure.

GP-9 Surface treatments may be used if any of the following conditions are met:

- AADT < 1000.
- Life-cycle cost analysis supports their use.
- Unstable foundations underlie more than 60% of the project.
- Project falls under the *Gravel to Pavement* program.
- Approved by the preconstruction engineer.

GP-10 Use 2.0 inches as the minimum thickness of asphalt concrete for new pavement designs or pavement designs that involve complete replacement of the old asphalt concrete layer.

GP-11 Use 2.0 inches as the minimum thickness of new asphalt concrete overlay placed on an existing layer of asphalt concrete, or two times the maximum aggregate size, whichever is greater.

GP-12 Designs utilizing the AKFPD software will be performed by personnel (DOT&PF staff or consultant) trained in its use.

GP-13 In case of reconstruction or resurfacing of a paved roadway, consider recycling or reuse of the existing asphalt concrete material in the new structure.

2.2. Policy on Selecting the Correct AKFPD Design Procedure

2.2.1 For Designing New Highway Pavements with ESALs < 1.0 Million

The excess fines method **may be used** for designing flexible highway pavement structures if:

1. The flexible surfacing material is composed of a standard form of asphalt concrete (no inclusions of unusual aggregate types or modified asphalt cements), and
2. The P_{200} content of all non-surfacing materials within the pavement structure falls within limits allowable by the excess fines design method.

The mechanistic method **may be used** for design work or for checking excess fines designs if the project's available materials meet criteria 1 and 2 listed above.

The mechanistic method **must be used** if the project's available materials do not meet criteria 1 and 2 listed above, or if the pavement structure incorporates one or more stabilized base course layers.

2.2.2. For Designing New Highway Pavements with ESALs > 1.0 Million

Use the mechanistic method.

2.2.3. For Designing Overlays of Existing Highway Pavements

Use the mechanistic method.

1. Do not overlay existing pavements if more than 80% of fatigue life of the existing pavement is exhausted (the AKFPD program determines this mechanistically based on historical traffic).
2. Do not overlay extensively cracked pavements, typically 20% or more of the surface cracked. Assume that all cracks in the existing pavement will reappear in the overlay within two years after the overlay is placed.

2.2.4. For Non-Highway Pavement Designs

Either the excess fines or mechanistic method may be used for designing flexible non-highway pavement structures, regardless of design vehicle type and/or available materials. These types of pavement structures can include asphalt sidewalks, paths and parking/staging areas.

2.3. Policy on Base Course Stabilization

It is the Department's policy to use bound stabilized bases on all roadway construction, reconstruction and rehabilitation projects.

In developing flexible pavement designs incorporating stabilized bases, refer to policies GP5, 6 and 7 in Section 2.1. In addition use the following:

1. *Alaska Soil Stabilization Design Guide*, Report No. FHWA-AK-RD-01-6B;
2. The mechanistic design method used in the AKFPD computer program; and

3. The definition of stabilized layers as found in Section 7.4.1 of this manual.

Exceptions to this policy are as follows:

1. Projects designed under the *Gravel to Pavement* Program
2. Projects exempted in writing by the regional preconstruction engineer. Rationale for an exemption may include:
    - Projects with a low AADT
    - Areas underlain by unstable foundations such as ice-rich permafrost, where settlement results in frequent maintenance
    - Projects for which a stabilized base will not provide a cost-effective improvement in the pavement performance, reduced maintenance, or reduced future rehabilitation costs through a comprehensive life-cycle cost analysis. The period of the life-cycle cost analysis shall be 30 years.
    - Roadways designed on behalf of agencies other than DOT&PF.

3. Excess Fines Design

3.1. Introduction

This chapter provides a complete discussion of the excess fines design method. The AKFPD excess fines method is approved only for the design of some new, highway pavements. Chapter 2 provides detailed information concerning appropriate applications for this design method.

3.2. Summary of Excess Fines Design

Research leading to development of the excess fines method started in 1976 with the study of 120 asphalt concrete paved road sections throughout Alaska. Results of this research effort are described in reports published between 1980 and 1983.[2–5] An empirically derived design method was generated from this research and officially adopted for use by the Alaska Department of Transportation and Public Facilities (DOT&PF) in 1982.[6] At first, pavement design work was done by hand calculation. By about 1984, the DOT&PF engineering community was gradually introducing a number of different computer programs to handle the computations. Research focused eventually on development of a single, standardized computer program for doing excess fines design. This development process produced the presently used Microsoft Windows-based computer program known as “AKPAVE98.” With slight modification, AKPAVE98 has been incorporated into the AKFPD computer program and will be used to perform an excess fines design.

3.3. Principal Concepts

Alaska’s excess fines design method relies on the following two empirically derived concepts:

1. An empirically definable relationship exists between pavement surface deflection at the center of a standard wheel load and the service life of the pavement in terms of passes of that wheel load. In the case of highway pavement design, the design load has long been standardized in the form of the 18,000 dual-wheeled axle (tire pressure originally defined for the standard load was 80 psi—now 90 psi). This standard axle load is also known as the Equivalent Single Axle Load (ESAL).

   Service Life = f (deflection)

2. An empirically definable relationship exists between pavement surface deflection at the center of a standard wheel load and the amount of P_{200} material contained within individual layers of the pavement structure.

   Deflection = f (amount of P_{200} in aggregate layers)

Simple calculations predict deflection at the surface of the pavement structure based on the amount of P_{200} in each granular layer of the structure. Another calculation determines the thickness of asphalt concrete pavement needed to reduce the predicted deflection level to accommodate a given number of ESALs without pavement failure.

3.3.1 Relationship Between P_{200} Content and Pavement Surface Deflection (A Measure of Pavement Structural Strength)

Based on Alaska DOT&PF research cited previously[2–5] the relationship between P_{200} content and deflection is accounted for by the springtime process of thaw weakening. As wintertime cooling continues, a freezing interface or “freezing front” moves downward through the granular layers of the pavement structure. As the freezing front advances downward, soil moisture continually migrates upward toward the interface between frozen and unfrozen material. The upward transport of moisture during soil freezing satisfies energy balance requirements within the soil mass. After soil moisture reaches the freezing front, it freezes and becomes incorporated as part of the newly frozen soil mass. The process of freezing front progression, upward moisture migration, and freezing continues throughout the winter as long as appropriate temperature gradients exist in the soil. DOT&PF research correlated the amount of frozen moisture accumulating within a particular granular layer to the amount of P_{200} contained in that layer, establishing a relationship between P_{200} and frozen moisture content. Figure 3-1 illustrates the condition of the pavement structure during the freezing process.

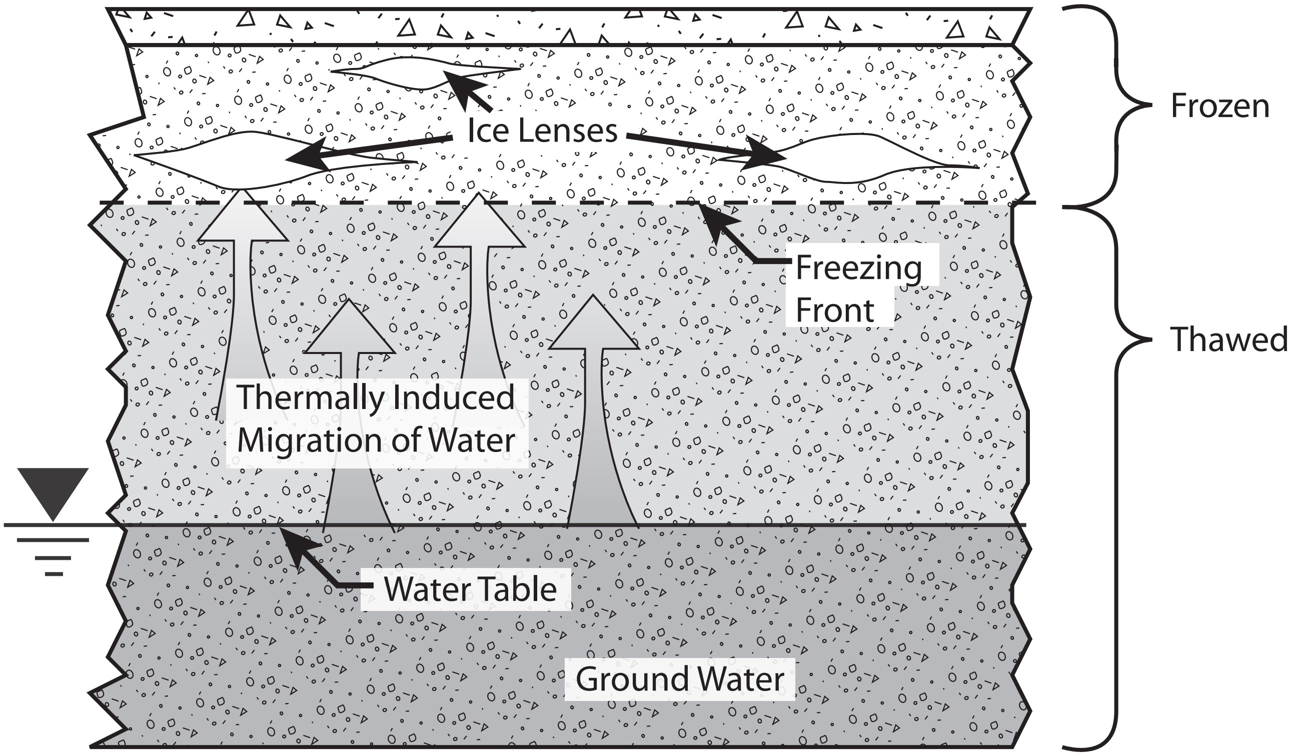


Figure 3-1. Progression of Freezing Front and Ice Formation

As common sense suggests, frozen moisture is of little concern. On the other hand, the combination of springtime thawing and high moisture content in pavement structural layers is very much a problem. DOT&PF research derived a useful functional relationship between thaw weakening of the pavement structure and the amount of P_{200} contained in various layers of the pavement structure. The indicator of thaw weakening employed during the research project was measurement of pavement surface deflection in response to a standard test load, thus establishing a relationship between P_{200} and deflection. The standard test load used during research was the one side of a standard ESAL. The dual wheel set weighed 9,000 pounds total with tire pressures set at 80 psi. Figure 3-2 shows the pavement structure weakened by thaw.

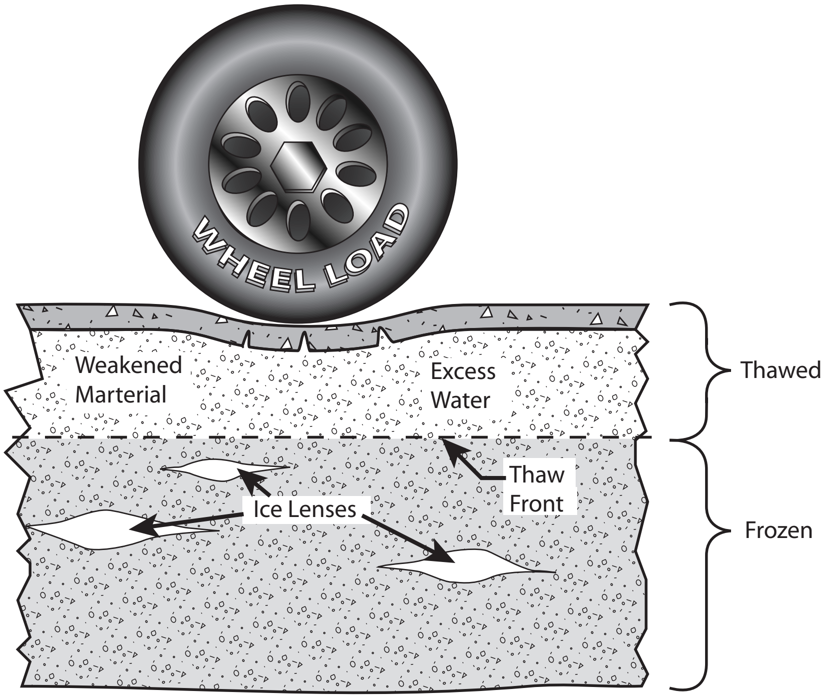


Figure 3-2. Soft Pavement Structure During Thawing

DOT&PF research refined the relationship between P_{200} and deflection by creating a function that attaches increasing importance to high P_{200} contents in upper layers of the pavement structure, which relates to the attenuating distribution of live-load stress with depth. Common sense and research provides the same conclusion: materials deep in the pavement structure “feel” almost none of the vehicle load and are therefore of less concern. Figure 3-3 illustrates the attenuation of strains (also stresses) with depth in the pavement structure.

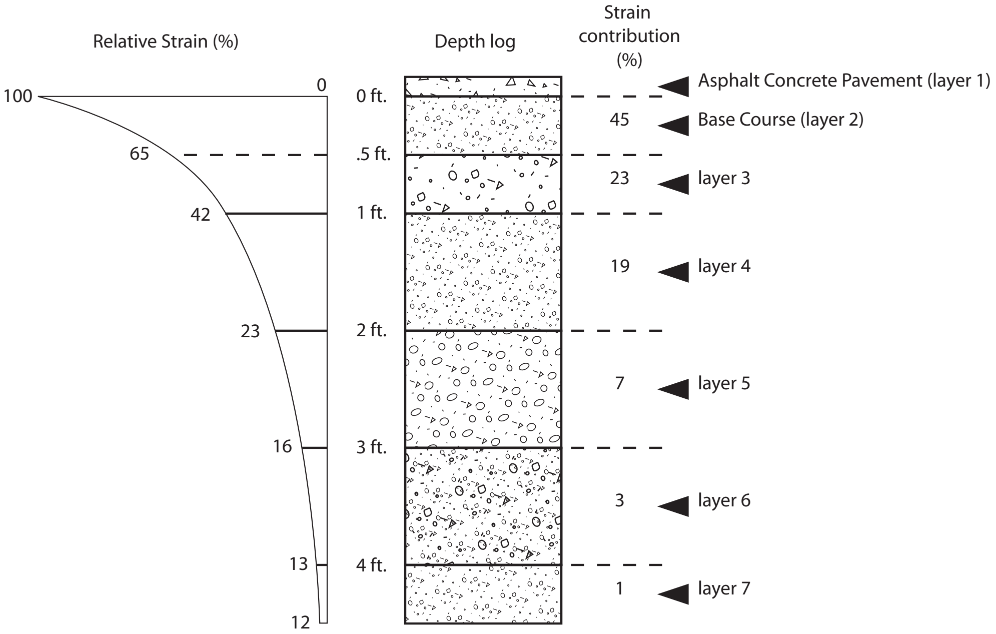


Figure 3-3. Attenuation of Vehicle Load Effect With Depth

3.3.2. Relationship Between Pavement Surface Deflection and Pavement Service Life

As explained above, DOT&PF research derived a functional relationship between aggregate layer P_{200} contents and deflection. However, an additional design step is necessary. The design process requires a relationship between calculated deflection, design ESALs, and required asphalt concrete pavement thickness. For this, DOT&PF modified and adopted The Asphalt Institute's TAI procedure from their 1977 MS-17 publication.[7]

3.3.3. Calculations Used in the Excess Fines Method

Separate each material layer into analysis layers based on the P_{200} content, with a maximum of 1-inch layer thickness. Analyze the pavement structure to a depth of 42 inches below the bottom of the asphalt concrete layer. This can include in-place material in the foundation.

Determine the critical fines content (P_{cr}) for each layer, using Figure 3-4. Enter the vertical axis with the depth from the bottom of the asphalt concrete layer to the top of each aggregate layer and move horizontally to intersect the P_{cr} line. Read the value of P_{cr} for that layer on the horizontal axis.

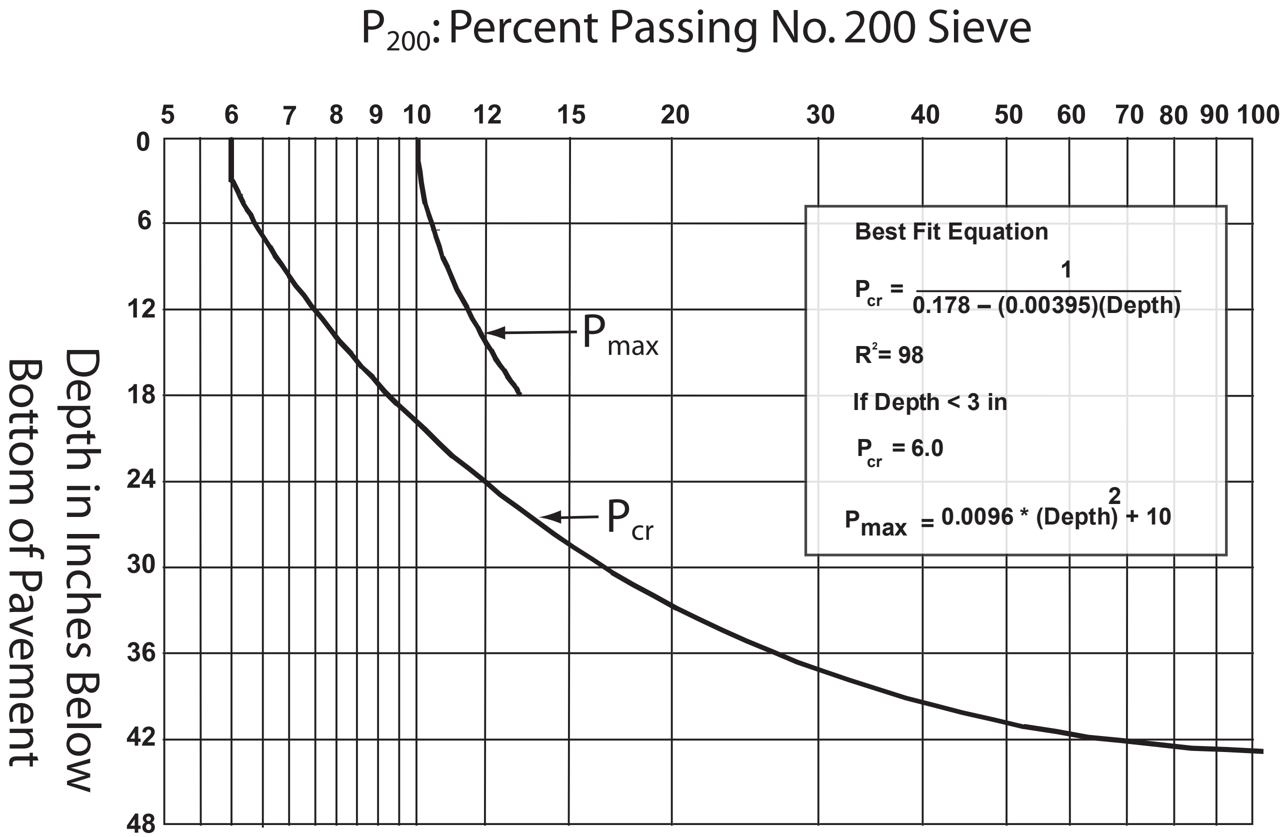


Figure 3-4. Critical and Maximum Fines Versus Depth

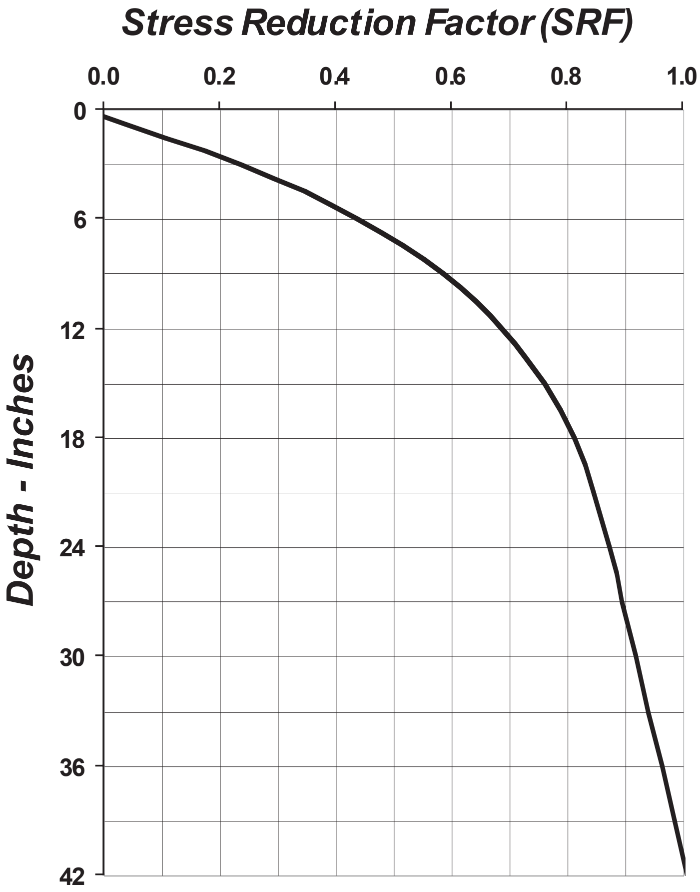
In no case shall the P_{200} exceed P_{max} for an analysis layer (i) with its top between 0 inches and 18 inches beneath the HMA (See P_{max} line on Figure 3-4).

Some materials degrade when crushed and handled. It is important that the P_{200} estimated for the base layer is the anticipated P_{200} of the crushed material after it has been placed and compacted. If the degradation value (Alaska Test Method, ATM T-13) of the material is less than 45, check with the regional materials engineer for guidance.

Calculate the excess fines for each layer (i) to the nearest tenth of a percent. If the calculated excess fines are less than or equal to zero, consider them equal to zero.

$$\text{Excess Fines (i)} = (P_{200} - P_{cr})_i$$

For each such layer (i) find the change in stress reduction factor (ΔSFR). The ΔSRF is equal to the stress reduction factor (SRF) at the bottom of layer (i) minus the SRF at the top of layer (i). SRF is presented in graphical form in Figure 3-5.



$SRF = -\,7.6477232 \times 10^{-7} y^4 + 9.7898212 \times 10^{-5} y^3 - 0.0046242158\, y^2 + 0.10298199\, y - 0.034613$

where: y = depth

(If SRF is negative, set SRF to zero)

Stress reduction vs. depth beneath a thin asphalt concrete pavement (assumes homogeneous elastic properties of materials and a standard ESAL loading).

Figure 3-5. Stress Reduction Factor

Calculate the excess fines factor (EFF_i) for each layer, i.

$$EFF_i = (\Delta\ SRF_i)\ [(P_{200} - P_{cr})_i{}^{0.8}]$$

Add all of the EFF_i values to get EFF_t, i.e., total EFF

$$EFF_t = \sum EFF_i$$

Calculate the predicted maximum deflection, Dp, according to the statistical relationship:

If $EFF_t = 0$, then $Dp = 0.034$

If $EFF_t > 0$, then $Dp = 0.056 + 0.0035(EFF_t)$

Determine the required pavement thickness. Enter Figure 3-6, with the predicted maximum deflection, Dp, on the horizontal axis, move vertically to intersect the appropriate equivalent axle loading (ESAL) curve, and read the required asphalt concrete pavement thickness from the vertical axis. The minimum pavement thickness is 2 inches. The thickness should be rounded up to the nearest .5 inch.

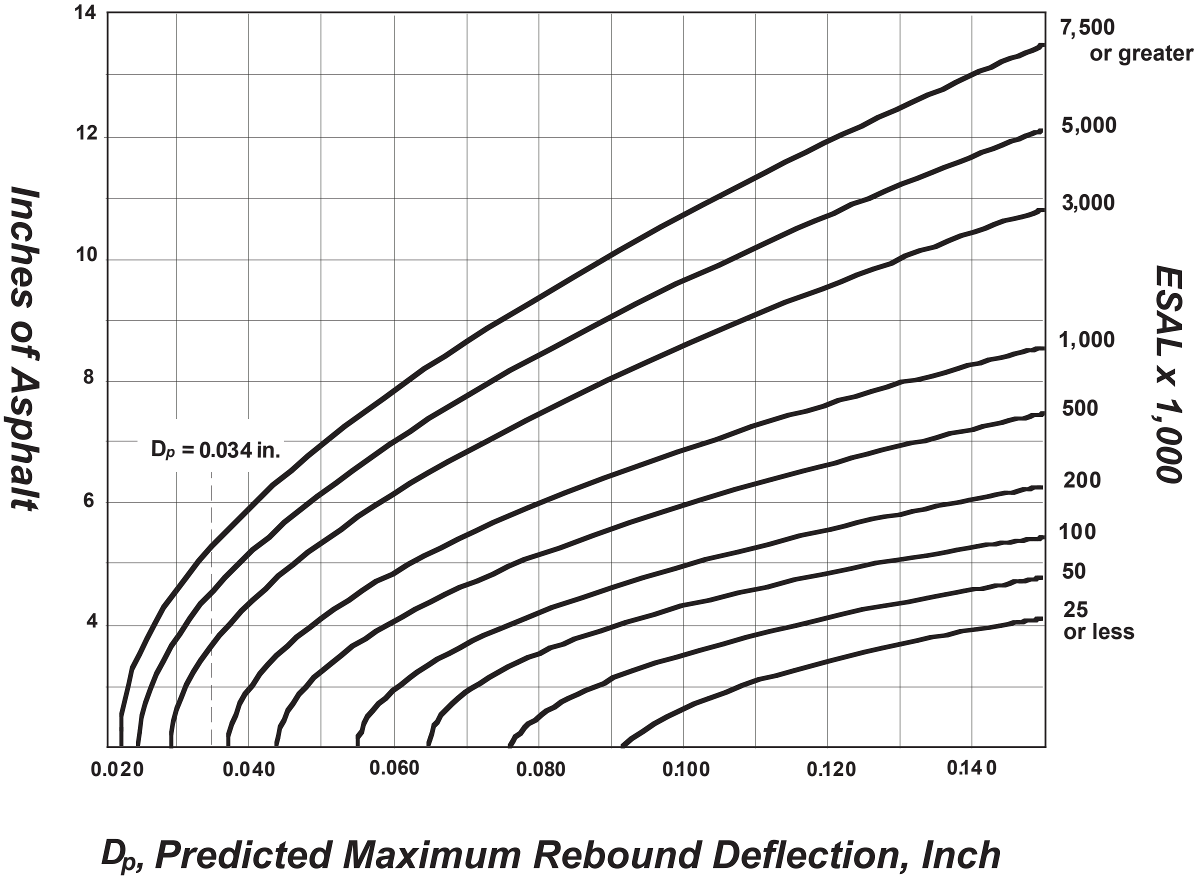


Figure 3-6. Pavement Design Chart

3.4. Stepping Through the Design Process: An Example

This example explains the excess fines design method as a series of simple computational steps. Each computational step in the example is aided by the tabular formatting shown in Table 3-1.

Step 1. Define design ESALs and a system of aggregate layers with P_{200} contents as shown below:

Layer Depth	P_{200} Content (%)
0 inch to 6 inch	8
6 inch to 18 inch	10
18 inch to 42 inch	20

Design ESALs = 1,430,000

Step 2. Subdivide actual layering into layering shown in column 1 of Table 3-1.

Step 3. Enter applicable fines content (P_{200}) in column 2 of Table 3-1.

Step 4. Determine critical fines content (P_{cr}) for each layer from Figure 3-4. Place in column 3 of Table 3-1.

Ensure that P_{200} in the upper 18 inches does not exceed P_{max} in Figure 3-4.

Step 5. Determine excess fines for each layer to the nearest tenth of a percent. Place in column 4 of Table 3-1.

Excess Fines = $P_{200} – P_{cr}$

If $P_{200} – P_{cr} < 0$, then excess fines = 0. Do not use negative values. (See layer 34 in Table 3-1.)

Step 6. Determine the change in stress reduction factor (Δ SRF) for each layer from Figure 3-5. To do this, first locate the SRF at the top of the layer and the SRF at the bottom of the layer. Place these numbers in columns 5 and 6, respectively, of Table 3-1. Then subtract the smaller number (SRF at the top of the layer) from the larger number (SRF at the bottom of the layer). This is best done by calculating the SRFs from the equation shown in Figure 3-5. Place the result for each layer in column 7 of Table 3-1.

Step 7. Determine the excess fines factor (EFF) for each layer, and place in column 8 of Table 3-1.

$$EFF = (\Delta SRF)(P_{200} – P_{cr})^{0.8}$$

Step 8. Sum the EFFs for all layers at the bottom of column 8 of Table 3-1.

Step 9. Determine the predicted maximum deflection (D_p)

EFF > 0, i.e., EFF = 2.1

Therefore: $D_p = 0.056 + 0.0035(EFF_t)$

$D_p = 0.056 + 0.0035\ (2.1)$

$D_p = 0.063$ inch (bottom of Table 3.1)

Step 10. Determine the required asphalt concrete pavement thickness from Figure 3-6.

Entering Figure 3-6 with $D_p = 0.063$ and ESALs = 1,430,000

Figure 3-6 requires pavement thickness = 5.5 inches (rounded up to nearest 0.5 inch)

Table 3-1. Excess Fines Pavement Design Example

Column	1	2	3	4	5	6	7	8
Obtained From:	**Trial Dimensions**	**Specifications or Field Data**	**Figure 3.4**	**Column 2 minus Column 3**	**Figure 3.5**	**Figure 3.5**	**Column 6 minus Column 5**	**Column $(7) * (4)^{0.8}$**
Layer Number	**Depth Interval (inches)**	**Fines Content (P_{200})**	**Critical Fines (P_{cr})**	**Excess Fines**	**SRF at Top of Layer**	**SRF at Bottom of Layer**	**(ΔSRF)**	**(EFF)**
1	0 to 1	8	6.0	2.0	0.0	0.064	0.064	0.11
2	1 to 2	8	6.0	2.0	0.064	0.154	0.090	0.16
3	2 to 3	8	6.0	2.0	0.154	0.235	0.081	0.14
4	3 to 4	8	6.0	2.0	0.235	0.309	0.074	0.13
5	4 to 5	8	6.2	1.8	0.309	0.376	0.067	0.11
6	5 to 6	8	6.3	1.7	0.376	0.437	0.061	0.09
7	6 to 7	10	6.5	3.5	0.437	0.491	0.054	0.15
8	7 to 8	10	6.7	3.3	0.491	0.540	0.049	0.13
9	8 to 9	10	6.8	3.2	0.540	0.584	0.044	0.11
10	9 to 10	10	7.0	3.0	0.584	0.623	0.039	0.09
11	10 to 11	10	7.2	2.8	0.623	0.658	0.035	0.08
12	11 to 12	10	7.4	2.6	0.658	0.689	0.031	0.07
13	12 to 13	10	7.7	2.3	0.689	0.716	0.027	0.05
14	13 to 14	10	7.9	2.1	0.716	0.740	0.024	0.04
15	14 to 15	10	8.1	1.9	0.740	0.761	0.021	0.04
16	15 to 16	10	8.4	1.6	0.761	0.780	0.019	0.03
17	16 to 17	10	8.7	1.3	0.780	0.797	0.017	0.02
18	17 to 18	10	9.0	1.0	0.797	0.811	0.014	0.01
19	18 to 19	20	9.4	10.6	0.811	0.825	0.014	0.09
20	19 to 20	20	9.7	10.3	0.825	0.836	0.011	0.07
21	20 to 21	20	10.1	9.9	0.836	0.847	0.011	0.07
22	21 to 22	20	10.5	9.5	0.847	0.856	0.009	0.05
23	22 to 23	20	11.0	9.0	0.856	0.865	0.009	0.05
24	23 to 24	20	11.5	8.5	0.865	0.873	0.008	0.04
25	24 to 25	20	12.0	8.0	0.873	0.881	0.008	0.04
26	25 to 26	20	12.6	7.4	0.881	0.888	0.007	0.03
27	26 to 27	20	13.3	6.7	0.888	0.895	0.007	0.03
28	27 to 28	20	14.0	6.0	0.895	0.902	0.007	0.03
29	28 to 29	20	14.8	5.2	0.902	0.910	0.008	0.03
30	29 to 30	20	15.8	4.2	0.910	0.917	0.007	0.02
31	30 to 31	20	16.8	3.2	0.917	0.924	0.007	0.02
32	31 to 32	20	18.0	2.0	0.924	0.932	0.008	0.01
33	32 to 33	20	19.4	0.6	0.932	0.939	0.007	0.00
34	33 to 34	20	21.0	0.0	0.939	0.947	0.008	0.00
35	34 to 35	20	22.9	0.0	0.947	0.955	0.008	0.00
36	35 to 36	20	25.2	0.0	0.955	0.963	0.008	0.00
37	36 to 37	20	27.9	0.0	0.963	0.971	0.008	0.00
38	37 to 38	20	31.4	0.0	0.971	0.979	0.008	0.00
39	38 to 39	20	35.8	0.0	0.979	0.986	0.007	0.00
40	39 to 40	20	41.8	0.0	0.986	≈ 1.0	0.014	0.00

Calculations: Predicted Deflection: D_p = 0.063 $EFF_t = \Sigma EFF$ =
If $EFF_t = 0$ then $D_p = 0.034$ Total of Column 8 = 2.1
If $EFF_t > 0$ then $D_p = 0.056 + 0.0035 (EFF_t)$

Pavement thickness from Figure 3-6 (Enter with D_p on the horizontal axis, rise vertically to curve for design ESALs, then horizontally to read pavement thickness on vertical axis) = 5.5 inch for 1,430,000 ESALs

3.5. Excess Fines Design Using the AKFPD Computer Program

Perform excess fines designs for projects using the AKFPD program. The previous example "by hand" was meant to acquaint you with the computations used by AKFPD.

3.5.1. Generalized Steps Through the Program

1. The designer assembles design input data:
    - Design ESAL data supplied by Regional Planning Section (see chapter 6)
    - P_{200} content of each layer of material that will be used to a depth of 42 inches below the asphalt concrete pavement layer
    - Proposed thickness of each layer
2. The designer loads data to AKFPD input screen and runs program.
3. AKFPD subdivides each aggregate layer into 1-inch-thick sublayers.
4. AKFPD assigns each sublayer the appropriate P_{200} content at that depth (using the P_{200} contents entered as design input data).
5. AKFPD calculates the amount of pavement deflection that would occur if the pavement structure were to be subjected to the dual tire loading from one side of a standard ESAL axle.* Pavement deflection is a function dependent on (1) the percent P_{200} at each sublayer depth and (2) the amount of load support contributed by each sublayer (derived from Boussinesq stress distribution theory).

    * The standard ESAL wheel load is now defined as two tires, each inflated to 90 psi, each loaded to 4,500 lbs, with a centerline-to-centerline separation of 13.5 inches.
6. AKFPD then calculates the required asphalt concrete pavement thickness. Pavement thickness is a function dependent on (1) pavement deflection and (2) the total number of design ESALs.
7. If the calculated asphalt concrete thickness is not acceptable, the designer adjusts the input data and reruns AKFPD.

3.5.2. Example 1—Getting Started and Performing a Simple Design

The following steps lead you through a simple example of AKFPD excess fines pavement design analysis and interpretation of the results.

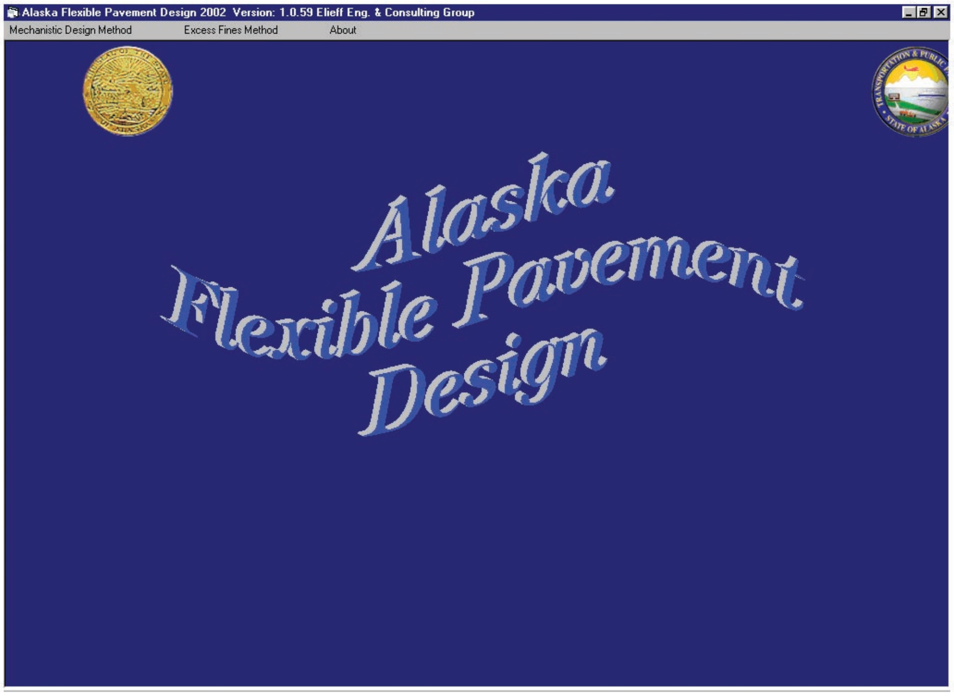
The first design example, which is explained in detail, does not use a previously saved input data file. You will use a previously saved input data file in the next example.

Mouse clicks are single clicks of the left button of computer mouse configured in the standard operating mode.

Step 1. Insert the AKFPD program CD disk into your computer's CD drive.

Step 2. Install AKFPD on your computer. If the software does not autoload, locate a listing of the CD's contents using the MS Windows ***My Computer Explore*** feature and run the "setup.exe" file. Alternatively, use the MS Windows ***Start Run*** feature by typing in the appropriate CD disk drive and the filename "setup.exe." The program can be removed by accessing the ***Start Control Panel*** feature of your computer, then selecting ***Add/Remove Programs***. From the list of installed programs select "Alaska Flexible Pavement Design 2003" and proceed with the uninstall process.

Step 3. Run AKFPD. Initiate the ***Start Programs*** feature of Windows, and from the listing of programs, run "Alaska Flexible Pavement Design 2003." The AKFPD title screen will appear (see Screen Clip 3-1):



Screen Clip 3-1

Step 4. Near the top left corner of the introductory screen, two program design method options are offered. One of the options is labeled ***Excess Fines Method***. Using your mouse, click on that option. A pull-down menu will appear (see Screen Clip 3-2).

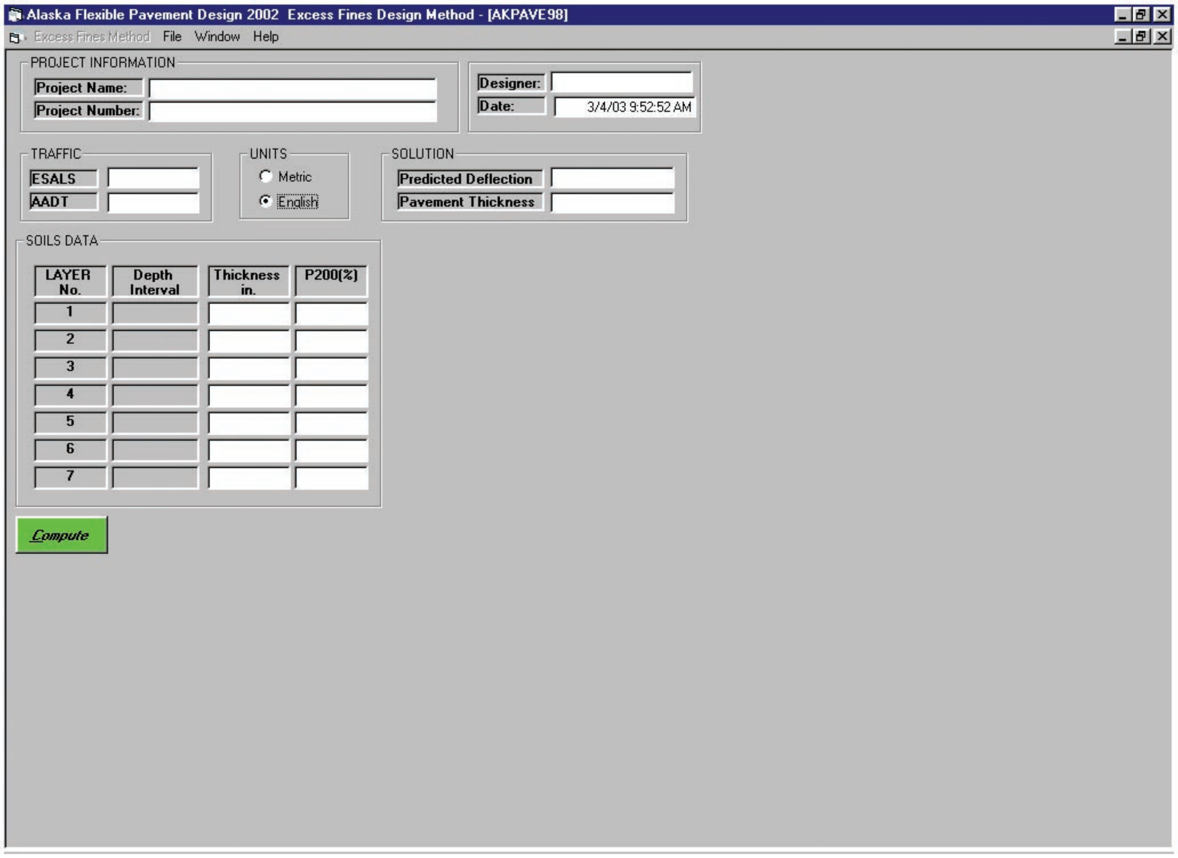
Screen Clip 3-2

Step 5. You now have two new options:

a. Click on ***New Analysis*** to begin a completely new excess fines pavement design. A blank design input data screen will appear that you must fill in before performing the analysis.

b. Click on ***Open Existing*** to begin an analysis using a previously saved input data file. The previously saved file can be analyzed without modification, or the file can be opened and modified before analysis.

Step 6. This example uses the ***New Analysis*** option. Clicking on that one brings up the input screen (see Screen Clip 3-3). This screen will contain all input and output data for the analysis.



Date: 3/4/03 9:52:52 AM

UNITS: ○ Metric ● English

Screen Clip 3-3

All data items required for doing the complete excess fines analysis are typed as input onto the input screen or selected/deselected on the screen by mouse click. The following steps explain input values necessary to fill various areas of the screen.

Step 7. Use the ***Project Information*** section of the input screen (see Screen Clip 3-4) for entering project identification information.

Fill the ***Project Name, Project Number,*** and ***Designer*** designator boxes with appropriate alphanumeric characters as in the Screen Clip 3-4. Select each box in turn with the mouse, and then initiate the prompt with a single mouse click. AKFPD automatically updates the ***Date*** box.

Project Name: Example_01

Project Number: AK-1220-RD(02)

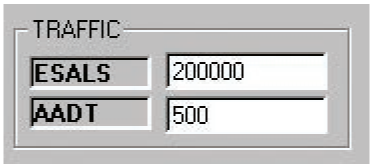
Designer: Billy Bob McConnor

Date: 3/4/03 9:21:52 AM

Screen Clip 3-4

To continue with the example, use your mouse to select applicable fields on your AKFPD input screen and type in the data indicated in Screen Clip 3-4.

Step 8. Use the screen's ***Traffic*** section (see Screen Clip 3-5) for entering design traffic information. Select the box to the right of ***ESALS*** and type in the project's design ESALs. Then select the box to the right of ***AADT*** and type in the project's average annual daily traffic.


TRAFFIC

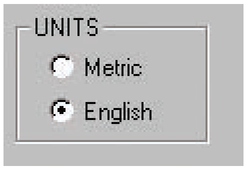
ESALS: 200000

AADT: 500

Screen Clip 3-5

To continue with the example, use your mouse to designate applicable fields on your AKFPD input screen and type in the data indicated in Screen Clip 3-5.

Step 9. The units section of the input screen contains toggles for selecting the system of numerical units to be used in the analysis (see Screen Clip 3-6). To operate the toggles, point your mouse button at the circle to the left of ***Metric*** or ***English*** and click the mouse's left button.


UNITS

○ Metric

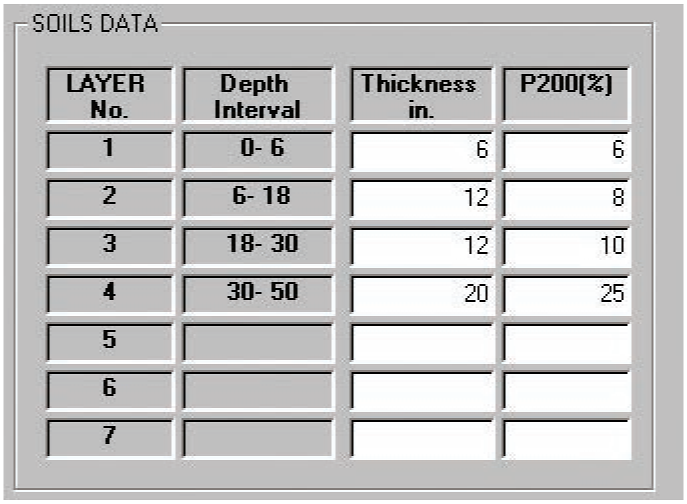
● English

Screen Clip 3-6

To continue with the example, use your mouse to designate the ***English*** field.

Step 10. Use the ***Soils Data*** area of the screen to enter the thickness of each layer and each layer's P_{200} content (see Screen Clip 3-7). P_{200} is defined as the weight percent passing the #200 sieve. Enter layer thickness in inches in the column labeled ***Thickness.*** Enter the P_{200} content of each layer in the column labeled ***P200(%).***

Type in thickness and P_{200} data starting with layer 1, then proceed downward, in order, through layers 2, 3, 4, etc. Notice that as layer thickness is entered for succeeding layers, the program keeps track of the depth intervals occupied by each layer. The sum of the layer thicknesses entered must be ≥ 42 inches (or ≥ 1,067 mm if metric units are used).

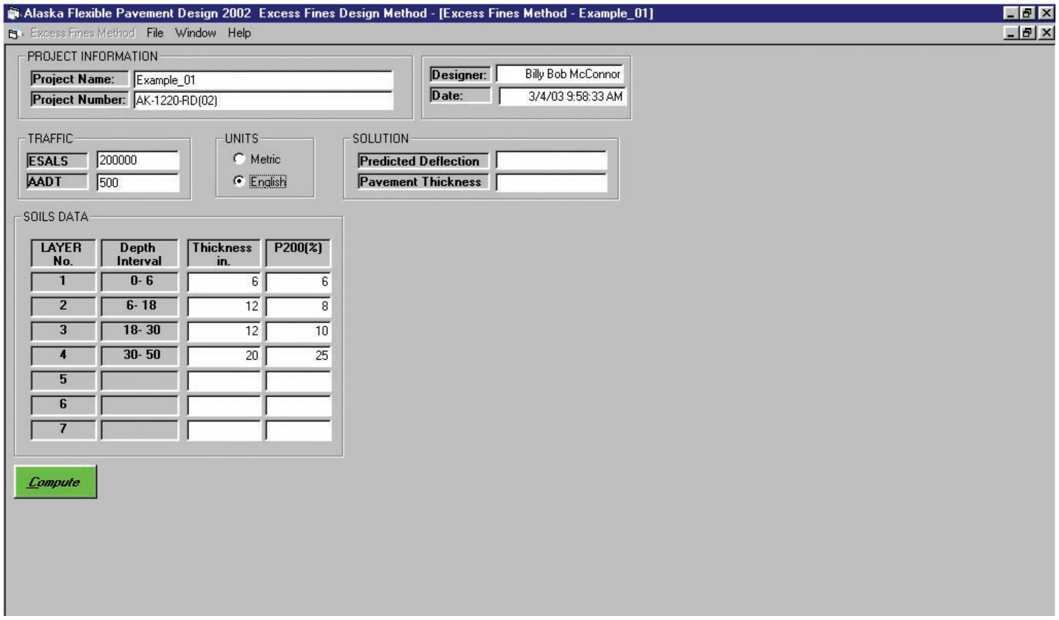

SOILS DATA

LAYER No.	Depth Interval	Thickness in.	P200(%)
1	0- 6	6	6
2	6- 18	12	8
3	18- 30	12	10
4	30- 50	20	25
5			
6			
7			

Screen Clip 3-7

To continue with the example, use your mouse to select applicable fields and type in the data indicated in Screen Clip 3-7.

Step 11. Your completed input screen should look like the one shown in Screen Clip 3-8. If it does not, use your mouse to select fields where data will need to be changed. Enter corrections as required until your input screen appears as shown.



Alaska Flexible Pavement Design 2002 Excess Fines Design Method - [Excess Fines Method - Example_01]

PROJECT INFORMATION

Project Name: Example_01

Project Number: AK-1220-RD(02)

Designer: Billy Bob McConnor

Date: 3/4/03 9:58:33 AM

TRAFFIC

ESALS 200000

AADT 500

UNITS

○ Metric

● English

SOLUTION

Predicted Deflection

Pavement Thickness

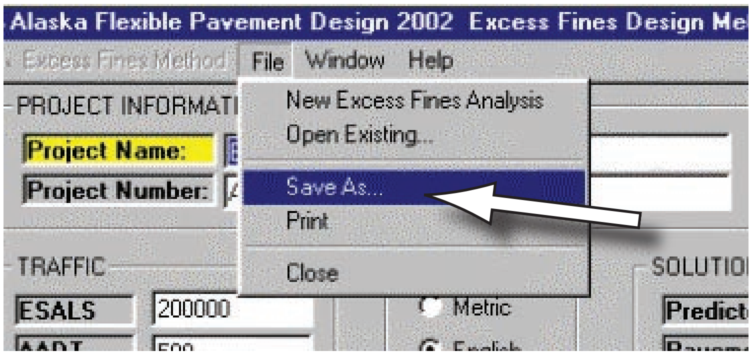
SOILS DATA

LAYER No.	Depth Interval	Thickness in.	P200(%)
1	0- 6	6	6
2	6- 18	12	8
3	18- 30	12	10
4	30- 50	20	25
5			
6			
7			

Screen Clip 3-8

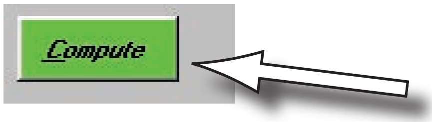
When you complete the input screen as indicated, you are ready to analyze the input data.

Step 12. You may now save your input data screen by assessing the ***File, Save As*** command shown in Screen Clip 3-9. Once saved, the input screen can be opened later using the ***File, Open Existing*** commands and analyzed as explained below. The input screen can also be opened and the data modified before analysis. Section 3.4.3 further explains the process of saving and recalling data.



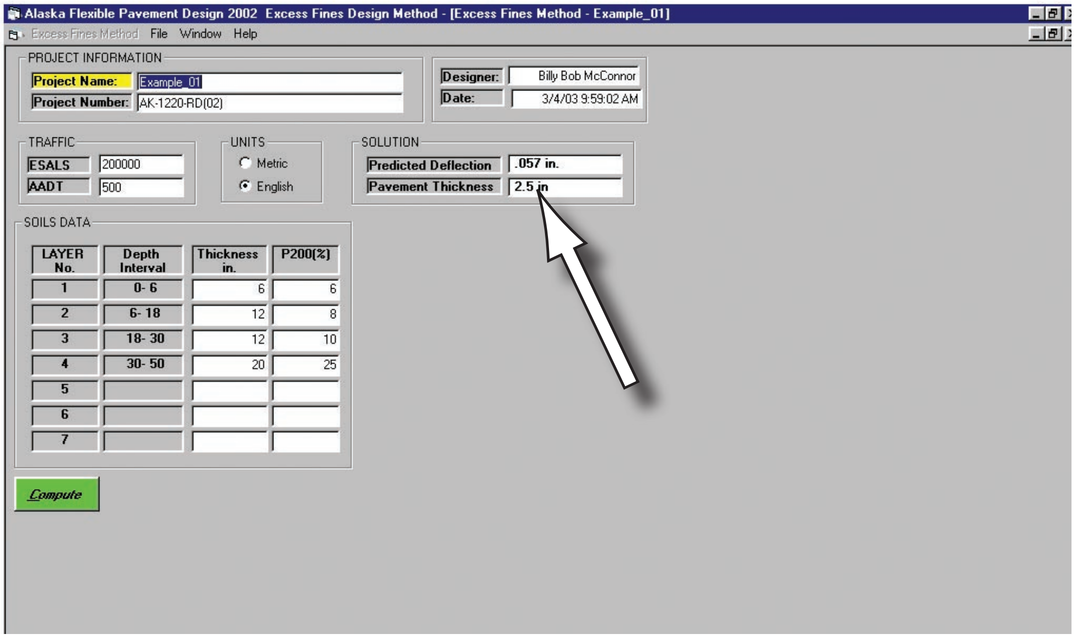
Screen Clip 3-9

Step 13. Perform the analysis and print the results. Initiate the computation by clicking on the ***Compute*** button located on the side of the screen (see Screen Clip 3-10).



Screen Clip 3-10

After you activate the ***Compute*** button, the ***Solution*** section of the screen will contain the results of the analysis as shown in Screen Clip 3-11.



PROJECT INFORMATION

Project Name: Example_01

Project Number: AK-1220-RD(02)

Designer: Billy Bob McConnor

Date: 3/4/03 9:59:02 AM

TRAFFIC

ESALS 200000

AADT 500

UNITS

○ Metric

● English

SOLUTION

Predicted Deflection .057 in.

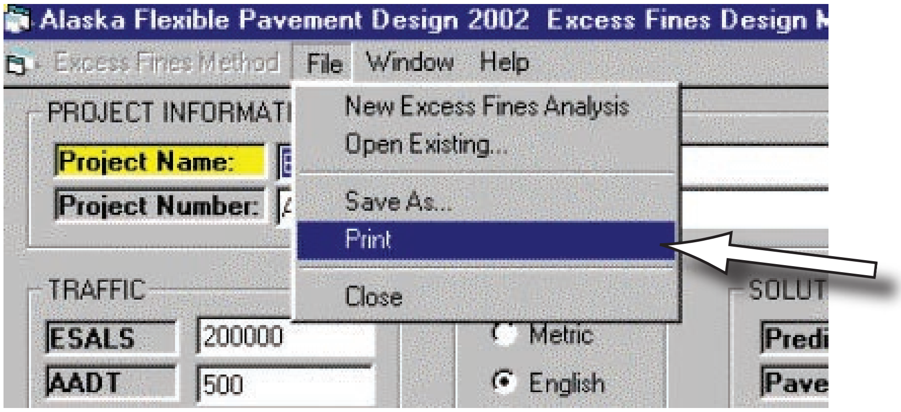
Pavement Thickness 2.5 in

SOILS DATA

LAYER No.	Depth Interval	Thickness in.	P200(%)
1	0- 6	6	6
2	6- 18	12	8
3	18- 30	12	10
4	30- 50	20	25
5			
6			
7			

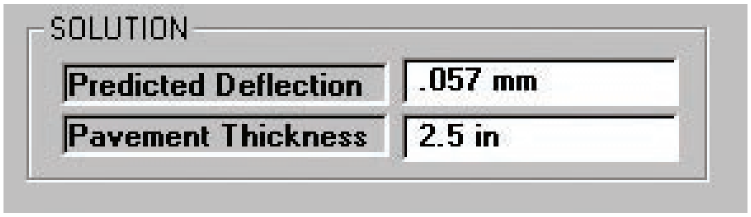
Screen Clip 3-11

Print the screen, containing both input and output data, by clicking the ***File, Print*** command as indicated in Screen Clip 3-12.



Screen Clip 3-12

Step 14. Interpret the results. The results of the example 1 analysis consist of the two values shown Screen Clip 3-13.



Predicted Deflection .057 mm

Pavement Thickness 2.5 in

Screen Clip 3-13

The AKFPD program uses calculations described in Section 3.2.3 to arrive at the ***Predicted Deflection*** of 0.057 inch shown above. Using the predicted deflection of 0.057 inches and the 200,000 design ESAL, AKFPD applies a numerical version of Figure 3-6 to determine the required asphalt concrete pavement thickness of 2.5 inches. In this case, no further interpretation is necessary—you will specify a minimum asphalt concrete thickness of 2.5 inches.

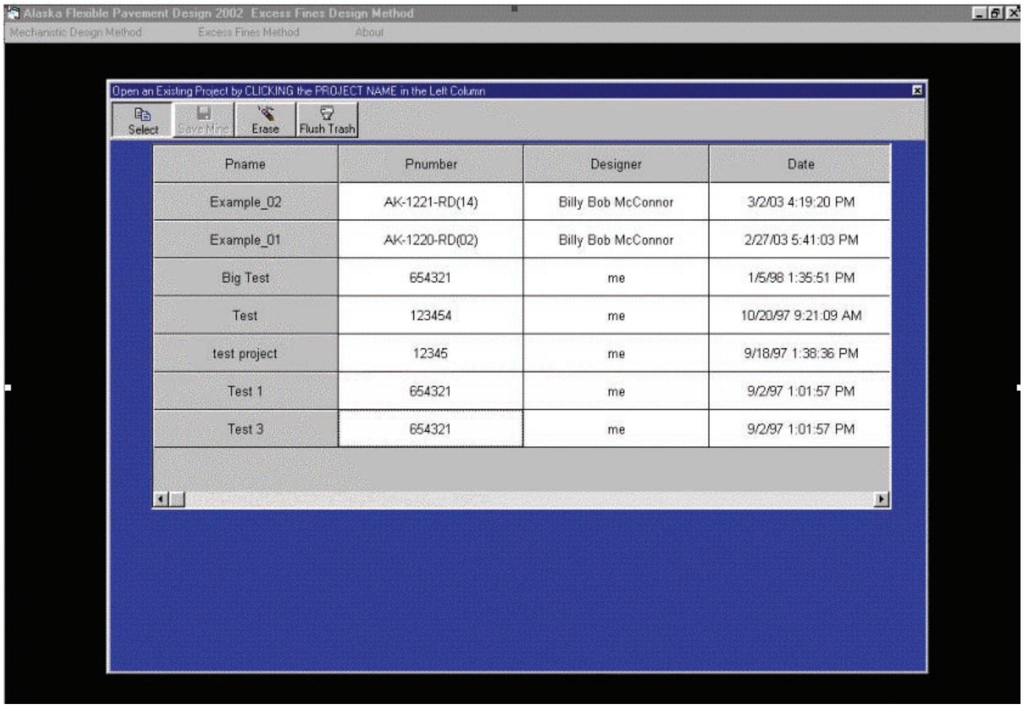
3.5.3. Saving, Recalling, and Modifying Files

Saving and Recalling the Input Screen

When you start the AKFPD program you can recall an existing data file (and modify it as necessary) instead of inputting new analysis data. Recall an existing file by accessing the ***Open Existing*** command on the ***Excess Fines Method*** pull-down menu from AKFPD's opening screen (see Screen Clip 3-14).

Screen Clip 3-14

If you select the ***Open Existing*** option, a menu similar to that shown in Screen Clip 3-15 appears. Use your mouse to point and click on one of the data files to open it.



Pname	Pnumber	Designer	Date
Example_02	AK-1221-RD(14)	Billy Bob McConnor	3/2/03 4:19:20 PM
Example_01	AK-1220-RD(02)	Billy Bob McConnor	2/27/03 5:41:03 PM
Big Test	654321	me	1/5/98 1:35:51 PM
Test	123454	me	10/20/97 9:21:09 AM
test project	12345	me	9/18/97 1:38:36 PM
Test 1	654321	me	9/2/97 1:01:57 PM
Test 3	654321	me	9/2/97 1:01:57 PM

Screen Clip 3-15

Using the menu shown in Screen Clip 3-15, you can remove a data file from the menu by clicking on the menu's ***Erase*** button. Mark one or more of the menu selections for removal, then click on the Flush Trash button.

During the analysis process you can save or open an existing data file. Save input screen data by accessing the ***File, Save As*** command indicated in Screen Clip 3-16. Once saved, the input screen can be opened later using the ***File, Open Existing*** commands and analyzed. Of course, the input screen can also be opened and the data modified before analysis.

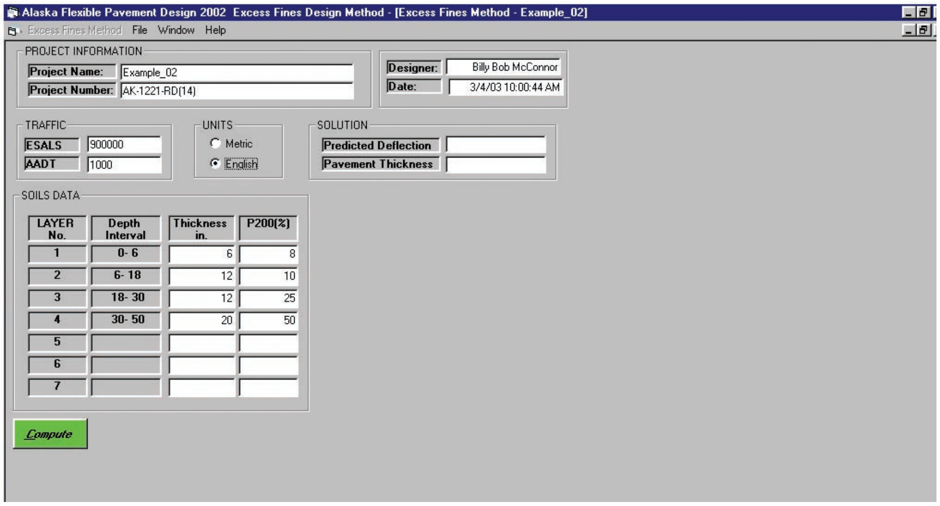
Screen Clip 3-16

3.5.4. Example 2—A Design Requiring Thick Pavement

This example considers a case where the excess fines design method will require a pavement thickness of more than 3 inches. When the design process requires more than 3 inches of pavement, an additional section of information appears on the excess fines input/output screen. The new section provides a table of alternatives where pavement thickness can be "swapped" for some thickness of stabilized base course. The simple methodology for doing this is shown in the following steps.

Keep in mind that any combinations of reduced pavement thickness and stabilized base course thickness are in ***addition*** to the thickness of unbound, crushed base course that you specified in the design.

Step 1. Begin this example design by initiating the ***Excess Fines Method, New Analysis*** input screen as described in example 1. When the input screen appears, use mouse and keyboard to fill the data fields as shown in Screen Clip 3-17. Make sure the input screen appears as shown in Screen Clip 3-17 before moving on.



Project Name: Example_02
Project Number: AK-1221-RD(14)
Designer: Billy Bob McConnor
Date: 3/4/03 10:00:44 AM

ESALS 900000
AADT 1000

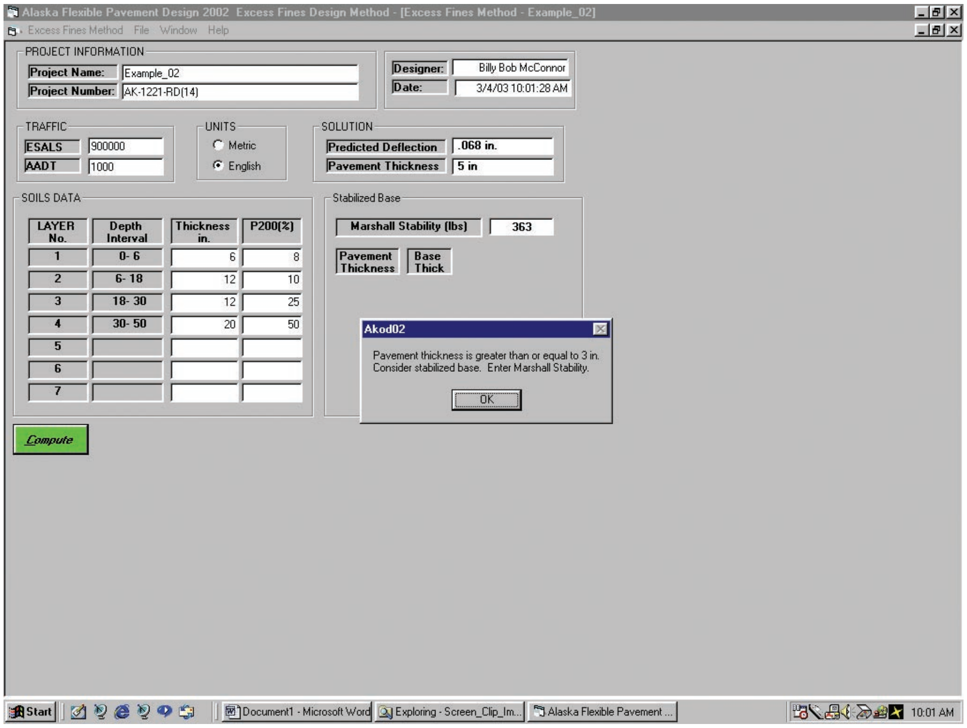
○ Metric
● English

Predicted Deflection
Pavement Thickness

LAYER No.	Depth Interval	Thickness in.	P200(%)
1	0- 6	6	8
2	6- 18	12	10
3	18- 30	12	25
4	30- 50	20	50
5			
6			
7			

Screen Clip 3-17

Step 2. Do the analysis and print the results. Click on the ***Compute*** button at the lower left of the input/output screen. The screen will then appear as in Screen Clip 3-18.



Project Name: Example_02
Project Number: AK-1221-RD(14)
Designer: Billy Bob McConnor
Date: 3/4/03 10:01:28 AM

ESALS 900000
AADT 1000

○ Metric
● English

Predicted Deflection .068 in.
Pavement Thickness 5 in

LAYER No.	Depth Interval	Thickness in.	P200(%)
1	0- 6	6	8
2	6- 18	12	10
3	18- 30	12	25
4	30- 50	20	50
5			
6			
7			

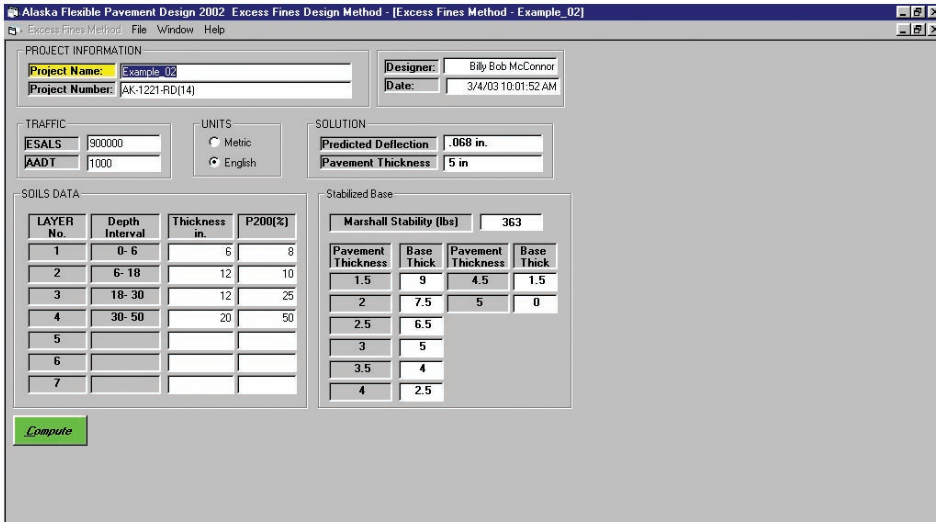
Marshall Stability (lbs) 363

Pavement Thickness	Base Thick

Pavement thickness is greater than or equal to 3 in. Consider stabilized base. Enter Marshall Stability.

Screen Clip 3-18

When this screen appears, click the ***OK*** button and the next screen will appear as in Screen Clip 3-19.



PROJECT INFORMATION

Project Name: Example_02

Project Number: AK-1221-RD(14)

Designer: Billy Bob McConnor

Date: 3/4/03 10:01:52 AM

TRAFFIC

ESALS 900000

AADT 1000

UNITS

○ Metric

● English

SOLUTION

Predicted Deflection .068 in.

Pavement Thickness 5 in

SOILS DATA

LAYER No.	Depth Interval	Thickness in.	P200(%)
1	0- 6	6	8
2	6- 18	12	10
3	18- 30	12	25
4	30- 50	20	50
5			
6			
7			

Stabilized Base

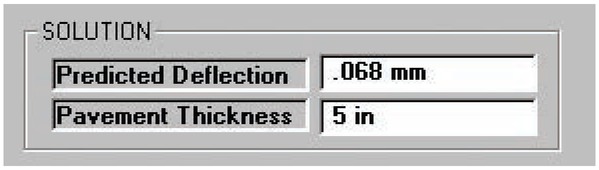
Marshall Stability (lbs) 363

Pavement Thickness	Base Thick	Pavement Thickness	Base Thick
1.5	9	4.5	1.5
2	7.5	5	0
2.5	6.5		
3	5		
3.5	4		
4	2.5		

Screen Clip 3-19

Print the input/output shown in Screen Clip 3-19 by using your mouse to activate the ***File, Print*** commands at the top of the screen.

Step 3. Interpret the results of the analysis. The ***Solution*** section of the screen (see Screen Clip 3-20) indicates that 5 inches of pavement is required.



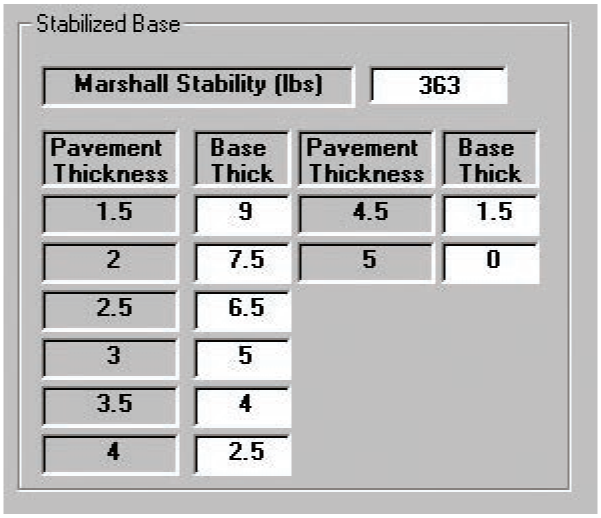
SOLUTION

Predicted Deflection .068 mm

Pavement Thickness 5 in

Screen Clip 3-20

However, the thickness "swap" table, shown in Screen Clip 3-21, contains the information you need to select from a number of different pavement thickness/ stabilized base thickness combinations.



Stabilized Base

Marshall Stability (lbs) 363

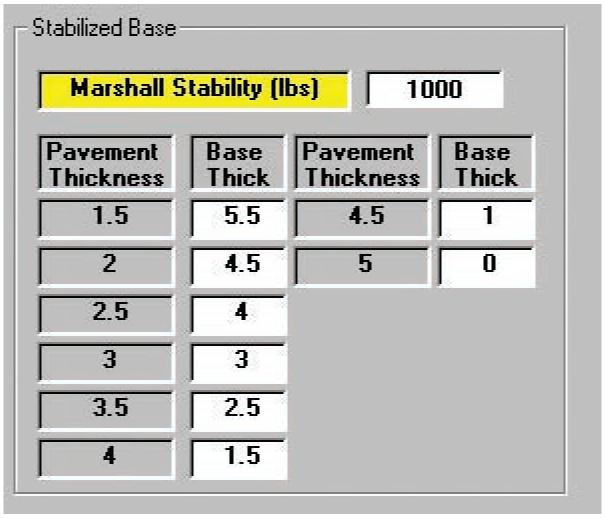
Pavement Thickness	Base Thick	Pavement Thickness	Base Thick
1.5	9	4.5	1.5
2	7.5	5	0
2.5	6.5		
3	5		
3.5	4		
4	2.5		

Screen Clip 3-21

Interpretation of this table shown in Screen Clip 3-21 is simple. Starting at the bottom of the table (bottom of right column), you can see that if no stabilized base is used, the full 5 inches of pavement thickness is required. Moving the top of the table (top of left column), a pavement thickness of only 1.5 inches is acceptable if combined with 9 inches of stabilized base. The list also contains a number of other equally valid combinations. Regardless of which combination you select from the table, however, you must ***also*** use all layers of materials you used as input—in this example, that includes the 6 inches of normal base course used as an input material layer.

You can obtain an estimation of the ***Marshall Stability*** (shown in Screen Clip 3-21 as 363 lbs) from your regional or headquarters materials experts. A presumptive value can be used or laboratory testing can be done to obtain actual Marshall stability. If you decide on laboratory testing, make every attempt to test materials obtained from design project sources.

You can change the Marshall stability to any value you choose by typing a new number into the Marshall Stability data field, followed by pushing **Return** on your keyboard. Notice that if you change the Marshall stability value to 1,000 lbs, the table will change as indicated below.



Marshall Stability (lbs): 1000

Pavement Thickness	Base Thick	Pavement Thickness	Base Thick
1.5	5.5	4.5	1
2	4.5	5	0
2.5	4		
3	3		
3.5	2.5		
4	1.5		

Screen Clip 3-22

4. Mechanistic Design

4.1. Introduction

This chapter provides a complete discussion of the mechanistic design method. The AKFPD mechanistic method is approved for designing all types of asphalt concrete pavement structures. Chapter 2 provides detailed information concerning appropriate applications for this design method.

There are many systems for mechanistically designing a flexible pavement structure. Although some Alaska researchers may have at least passing familiarity with a wide range of mechanistic design technologies, most of these methods have never been used for designing pavements in Alaska. The following presentation covers only the mechanistic methods the DOT&PF has adopted for use and associated underlying principles.

4.2. Summary of Mechanistic Design

In 1976, DOT&PF began a comprehensive research effort to improve its method for designing flexible pavement structures. That same year, the International Pavement Design Conference at the University of Michigan, Ann Arbor, introduced several computer programs for doing mechanistic pavement design. It appeared that mechanistic design methods might offer great potential for application in Alaska. However, the computer programs were considered to be research-level design tools at the time, and the expertise for installing and running them was not readily available. Furthermore, mechanistic design programs required mainframe computer resources—these were the days before powerful personal computers were available.

Most of the research thrust between 1976 and 1982 was toward developing an empirical method of design based on data collected from Alaska roadway sections. This line of research was successful in producing the excess fines method of pavement design in 1982. During this same period, though, interest continued to grow in the area of mechanistic design. By 1983, several mechanistic design programs had been collected and installed for DOT&PF access on the Boeing computer system in Seattle, Washington. This work was done as part of a DOT&PF research project that also produced the first DOT&PF guide for mechanistic pavement design.[8] DOT&PF mechanistic design classes have continually used *Use of Layered Theory in the Design and Evaluation of Pavement Systems*.

Mechanistic methods were introduced to the general DOT&PF community in 1983. Until the late 1980s, mechanistic methods were used mostly for research work, and highway pavement designs were nearly always handled using the excess fines method. During the period 1988 to 1990, the AKOD (Alaska Overlay Design) program was developed.[9] The AKOD program combined all of the separate computational steps required by the mechanistic design process into a few easily used input and output screens. AKOD gave mechanistic design capability to all DOT&PF engineers. Development of the AKOD program continued through the 1998 revision (AKOD98). A new program was developed as the mechanistic design component of AKFPD. The new program is an updated, highly modified derivative of the AKOD concept.

The heart of the mechanistic design method is the difficult calculation of stresses and strains, i.e., structural response, at selected locations within the pavement structural layers. Hicks[8] discussed several programs useful for performing these calculations and selected one of these, ELSYM5, as the stress/strain computational subroutine in AKOD. ELSYM5 has also been incorporated into AKFPD to perform this same function.

In addition to references previously cited regarding mechanistic design, textbooks by Yoder and Witczak,[10] Ullidtz,[11, 12] and Huang[13] provide an excellent broad base of information.

4.3. Design Principles

Alaska’s mechanistic design method relies on the following three principles:

1. The pavement structure is amenable to structural analysis as a basic mechanical system of elastic layers, i.e., the structural response of the system can be calculated if the loads and the physical properties of the system’s layers are known. In the Alaska mechanistic method, structural response is calculated in terms of stresses and strains at specific critical locations within the layered pavement structure (the computer program module ELSYM5 is used for this purpose).
2. Structural response at critical locations in the pavement structure is functionally related to pavement performance. Using this principle, it is possible to plug stress and strain values (calculated by ESYM5) into simple, empirical equations and thereby calculate the number of design load repetitions that will cause the structure to fail (requires application of empirically derived damage equations).

   $$\text{Damage} = f\,(\sigma, \varepsilon, \text{loads})$$

3. Pavement failure is the end result of a linear, incremental mechanical process. Pavement structural failure can therefore be modeled using Miner’s law—a method of predicting failure by summing up fractional increments of damage.

   $$\sum_{i=1}^{i=total} \left(N_a \big/ N_f \right)_i \geq 1 \text{ (a definition of failure)}$$

4.3.1. Calculating Stresses and Strains

The first computational step in Alaska’s mechanistic design process is determining stresses and strains, i.e., structural response, at selected locations within the pavement structural layers using layered system analysis. In his 1983 publication,[8] Hicks discussed several programs useful for analyzing elastic layered systems, and he selected one of these, ELSYM5, as the stress/strain computational subroutine for use in AKOD. Nearly 20 years later, ELSYM5 has been incorporated into AKFPD to perform this same important computational function.

In simplest terms, the engineer supplies ELSYM5 with input values of thickness and strength (modulus and Poisson’s ratio) for each layer. Input also includes vehicle load configuration and magnitude. Then, ELSYM5 calculates stresses and strains at any location within the pavement structure selected by the designer. Figure 4-1 shows a pavement structure defined in terms of individual elastic layers.

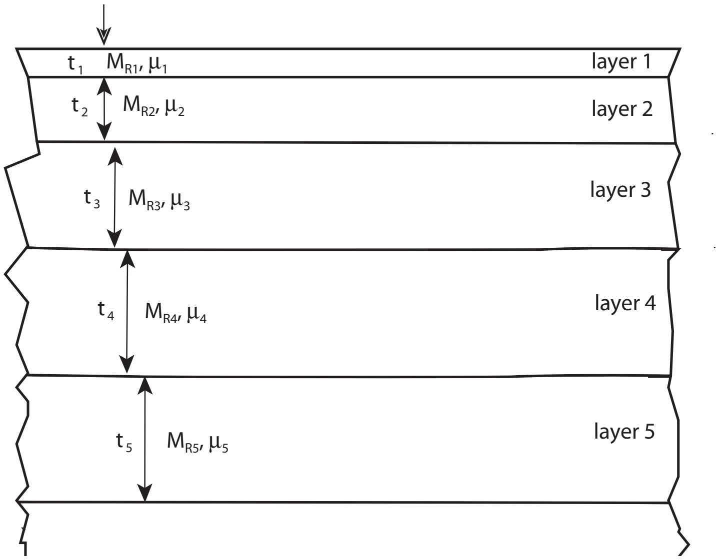


Figure 4-1. Typical Pavement Structure Showing Elastic Layers

The mathematical and programming details of how ELSYM5 performs these calculations are far beyond the scope of this manual. However, it is important to understand the general nature of the function performed by ELSYM5 as well as the principles and assumptions underlying ELSYM5's stress and strain calculations.

Hicks covered this subject quite well in Chapter 2 of his 1983 publication.[8] For analyzing layered pavement systems, he wrote: "Procedures for prediction of traffic induced deflections, stresses and strains in pavement systems are based on the principle of continuum mechanics. The essential factors that must be considered in predicting the response of layered pavement systems are: (1) the stress-strain behavior of the materials; (2) the initial and boundary conditions of the problem; and (3) the partial differential equations which govern the problem. The highway engineer, however, need only concern himself with the stress-strain behavior of the material, the physical configuration of the problem, and the general assumptions that have been made or implied in developing solutions to the layered system problem." In the Alaska mechanistic method, the "solution to the layered system problem" is ELSYM5.

ELSYM5 was selected for use in the AKFPD program because its theoretical basis and operational characteristics (within the personal computer environment) are suited to handling Alaska pavement designs. With ELSYM5, or any other layered system solution, you must use realistic input values and must understand the assumptions and limitations used in developing the solution.

Hicks identified assumptions used in developing elastic layered system solutions such as ELSYM5.

Assumptions applicable to all elastic layer solutions:

- Each layer is infinite in horizontal extent and is composed of isotropic, homogeneous, linearly elastic material.
- Surface loadings can be represented as circular areas of uniform stress.
- Interface conditions between layers can be designated as either perfectly rough (called the "continuous" or "full friction" condition) or perfectly smooth (called the "no friction" or "slippery" condition).
- The underlying layer continuously supports the layer above.
- Inertial forces and vibrations are considered small in the elastic system and can be disregarded. Vibrations can damage the pavement by densifying granular materials and causing rutting, but this effect is not accounted for in mechanistic design.
- Deformations in the elastic system are small and can be disregarded.
- Temperature variations do not affect the elastic layered system.

Assumptions and limitations specific to ELSYM5:

- All loads are identical, uniform, and circular.
- All loads are placed at the surface of the elastic system and oriented normal to that surface.
- A pavement structure of up to five layers can be analyzed.
- The surface of the top layer is free of shear stresses.
- Interfaces between layers are continuous, i.e., full friction.
- Nonlinear elastic behavior of materials—stress sensitivity—cannot be accommodated in ELSYM5 (see discussion below).

- The pavement structure modeled by ELSYM5 is an axisymmetric solid, which means that both load and pavement geometrics are symmetrical about a common centerline. Because of this axisymmetry, ELSYM5 cannot be used to analyze the effects of loads applied near the pavement edge, near cracks, or other edge-type boundaries.

ELSYM5 input requirements:

- One or more wheel loads must be specified at designer-selected locations at the surface of the pavement structure. A maximum of eight identical loads can be used (see limitations listed above). The solution uses the principles of superposition to solve for stresses and strains due to application of multiple wheel loads. This means that ELSYM5 first calculates the stresses and strains caused by each load independently. Then, by applying superposition, total stresses and strains at any point in the elastic layer system are determined as the sum of stress and strain contributions from each load for that point.

  Chapter 6 contains information about vehicle loadings that the engineer can use for designing pavements.

- The thickness must be defined for each layer of the pavement structure. Each layer except the bottom one is assigned a finite thickness. The bottom elastic layer can be given a finite thickness or defined as having semi-infinite thickness (a “bottomless” layer). If you assign a finite thickness to the bottom layer, the program automatically assumes that the base of the bottom layer is rigidly supported. In this case the program also assumes that the interface between the base of the bottom layer and the rigid support is continuous.

- Each layer of the pavement must be assigned two elastic properties.

  1. Resilient modulus M_R (sometimes called the repeated-load or “dynamic” elastic modulus)

     $M_R = \sigma_d / \varepsilon_r$ Where:

     σ_d = repeated axial stress (psi)

     ε_r = recoverable elastic (resilient) strain

     The repeated axial stress (σ_d) is defined as a repeated series of pulse loadings, where each load pulse is followed by a short rest period. One cycle of the pulsed load/rest series usually consists of a load pulse lasting 0.1 second followed by a rest period of 0.9 second.

     The recoverable elastic strain (ε_r) is defined as that portion of strain, due to σ_d, that is completely recovered when the load is released. For all materials that are not perfectly elastic, a portion of the load-induced strain will be nonrecoverable. This nonrecovery phenomenon is due to plastic deformation or some other form of permanent displacement.

  2. Poisson’s ratio

     $\mu = \varepsilon_{lateral} / \varepsilon_{load\ axis}$ Where:

     $\varepsilon_{lateral}$ = lateral strain (normal to the axial load direction) caused by application of the axial load

     $\varepsilon_{load\ axis}$ = axial strain (parallel to the axial load direction) caused by application of the axial load

Chapter 5 provides specific information about appropriate modulus and Poisson’s ratio values that the engineer can use for designing pavements. M_R should not be confused with another measure of dynamic elastic modulus known as the complex modulus (E*). E* is not presently used in DOT&PF mechanistic design methodology.

Some materials degrade when crushed and handled. **It is important that the M_R value used as design input truly represents the strength of the material after it has been placed and compacted.** If the degradation value (Alaska Test Method T-13) of the material is less than 45, check with the regional materials engineer for guidance.

You must define the locations where ELSYM5 will calculate stresses and strains within the layered elastic system.

ELSYM5 output used in Alaska's mechanistic design method:

ELSYM5 will determine the stress/strain response at any location within a specified elastic layered system due to a specified load. In fact, ELSYM5 produces more output values than are actually used in Alaska's mechanistic design method. You must know which ELSYM5 output values to use and where (within the layered structure) ELSYM5 must calculate these values. Only two of values produced by ELSYM5 are used in Alaska's method, and the locations that must be selected for analysis are very specific.

The two output values of interest are:

1. Maximum horizontal tensile strain, ε_t, at the bottom of specified layers
2. Maximum vertical compressive stress, σ_v, at the top of specified layers

The following section describes, in detail, which layers are specified for evaluation according to strain and which are evaluated according to stress, and why.

A few more words are necessary about selecting ELSYM5 analysis locations. As has been stated above, you will specify calculation of stresses and strains either at the top or the bottom of specified layers. But where (in a horizontal sense) along the top or the bottom of a layer will the **maximum** stress or strain value be found? The wheel configuration of the design load (wheel locations) determines where maximum stresses or strains will be found. In the simplest case of a single wheel design load, the maximum value will be found directly under the center of the load. For design load configurations having two or more wheels, various locations along the bottom of the layer must be searched to find the maximum value. It is important to realize that, because of superposition effects, the horizontal location where the maximum value will be found will change as the depth of the analysis increases. Comparison of Figure 4-2 and 4-3 provides a visual, conceptual example of how superposition applies to a layered pavement structure. Figure 4-2 shows how the load of single wheel is distributed with depth. For example, the load-induced vertical compression stress "felt" by the soil at 36 inches depth would be much less than the stress at the pavement surface directly beneath the tire. Figure 4-3 shows how the depth-distributed loads from two tires superimpose (and add together) at some depth. In Figure 4-3, see how the load distributions of the two tires overlap between the tires. When multiwheel design loads are involved, it is often possible to simplify the search for the maximum horizontal strain value at the bottom of heavily bound layers. Figure 4-4 indicates how analysis locations are selected, and how taking advantage of the symmetry of multiwheel configurations can minimize the number of search locations.

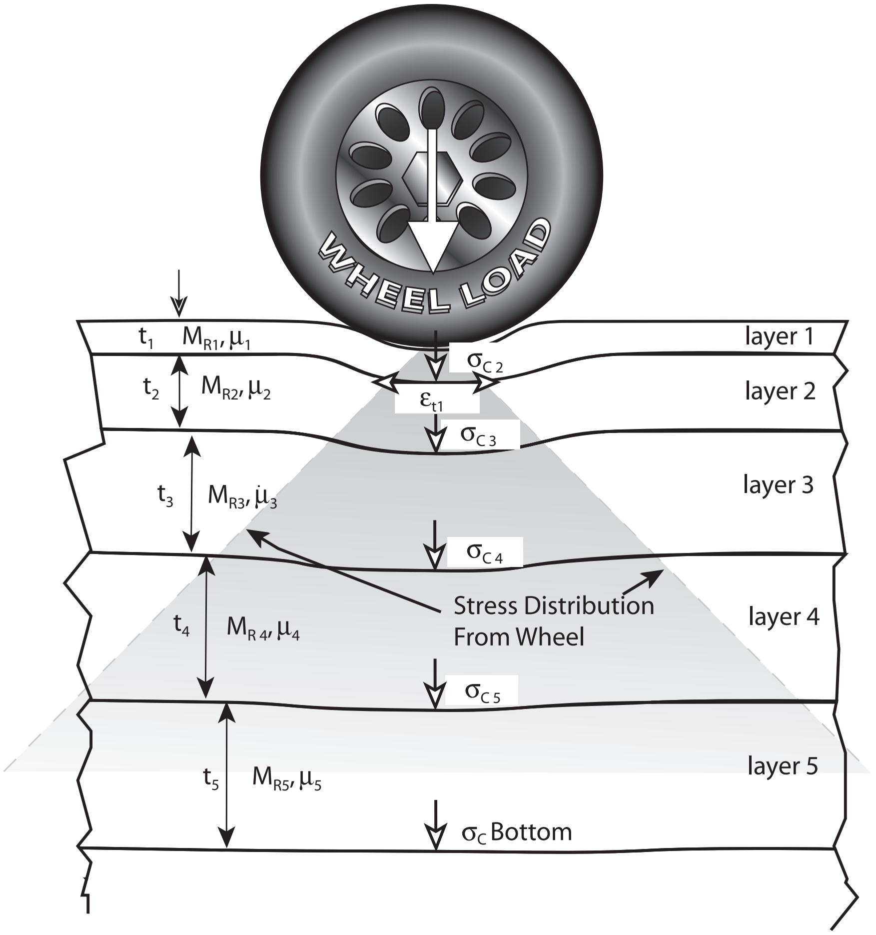


Figure 4-2. Elastic Pavement Layers Undergoing Simple Loading

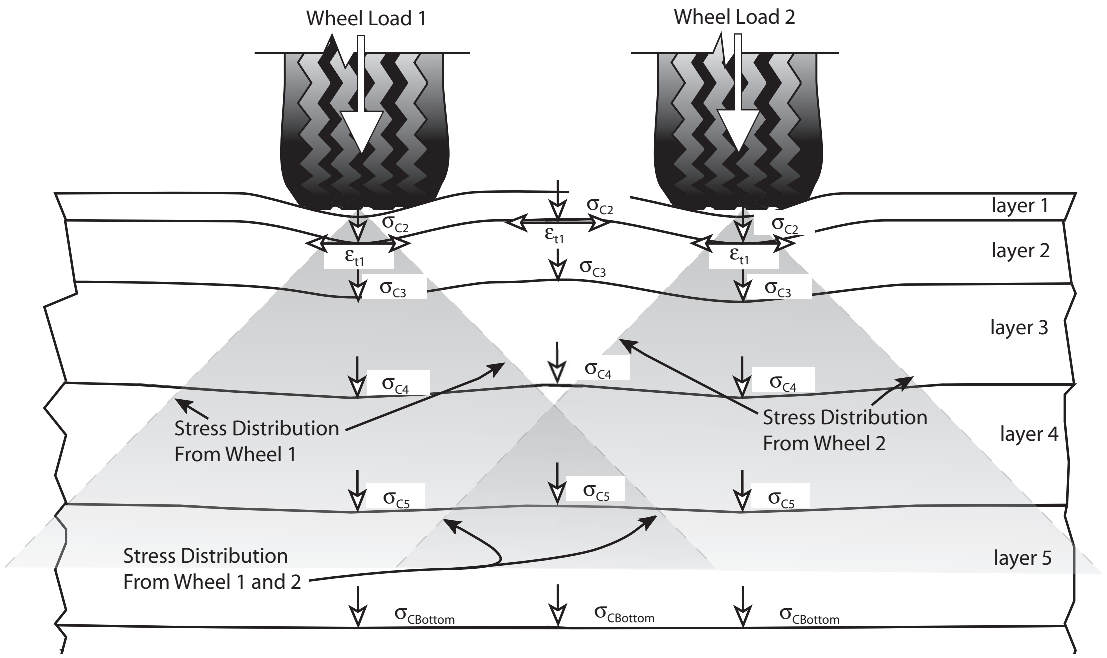


Figure 4-3. Elastic Pavement Layers Illustrating Superposition Effect

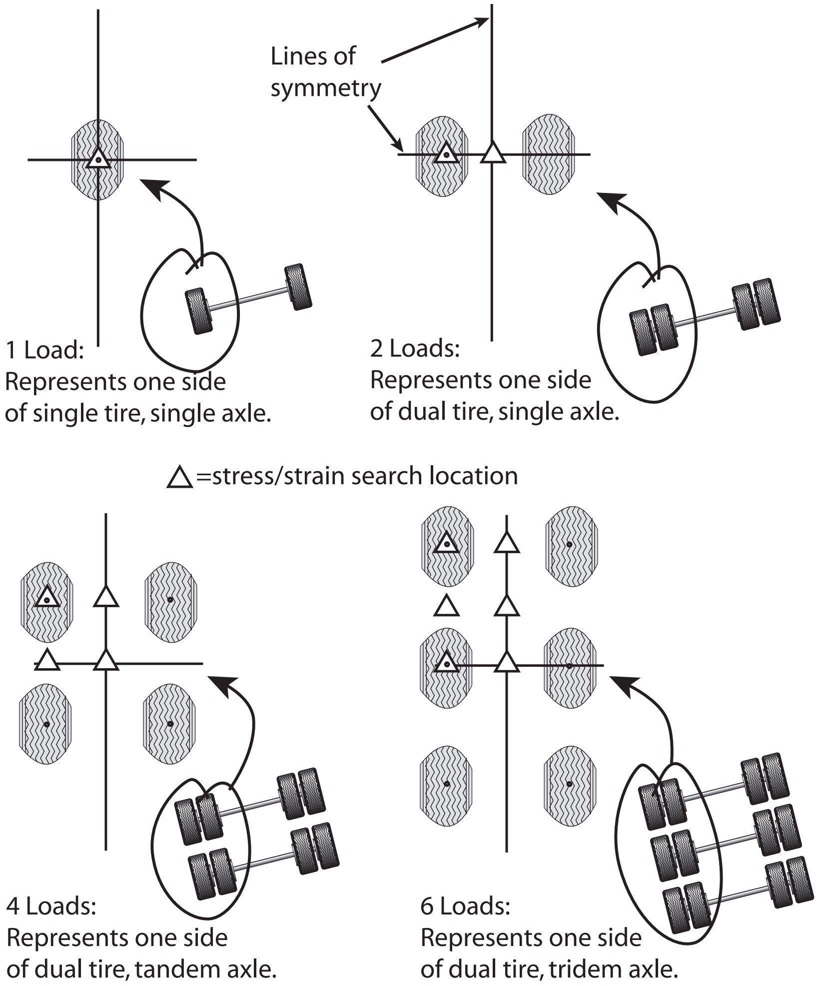


Figure 4-4. Plan View of Design Loads With Structural Response Search Locations Shown

4.3.2. Relating Structural Response to Performance (Estimating the Number of Load Repetitions to Failure)

Empirical equations have been developed that relate stresses and strains at specific locations within the pavement structure to the number of design load repetitions that will cause the structure to fail. These equations are variously known as "damage equations" or "transfer functions." From many such equations found in the literature, DOT&PF has selected two equations for application in the Alaska mechanistic design method. These equations have been incorporated into the AKFPD program and are discussed below.

Why two damage equations used instead of just one? The answer is that the Alaska mechanistic design method defines two distinctly different modes of pavement structural failure. Each mode of failure is controlled by a different structural response parameter.

Fatigue Failure: This type of failure exhibits itself as fatigue cracks (alligator cracks) that are seen at the pavement surface. Only heavily bound layers such as the asphalt concrete surfacing and heavily bound bases are susceptible to this failure mode. Fatigue cracking originates at the bottom of the bound layer and propagates upward to the surface. All heavily bound layers will become fatigue cracked after they are subjected to enough load repetitions. Fatigue failure of heavily bound layers is analogous to a paper clip failing after it is bent many times. Figure 4-5 is a photograph showing advanced alligator cracking.

Figure 4-5. Advanced Alligator Cracking of Highway Pavement

The Asphalt Institute (TAI) developed an equation that predicts, for each heavily asphalt-bound layer, the number of load repetitions until fatigue failure (bottom-up cracking failure) occurs. The TAI equation applies only to heavily bound layers where asphalt cement has been used as the binder. The TAI equation may not be fully accurate if polymer-modified asphalt cements are used or if the asphalt concrete is not representative of standard hot mix materials, e.g., stone mastic asphalt (SMA). However, until an improved method is developed, the TAI equation provides adequate results. The response parameter used in the TAI equation for each layer is the maximum horizontal tensile strain (ε_h) at the bottom of that layer.

Functional Failure: This mode of failure appears as a combination of roughness and rutting (sometimes called functional distress). Failure occurs after the pavement structure is subjected to enough load repetitions to cause permanent deformations of unbound or lightly bound lower layers. All layers that are not heavily bound and susceptible to fatigue failure are susceptible to functional failure.

The Per Ullidtz equation predicts, for each unbound or lightly bound layer, the number of load repetitions until functional failure of that layer occurs. The response parameter used in the Per Ullidtz equation is the vertical compressive stress (σ_v) at the top of unbound or very lightly bound layers.

The TAI equation—for fatigue failure (applicable to asphalt concrete and other heavily bound layers) is:

$$N_f = C \times 0.07958 \times \varepsilon_h^{-3.291} \times \left|E^*\right|^{-0.854}$$

(for fatigue cracking over 45% of the wheel path area equivalent to about 20% cracking of the total area)

$$C = 10^M$$

$$M = 4.84 \times \left(\frac{V_b}{V_v + V_b} - 0.69 \right)$$

where:

N_f = fatigue life (number of design load repetitions to fatigue failure)

ε_h = maximum horizontal tensile strain at the bottom of the bound layer, $\text{in}/_{\text{in}}$

$\left|E^*\right|$ = dynamic modulus of the asphalt concrete material, psi

(use M_R value for asphalt concrete)

V_v = percent air voids volume in total mix

V_b = percent binder volume

where:

$$V_b = \frac{\gamma_{mix} \cdot \%\text{AC}}{G_b \cdot \gamma_W}$$

where:

γ_{mix} = mix density, pcf

% AC = binder content, weight %

G_b = binder specific gravity

γ_W = water density, pcf (62.4 pcf)

The Per Ullidtz equation—for functional failure (applicable to unbound or lightly bound layers) is:

$$N_f = \frac{1}{R} \times 3.069\, x 10^{10} \times \left(\frac{E}{E_0} \right)^{3.26\,b} \times \sigma_v^{-3.26}$$

(for about 1-inch rut depth)

where:

N_f = number of design load repetitions to functional failure

R = regional factor = 2.75 for Alaska conditions

E = dynamic modulus of the unbound or lightly bound material, psi

$E_0 = 23,000$ psi

$b = 1.16$ if $E < E_0$; otherwise $b = 1$

σ_v = maximum vertical compressive stress at the top of the layer, psi

Keep in mind where the horizontal tensile strain ε_h and vertical compressive stress σ_v values used in the above equations come from; they are calculated by the ELSYM5 module of the AKFPD program.

N_f values calculated using the above equations define the maximum number of design-load repetitions (the allowable repetitions) that can be applied to the pavement structure before it fails. In other words, these equations define the potential “life” of the pavement structure in terms of load repetitions to failure (N_f). It should be obvious that any number of load repetitions < N_f will consume a fraction of that life. Similarly, load repetitions ≥ N_f will destroy the pavement structure. Conceptually, the fractional portion of the pavement structure’s life consumed by a total number of applied loads (N_a) can be calculated simply by dividing the number of applied loads by the allowable repetitions to failure (N_a/N_f). Failure is said to occur when $N_a/N_f \geq 1$. This line of reasoning leads to discussion of the next principle.

4.3.3 Predicting Structural Failure by Summing up Damage Increments

Mechanistic design applies the incremental damage concept through the use of Miner’s law.

The $N_a/N_f \geq 1$ equation introduced above is conceptual. The equation is used in a modified form in the actual pavement design process. The modified equation (known as Miner’s law) expresses failure as an incremental process that is calculated using simple summation. In Miner’s law, a failed condition is approached as fractional increments of damage are added together. Each increment can be thought of as a fraction of total failure caused by design load repetitions applied when a specific combination load and/or materials conditions exist (such as during different seasons of the year).

The Miner’s law expression presented below shows that a condition of failure exists when the sum of damage increments exceeds 1.

$$\sum_{i=1}^{i=total} \left({}^{N_a}\!/\!{}_{N_f} \right)_i \geq 1$$

where:

N_a = the actual number of design vehicle loads applied during the i^{th} set of conditions

N_f = the number of design loads that would cause failure during the i^{th} set of conditions

The $\left({}^{N_a}\!/\!{}_{N_f} \right)_i$ term represents the fractional increment of damage occurring during the i^{th} set of load and materials conditions. The Miner’s law concept can be explained fairly easily by an example. The following example examines an asphalt concrete pavement layer and the fractional portions of fatigue life consumed during various seasons of the year.

A Simple Application of Miner's Law

In this example, let's first analyze the asphalt concrete pavement layer of a pavement structure using ELSYM5 and the TAI damage equation previously discussed (TAI applies to heavily bound layers). The pavement is analyzed for three sets of conditions (i = 1 through 3). The three sets of conditions are: spring, summer, and fall. ELSYM5 will be used to calculate the maximum tensile strain at the bottom of the asphalt concrete layer for each season, based on the properties of the materials (materials properties will be different for each season) and the design load. Using the maximum tensile strain calculated by ELSYM5 for each season, the TAI equation will be used to calculate the number of loads to fatigue failure (N_f) for each season. The actual number of load repetitions expected during each season (N_a) is known based on traffic forecasting, e.g., ESALs. The application of Miner's law is laid out in tabular form below.

Season	N_a	N_f	N_a/N_f
Spring	300,000	600,000	0.50
Summer	1,000,000	5,000,000	0.20
Fall	900,000	7,000,000	0.13

Miner's law summation is: $(N_a/N_f)_{spring} + (N_a/N_f)_{summer} + (N_a/N_f)_{fall} = 0.83$

Miner's law states that the failure will not occur unless: $$\sum_{i=1}^{i=total}\left({}^{N_a}\!\big/_{N_f} \right)_i \geq 1$$

Therefore, the asphalt concrete pavement should not fail in fatigue with the expected number of load repetitions. Furthermore, the results indicate that no more than about 83% of the fatigue life of the asphalt concrete pavement will be consumed by the expected load repetitions.

4.4. Stepping Through the Design Process—An Example

1. The designer assembles design input data.

   a. Wheel configuration, tire pressure, and intensity of design load

      Dual tire load of 4,500 lbs/tire, with 90 psi tire pressure

      Tires separated 13.5 inches center-to-center

   b. Number of applied design load cycles expected during the pavement's design life (this total number is subdivided according to the percentages of load applications during spring, summer, fall, and winter)

      1,000,000 load repetitions total, subdivided as:

      30% in spring = 300,000 load repetitions = $N_{a,\ Spring}$

      50% in summer = 500,000 load repetitions = $N_{a,\ Summer}$

      20% in fall = 200,000 load repetitions = $N_{a,\ Fall}$

   c. M_R and μ of each layer in the proposed pavement structure (one set of these materials properties must be defined for each season of the year, i.e., spring, summer, fall, and winter)

Materials Properties **Material Type**	**Thickness (inches)**	**Spring**		**Summer**		**Fall**	
		M_R (ksi)	μ	**M_R (ksi)**	μ	**M_R (ksi)**	μ
Asphalt Concrete	3.5	754	0.30	508	0.30	508	0.30
Base Course	6	44	0.35	51	0.35	51	0.35
Subbase	36	26	0.40	36	0.40	36	0.40
Subgrade	Semi-I*	44	0.35	10	0.45	10	0.45

(* semi-infinite thickness)

d. Proposed thickness of each layer in the proposed pavement structure

Layer thicknesses are included in the above table

e. Asphalt concrete mix properties

density of asphalt concrete = 150 pcf

% asphalt cement by total weight of mix = 5.5

% air voids = 4

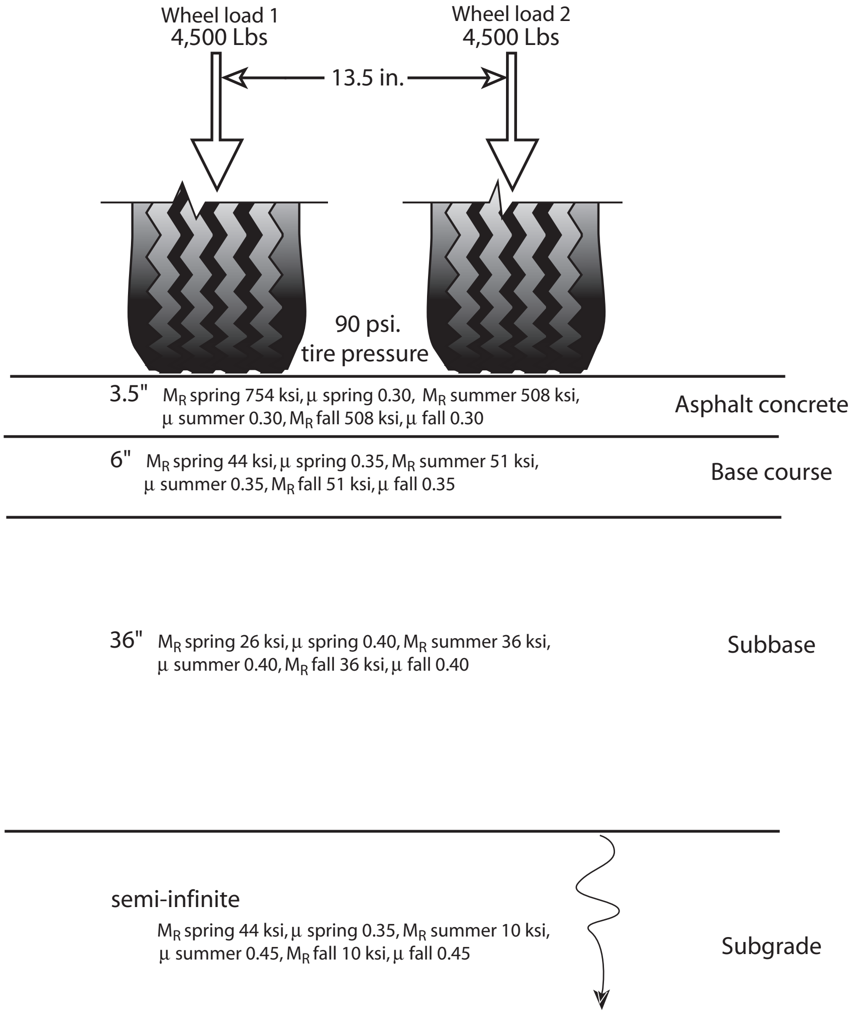


Figure 4-6. Pavement Structure Used in Example Problem

2. The designer loads data to AKFPD input screen and runs program.
3. AKFPD calculates response stresses and strains at critical locations within the pavement structure due to application of the design load. A separate set of response stresses and strains is calculated for each critical location and for each season, based on materials properties for that season.

Calculated Stresses and Strains

Season	Tensile Strain (micro-strain) at Critical Location	Compressive Stress (psi) at Critical Locations		
	Bottom of Asphalt Concrete (depth = 3.5”)	Top of Base (depth = 3.5”)	Top of Subbase (depth = 9.5”)	Top of Subgrade (depth = 45.5”)
Spring	192	26.4	11.6	1.9
Summer	202	33.5	13.6	1.0
Fall	202	33.5	13.6	1.0

4. AKFPD then calculates the number of times the design load can be applied before all of the pavement’s life is expended and pavement failure occurs. The number of allowable loads is separately calculated for each critical location and for each season, using the previously calculated stresses and strains as input values to empirical damage equations (transfer functions).

Calculated Loads to Failure

Season	Loads to Failure, N_f, Based on Analyses at Critical Locations			
	For Asphalt Concrete	For Base Course	For Subbase	For Subgrade
Spring	3,030,000	2,090,000	5,480,000	11,094,000,000
Summer	3,590,000	1,550,000	9,430,000	467,510,000
Fall	3,590,000	1,550,000	9,430,000	467,510,000

5. AKFPD then calculates seasonal **fractional amounts** of pavement life expended (seasonal damage fractions) by dividing the number of design loads for each season by the number of allowable loads for that season.

Calculate Fractions of Pavement Life Expended During Each Season

Season	N_a/N_f Based on Analyses at Critical Locations			
	For Asphalt Concrete	For Base Course	For Subbase	For Subgrade
Spring	3.00e5 / 3.03e6 = 0.099	3.00e5 / 2.09e6 = 0.144	3.00e5 / 5.48e6 = 0.055	3.00e5 / 1.11e10 = 0.00003
Summer	5.00e5 / 3.59e6 = 0.139	5.00e5 / 1.55e6 = 0.323	5.00e5 / 9.43e6 = 0.053	5.00e5 / 4.68e8 = 0.00107
Fall	2.00e5 / 3.59e6 = 0.056	2.00e5 / 1.55e6 = 0.129	2.00e5 / 9.43e6 = 0.021	2.00e5 / 4.68e8 = 0.00043

6. AKFPD next applies Miner’s law to determine **total amount** of pavement life expended by adding together the seasonal fractions. According to Miner’s law, the pavement has failed if this total damage summation for any layer of material is ≥ 1.

Using Miner's Law, Sum Up Seasonal Damage Fractions

Season	Sum Damage: $(N_a/N_f)_{spring} + (N_a/N_f)_{summer} + (N_a/N_f)_{fall}$ Based on Analyses at Critical Locations			
	For Asphalt Concrete	**For Base Course**	**For Subbase**	**For Subgrade**
Spring	0.099	0.144	0.055	0.00003
Summer	0.139	0.323	0.053	0.00107
Fall	0.056	0.129	0.021	0.00043
Miner's Law Damage Summation for Each Column	0.294	0.596	0.129	0.00153

Interpreting Miner's law for this example: Miner's law states that the pavement structure will fail if the damage summation for any critical location exceeds 1, i.e.,

$$\sum_{i=1}^{i=total}\left({}^{N_a}\!\!\diagup\!{}_{N_f} \right)_i \geq 1$$

In this example, damage sums do not exceed 1 for any critical location. The proposed design is therefore structurally acceptable. Select the most economical design (using life-cycle cost analysis) from several different designs that are found to be structurally acceptable (using mechanistic design).

In addition to determining acceptability or unacceptability of the proposed pavement structure, Miner's law provides some useful insight into the structure's behavior. Referring to the previous table, one can determine which critical locations (and therefore which materials) are controlling acceptability of the proposed design. In this case, the damage summation assessed at the top of the subgrade is near zero at less than 0.2% (table sum = 0.00153), showing that the subgrade is essentially completely protected from load effects by overlying structural layers. We can see that the asphalt concrete pavement has received enough load repetitions to use up about 30% (table sum = 0.294) of its available life, and that 60% (table sum = 0.596) of the base course's life has been exhausted. Such information can help you predict which failure modes are most probable in the future.

If the total damage summation had been ≥ 1 for any layer of material, the pavement structure (as a whole) cannot withstand the required number of cycles of the design load. In that case the designer would rerun the program using different sets of input variables, such as different aggregate layer thicknesses, higher quality aggregate materials, thicker asphalt concrete pavement, etc., until the total damage summation for each layer of material is less than 1.

4.5. Overlaying an Existing Asphalt Concrete Layer

Pavement overlay involves placing an additional (new) asphalt concrete pavement layer on top of an existing asphalt concrete layer. The new total thickness is designed to withstand a specified number of future design load repetitions. The method of designing the required thickness for the new layer accounts, mechanistically, for the amount of fatigue damage done to the old asphalt concrete layer by past load repetitions (before the overlay). You can choose to operate AKFPD in an overlay design mode. If operated in this mode, AKFPD will automatically calculate the required overlay thickness.

The process of determining an overlay thickness for an existing paved structure uses essentially the same series steps shown above. Conceptually, the old asphalt concrete layer simply becomes redefined as the second layer of a "new" pavement structure. AKFPD then determines the thickness of new pavement required to satisfy the structural requirements of future traffic. The minimum overlay thickness is 2.0 inch.

Refer to Section 2.2.3 for overlay design guidelines.

4.6. Mechanistic Design Using the AKFPD Computer Program

4.6.1. Generalized Steps Through the Program for Designing a New Pavement Structure

1. The designer assembles design input data:
   a. Wheel configuration, tire pressure, and load intensity of design load
   b. Number of design load cycles expected during the pavement's design life (this total number is subdivided according to the percentages of load applications during spring, summer, fall, and winter)
   c. M_R and μ of each layer in the proposed pavement structure (one set of these materials properties must be defined for each season of the year, i.e., spring, summer, fall, and winter)
   d. Asphalt concrete mix properties
   e. Proposed thickness of each layer in the pavement structure
2. The designer loads data to AKFPD input screen and runs program.
3. AKFPD calculates response stresses and strains at critical locations within the pavement structure due to application of the design load. A separate set of response stresses and strains is calculated for each season based on materials properties for that season.
4. AKFPD then calculates allowable loads, i.e., the number of times the design load can be applied before the pavement's life is 100% expended and pavement failure occurs. A separate set of allowable loads is calculated for each season using the previously calculated stresses and strains as input values to empirical damage equations (sometimes called transfer functions).
5. AKFPD then calculates seasonal **fractional amounts** of pavement life expended (seasonal damage fractions) by dividing the number of design loads for each season by the number of allowable loads for that season.
6. AKFPD next applies Miner's law to determine **total amount** of pavement life expended by adding together the seasonal fractions. According to Miner's law, the pavement has failed if this "total damage summation" is ≥ 1.
7. If the total damage summation is ≥ 1, the pavement structure is not sufficient to withstand the required number of cycles of the design load. Rerun the program using different sets of input variables, e.g., different aggregate layer thicknesses, higher quality aggregate materials, thicker asphalt concrete pavement, etc., until the total damage summation is less than 1.

4.6.2. Example 1—Getting Started and Performing a Simple Design

The following steps lead you through a simple example of AKFPD mechanistic pavement design analysis and interpretation of the results.

This design example does not use a previously saved input data file. In other examples, you will explore use and modification of previously saved input data files.

You will gain cumulative experience by going through each design example in turn because each successive example builds on information and tips contained in the previous one.

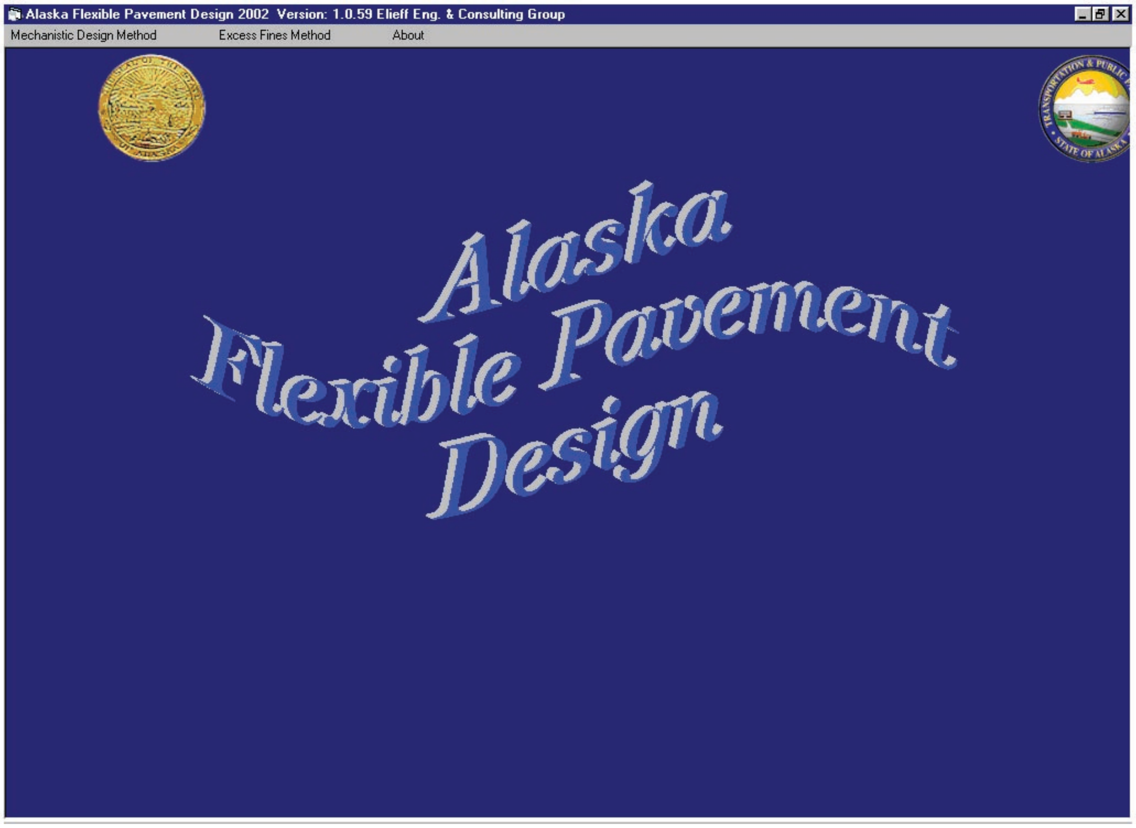
Mouse clicks are single clicks of the left button of the computer mouse configured in the standard operating mode.

Step 1. Insert the AKFPD program CD disk into one of your computer's CD drives.

Step 2. Install AKFPD onto your computer. If the software does not autoload, locate a listing of the CD's contents using the Windows ***My Computer Explore*** feature and run the program "setup.exe" file. Alternatively, use the Windows ***Start Run*** feature by typing in the appropriate CD disk drive and the filename "setup.exe." *The program can be removed by accessing the* ***Start Control Panel*** *feature of your computer, then selecting* ***Add/Remove***

Programs. *From the list of installed programs select "Alaska Flexible Pavement Design 2002" and proceed with the uninstall process.*

Step 3. Run AKFPD. Initiate the ***Start Programs*** feature of Windows, and from the listing of programs shown on your computer, run the program "Alaska Flexible Pavement Design 2002." The AKFPD title screen will appear as shown in Screen Clip 4-1.



Screen Clip 4-1

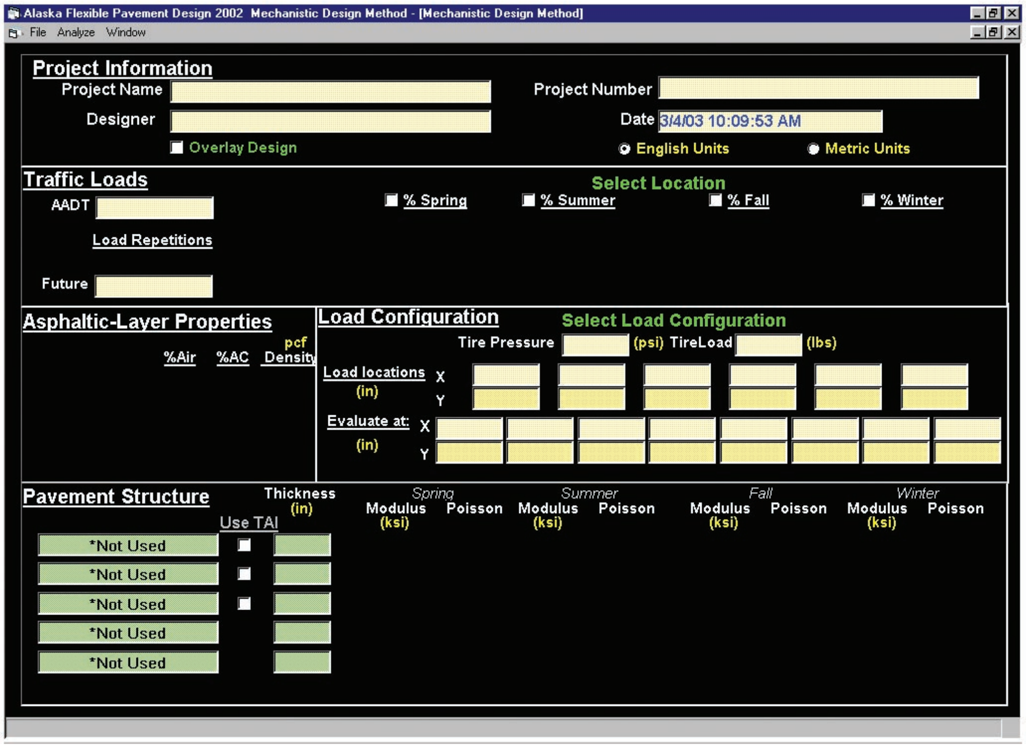
Step 4. Near the top left corner of the introductory screen, two program design method options are offered. One of the options is labeled ***Mechanistic Design Method.*** Using your mouse, click on that option. The pull-down menu shown in Screen Clip 4-2 will appear.

Screen Clip 4-2

Step 5. You now have two new options:

1. Click on ***New Analysis*** to begin a completely new mechanistic pavement design. A blank design input data screen will appear, which must be completely filled in by the designer before performing the analysis.
2. Click on ***Open Existing*** to begin an analysis using a previously saved input data file. The previously saved file can be opened then analyzed without modification, or the file can be opened and modified before analysis.

Step 6. This simple example uses the ***New Analysis*** option. Clicking on that one brings up the screen shown in Screen Clip 4-3.



Date 3/4/03 10:09:53 AM

☐ Overlay Design

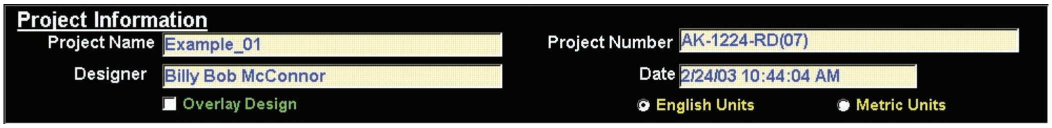
● English Units ○ Metric Units

Screen Clip 4-3

Type all data items required for the complete mechanistic analysis into this screen indicated in Screen Clip 4-3. Select/deselect on the screen by clicking. The following steps explain input values necessary to fill various areas of the screen.

Step 7. Use the ***Project Information*** section of the screen (see Screen Clip 4-4) for entering project identification information. Along the bottom of that section are toggles for selecting the system of numerical units to be used and selecting (or deselecting) overlay design mode. To operate the toggles, fill or clear the appropriate boxes with appropriate clicks.

Fill the ***Project Name, Project Number,*** and ***Designer*** designator boxes with appropriate strings of standard alphanumeric characters as in Screen Clip 4-4. Select each box with the mouse pointer. A single mouse click initiates the typing prompt. AKFPD automatically updates the ***Date*** box.


Project Information

Project Name: Example_01

Project Number: AK-1224-RD(07)

Designer: Billy Bob McConnor

Date: 2/24/03 10:44:04 AM

☐ Overlay Design

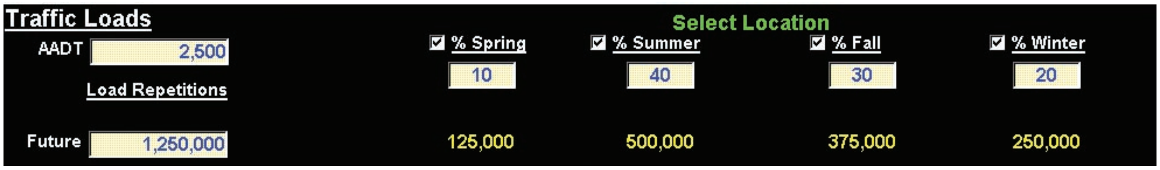
● English Units

○ Metric Units

Screen Clip 4-4

Because this is not an overlay design, note that the ***Overlay Design*** box remains clear. To continue with the example, use your mouse to designate applicable fields on your AKFPD input screen and type in the data indicated above.

Step 8. Use the ***Traffic Loads*** section of the input screen (see Screen Clip 4-5) for entering traffic frequency information. Select the ***AADT*** box using the mouse, and then type in the project's design average annual daily traffic number. Select the ***Future*** box. Type in the project's design ESALs.


Traffic Loads

AADT: 2,500

Load Repetitions

Future: 1,250,000

Select Location

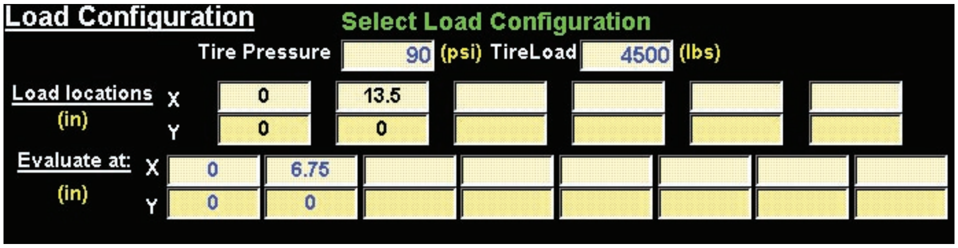
☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
10	40	30	20
125,000	500,000	375,000	250,000

Screen Clip 4-5

The elasticity of the pavement structure varies with the seasons. Therefore, the amount of wear caused to the pavement structure by a given number of vehicle loads is more or less severe depending on the season the load is applied. Therefore, the project's design ESAL number entered into the ***Future*** box must be seasonally subdivided to designate percentages of the total future ESAL (1,250,000) that are applied in each season. To allocate design ESAL percentages for each season, first click on each of the small boxes immediately to the left of each season identifier (see Screen Clip 4-5). As you click each box, a check mark will appear beside the season identifiers. Next, use the mouse to designate, for data entry, each of the boxes located below the season identifiers. Within each box, enter the desired percentages as shown in Screen Clip 4-5.

To continue with the example, use your mouse to designate applicable fields on your AKFPD input screen and enter the data shown in Screen Clip 4-5.

Step 9. Use the ***Load Configuration*** section of the input screen, shown in Screen Clip 4-6, for entering the characteristics of the design load and the x, y locations (in plan view) where pavement structural response will be calculated. This example is in English units so x, y coordinates are in inches.


Load Configuration

Select Load Configuration

Tire Pressure: 90 (psi) TireLoad: 4500 (lbs)

Load locations (in)	X	0	13.5						
	Y	0	0						
Evaluate at: (in)	X	0	6.75						
	Y	0	0						

Screen Clip 4-6

Under ***Select Load Configuration,*** enter data representing a simple dual-wheel design load. The load used in this example is the modified* ESAL normally used by DOT&PF for highway design. A ***Tire Pressure*** of 90 psi and ***Tire Load*** (for each tire) of 4,500 pounds is used.

> ** The modified ESAL load provides a slightly more severe, and therefore conservative, condition than the 80-psi tire pressure once used for DOT&PF highway pavement designs. Nowadays, 110-psi pressure represents current practice within the trucking industry.*

Use boxes located right of ***Load locations,*** in Screen Clip 4-6, for designating x, y coordinates (plan view) for the center of each of the tire loads. The x, y coordinates used in this example indicate that the tire centers are separated by 13.5 inches. Therefore, coordinates describing these tire locations are 0, 0 and 13.5, 0.

Use boxes located right of ***Evaluate at,*** in Screen Clip 4-6, for designating the plan view locations, within the pavement structure, to be analyzed for structural response. This example uses two locations. One location for analysis is directly under one of the wheel loads (use x, y coordinates of 0, 0). The second location is halfway between the wheel loads (use x, y coordinates of 6.75, 0).

Why not also evaluate structural response directly under the second wheel (at x, y coordinates of 13.5, 0)? By inspection you can see that the dual wheel configuration is symmetrical about two lines (see symmetry shown for two *loads* in Figure 4-4). One line of symmetry passes through the wheel centers, while the second line of symmetry is perpendicular to the previous line and located halfway between the wheel centers. Load symmetry indicates symmetry of structural response. Such symmetry indicates that the pavement structure's load response at coordinates 0, 0 and 13.5, 0 will be the same.

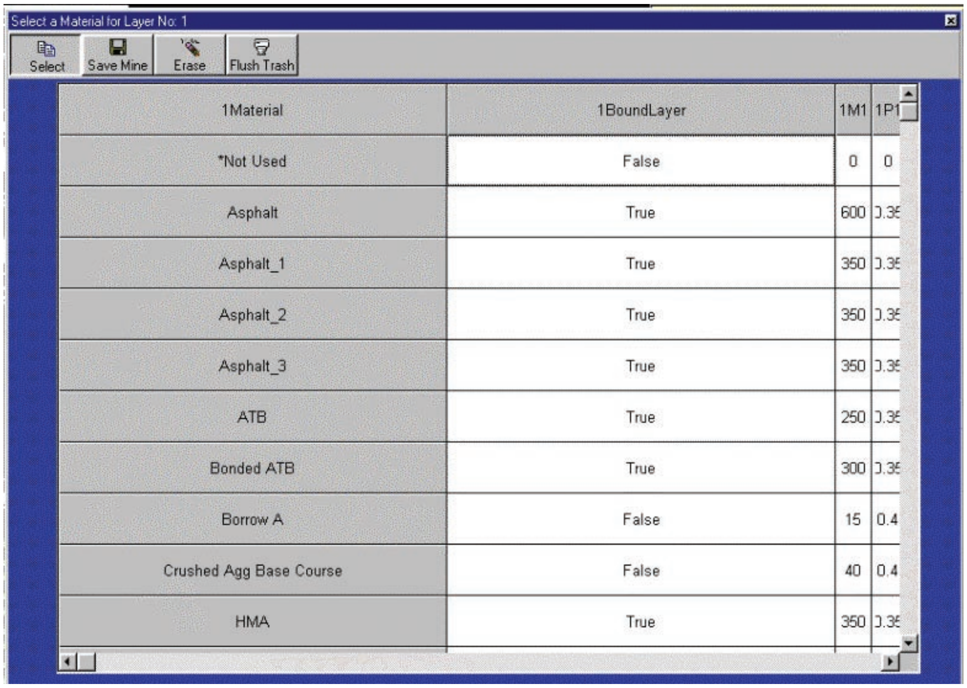
To continue with the example, use your mouse to designate applicable fields on your AKFPD input screen and type in the data indicated shown in Screen Clip 4-6.

Step 10. Use the ***Pavement Structure*** section of the input screen shown in Screen Clip 4-7 for entering the characteristics of each layer of material in the pavement structure. You can define up to five layers. Each layer is defined by its thickness and also by its resilient modulus (M_R) and Poisson's ration (μ) for each season of design load application (check your input screen against Step 8 of this example to verify that you have activated spring, summer, fall, and winter seasons as shown).

To begin entering materials properties, click the top left box labeled **** Not Used*** (shown in Screen Clip 4-7).

Screen Clip 4-7

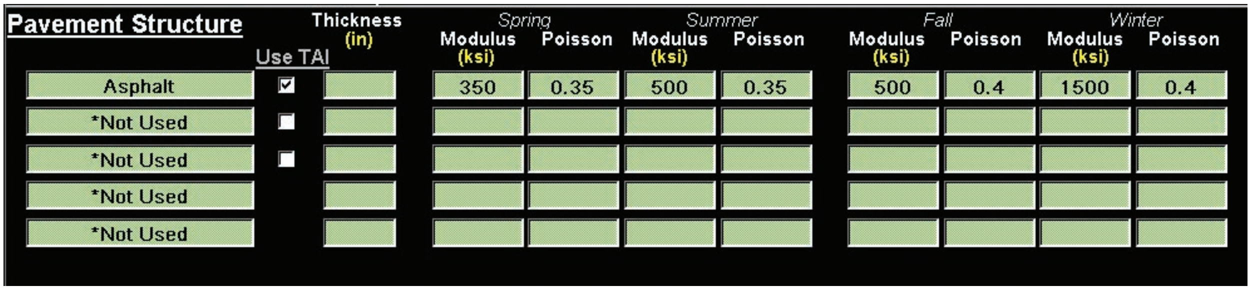
An auxiliary menu containing materials properties will appear as shown in Screen Clip 4-8.



1Material	1BoundLayer	1M1	1P1
*Not Used	False	0	0
Asphalt	True	600	0.35
Asphalt_1	True	350	0.35
Asphalt_2	True	350	0.35
Asphalt_3	True	350	0.35
ATB	True	250	0.35
Bonded ATB	True	300	0.35
Borrow A	False	15	0.4
Crushed Agg Base Course	False	40	0.4
HMA	True	350	0.35

Screen Clip 4-8

For this example, use the mouse to point and click at the material identified as ***Asphalt*** on the list. The menu will then disappear and presumptive M_R and μ values such as shown in Screen Clip 4-9 will appear.

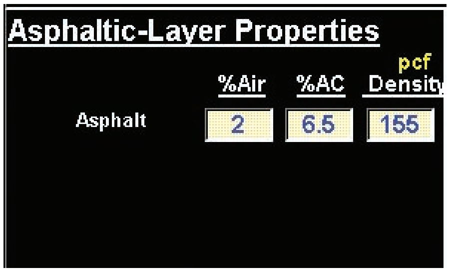


Pavement Structure	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑		350	0.35	500	0.35	500	0.4	1500	0.4
*Not Used	☐									
*Not Used	☐									
*Not Used										
*Not Used										

Screen Clip 4-9

Notice that a check mark has automatically been placed in the top box located in the ***Use TAI*** column. The check mark specifies that the TAI equation (see Section 4.3.2) will be used to calculate the number of design load repetitions until failure—this is the correct equation to use for normal asphalt concrete materials. The critical structural response parameter used in the TAI equation is tensile strain at the bottom of the layer.

When one of the materials receives a check mark in the ***Use TAI*** column, data fields will appear on the input screen section labeled ***Asphaltic-Layer Properties*** (see Screen Clip 4-10). You must enter data in each of these boxes because they are required variables in the TAI equation. If you have included default asphalt concrete mix properties in the database for the material type you selected, then values will appear automatically. If the database does not contain default mix properties, blank data fields will appear and you must type the appropriate mix data into each of the three data fields.

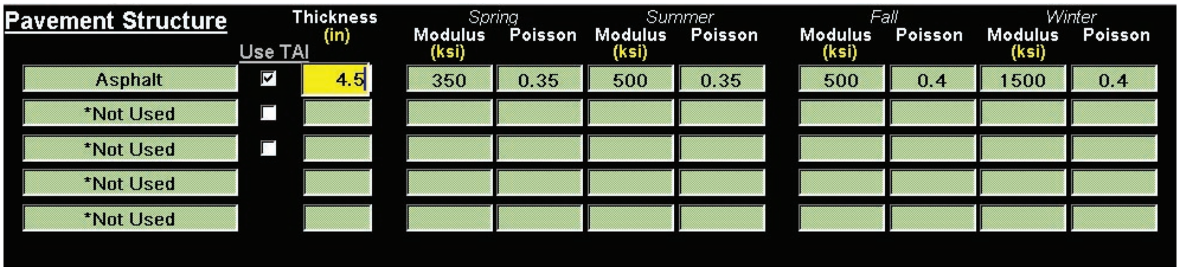


Asphaltic-Layer Properties

	%Air	%AC	pcf Densit
Asphalt	2	6.5	155

Screen Clip 4-10

Now click in the upper box in the ***Thickness*** column and enter the 4.5-inch asphalt concrete thickness as shown in Screen Clip 4-11.

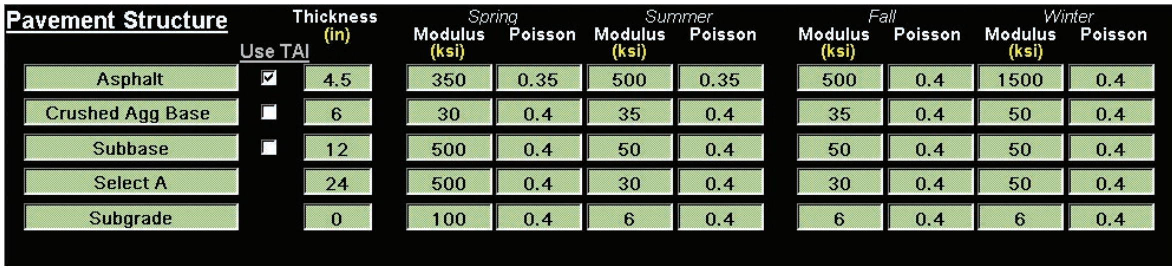


Pavement Structure

	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑	4.5	350	0.35	500	0.35	500	0.4	1500	0.4
*Not Used	☐									
*Not Used	☐									
*Not Used										
*Not Used										

Screen Clip 4-11

Enter properties for the remaining layers in the manner described above until you complete the data entry process as shown in Screen Clip 4-12.



Pavement Structure

	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑	4.5	350	0.35	500	0.35	500	0.4	1500	0.4
Crushed Agg Base	☐	6	30	0.4	35	0.4	35	0.4	50	0.4
Subbase	☐	12	500	0.4	50	0.4	50	0.4	50	0.4
Select A		24	500	0.4	30	0.4	30	0.4	50	0.4
Subgrade		0	100	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-12

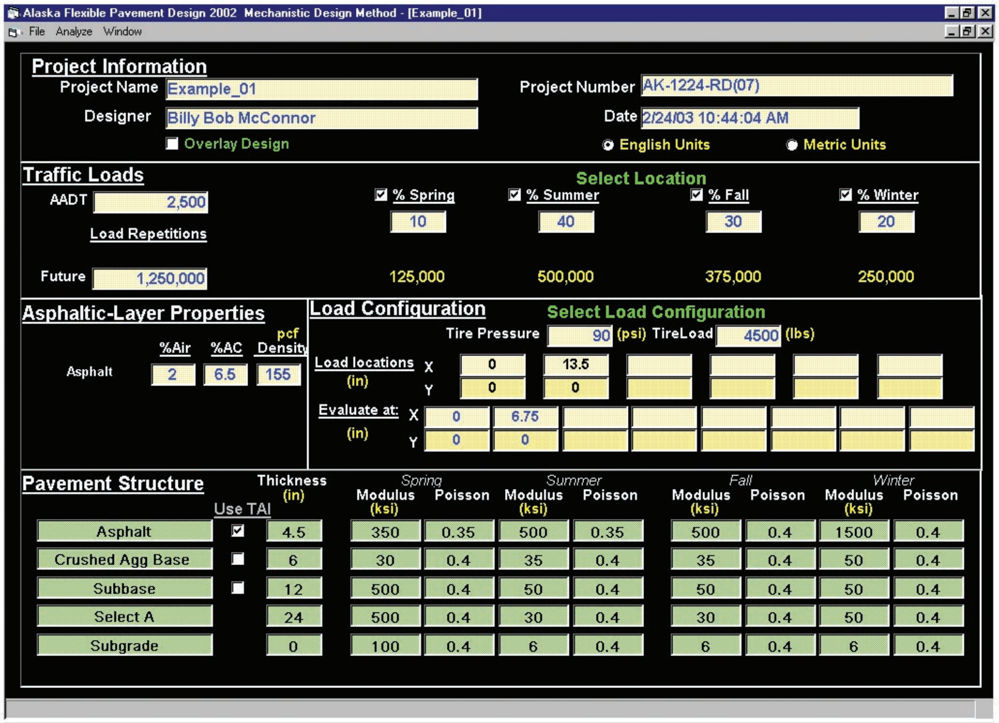
In this example, the thickness of the bottom layer is entered as 0. A thickness of 0 used for the bottom layer tells AKFPD that the bottom layer has infinite thickness. If you enter thickness other than 0 (48 inches, for example), AKFPD will assign the lower layer this thickness, and then automatically insert a hard surface (having infinite stiffness) under the bottom layer. When the hard surface is used, the AKFPD analysis automatically assumes a condition of no slippage at the interface, i.e., the bottom layer is assumed fully bonded to the hard surface.

If data obtained from the menu is different than that shown in Screen Clip 4-12, click in any box and you can change the number as desired. The menu selections contain default data that you can change.

In Screen Clip 4-12, notice that check marks are not automatically placed in the ***Use TAI*** column when the materials selected are not asphalt concrete types. When no check mark is entered for a material, the Per Ullidtz equation (see Section 4.3.2) will be used to calculate the number of design load repetitions until failure—this is the correct equation to use for normal aggregate or soil materials or for lightly stabilized materials containing less than 3% asphalt cement. The critical structural response parameter used in the Per Ullidtz equation is compressive stress at the top of the layer.

To continue with the example, use your mouse to designate applicable fields on your AKFPD input screen and type in the data indicated on Screen Clip 4-12.

Step 11. Your completed input screen should look like the one shown as Screen Clip 4-13. If it does not, use your mouse to designate fields where data will need to be changed. Enter corrections until your input screen appears exactly as shown.



Project Information

Project Name: Example_01

Project Number: AK-1224-RD(07)

Designer: Billy Bob McConnor

Date: 2/24/03 10:44:04 AM

☐ Overlay Design

● English Units ○ Metric Units

Traffic Loads

AADT: 2,500

Select Location

	☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
	10	40	30	20
Load Repetitions Future 1,250,000	125,000	500,000	375,000	250,000

Asphaltic-Layer Properties

	%Air	%AC	pcf Density
Asphalt	2	6.5	155

Load Configuration

Select Load Configuration

Tire Pressure 90 (psi) TireLoad 4500 (lbs)

Load locations (in)	X	0	13.5						
	Y	0	0						
Evaluate at: (in)	X	0	6.75						
	Y	0	0						

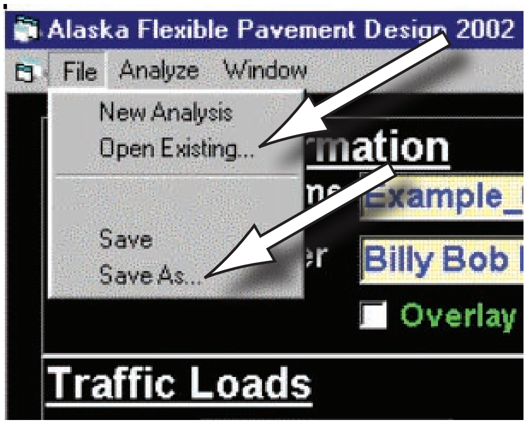
Pavement Structure

	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑	4.5	350	0.35	500	0.35	500	0.4	1500	0.4
Crushed Agg Base	☐	6	30	0.4	35	0.4	35	0.4	50	0.4
Subbase	☐	12	500	0.4	50	0.4	50	0.4	50	0.4
Select A		24	500	0.4	30	0.4	30	0.4	50	0.4
Subgrade		0	100	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-13

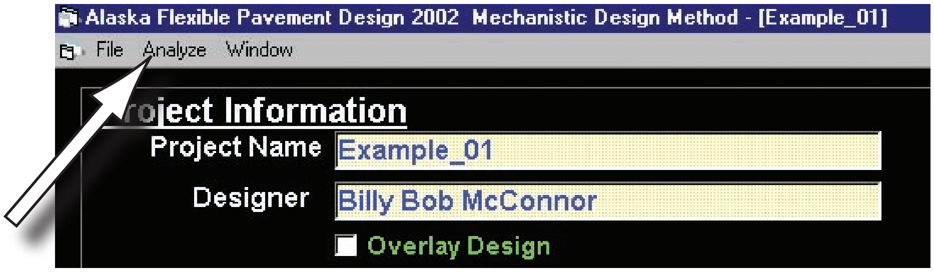
When you complete the input screen as indicated, you are ready to analyze the input data.

Step 12. You may now save your input data screen by accessing the ***File, Save As*** commands indicated in Screen Clip 4-14. Once saved, the input screen can be opened later using the ***File, Open Existing*** commands and analyzed as explained below. The input screen can also be opened and the data modified before analysis. Section 4.6.3 further explains the process of saving and recalling data.



Screen Clip 4-14

Step 13. Perform the analysis and print the results. You are ready to initiate the computation process by clicking the ***Analyze*** button at the top left corner of the input screen shown in Screen Clip 4-15.



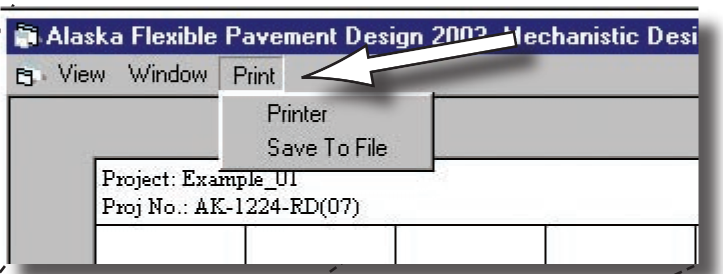
Project Name Example_01

Designer Billy Bob McConnor

☐ Overlay Design

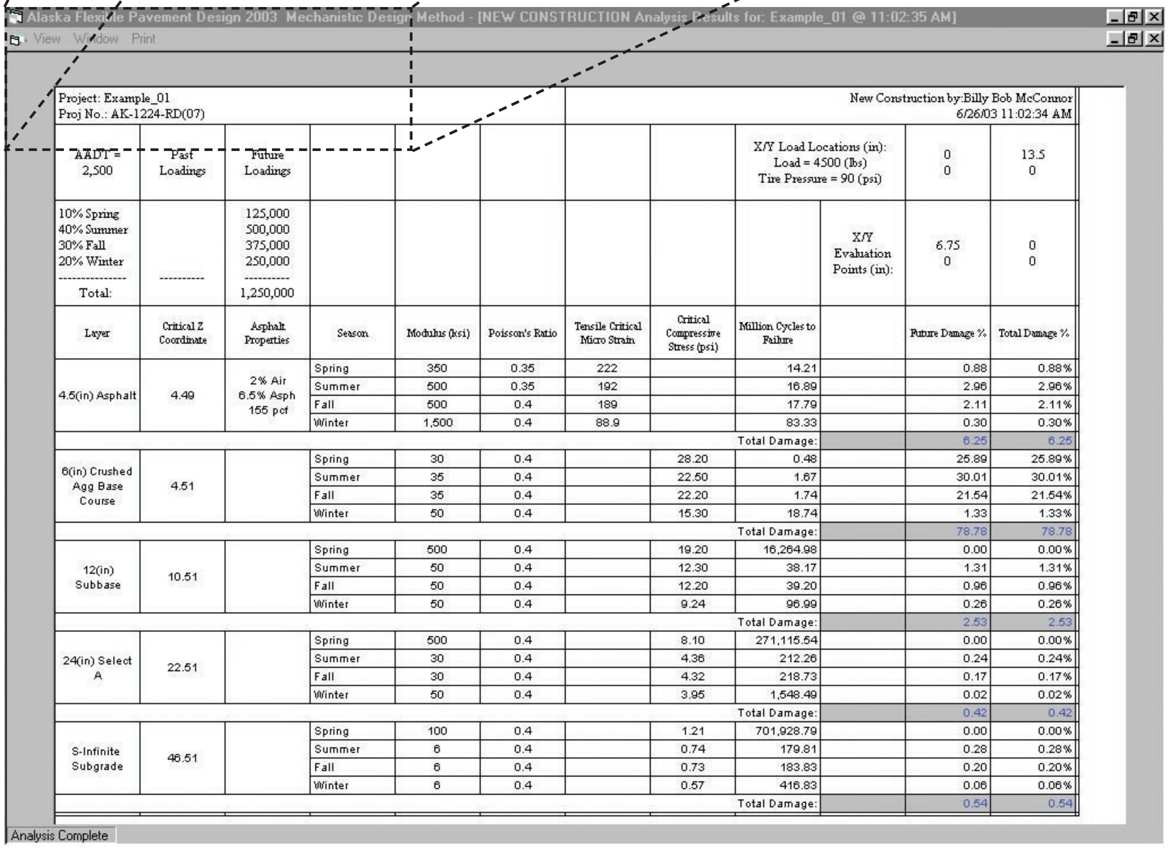
Screen Clip 4-15

The output screen shown as Screen Clip 4-16 will appear. You can print the screen in a format suitable for presentation by clicking the ***Print*** button at the top left corner of the output screen.



Project: Example_01
Proj No.: AK-1224-RD(07)

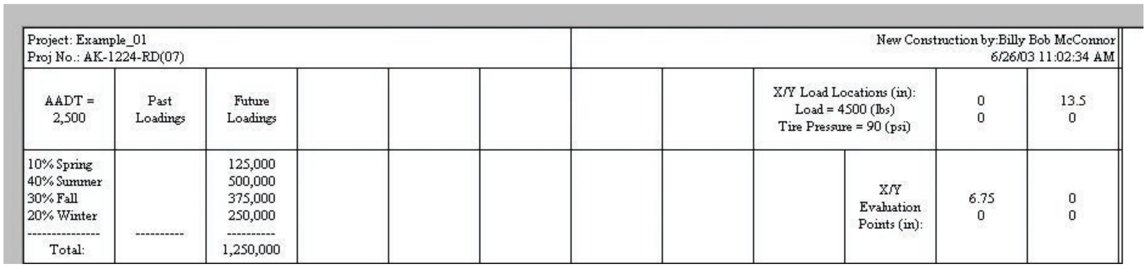
Screen Clip 4-15A



Project: Example_01 Proj No.: AK-1224-RD(07)						New Construction by:Billy Bob McConnor 6/26/03 11:02:34 AM					
AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 90 (psi)		0 0	13.5 0
10% Spring 40% Summer 30% Fall 20% Winter --------------- Total:	-----------	125,000 500,000 375,000 250,000 ---------- 1,250,000							X/Y Evaluation Points (in):	6.75 0	0 0
Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure		Future Damage %	Total Damage %
4.5(in) Asphalt	4.49	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	222		14.21		0.88	0.88%
			Summer	500	0.35	192		16.89		2.96	2.96%
			Fall	500	0.4	189		17.79		2.11	2.11%
			Winter	1,500	0.4	88.9		83.33		0.30	0.30%
								Total Damage:		6.25	6.25
6(in) Crushed Agg Base Course	4.51		Spring	30	0.4		28.20	0.48		25.89	25.89%
			Summer	35	0.4		22.50	1.67		30.01	30.01%
			Fall	35	0.4		22.20	1.74		21.54	21.54%
			Winter	50	0.4		15.30	18.74		1.33	1.33%
								Total Damage:		78.78	78.78
12(in) Subbase	10.51		Spring	500	0.4		19.20	16,264.98		0.00	0.00%
			Summer	50	0.4		12.30	38.17		1.31	1.31%
			Fall	50	0.4		12.20	39.20		0.96	0.96%
			Winter	50	0.4		9.24	96.99		0.26	0.26%
								Total Damage:		2.53	2.53
24(in) Select A	22.51		Spring	500	0.4		8.10	271,115.54		0.00	0.00%
			Summer	30	0.4		4.36	212.26		0.24	0.24%
			Fall	30	0.4		4.32	218.73		0.17	0.17%
			Winter	50	0.4		3.95	1,548.49		0.02	0.02%
								Total Damage:		0.42	0.42
S-Infinite Subgrade	46.51		Spring	100	0.4		1.21	701,928.79		0.00	0.00%
			Summer	6	0.4		0.74	179.81		0.28	0.28%
			Fall	6	0.4		0.73	183.83		0.20	0.20%
			Winter	6	0.4		0.57	416.83		0.06	0.06%
								Total Damage:		0.54	0.54

Screen Clip 4-16

Step 14. The upper portion of the output screen documents several types of input data. Included are project identification, load description data, specified evaluation locations, design AADT, design ESALs data, and seasonal percentages of ESAL application. These are shown in Screen Clip 4-17.

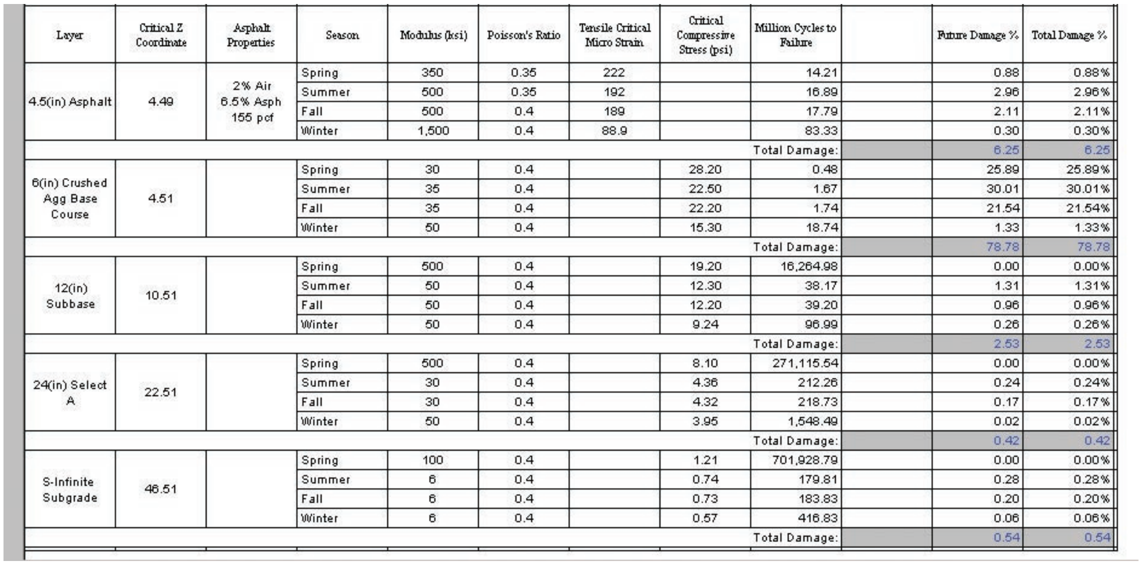


Project: Example_01 Proj No.: AK-1224-RD(07)						New Construction by:Billy Bob McConnor 6/26/03 11:02:34 AM					
AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 90 (psi)		0 0	13.5 0
10% Spring 40% Summer 30% Fall 20% Winter --------------- Total:	 ----------	125,000 500,000 375,000 250,000 ---------- 1,250,000							X/Y Evaluation Points (in):	6.75 0	0 0

Screen Clip 4-17

Step 15. The bottom portion of the screen contains the results of the mechanistic analysis as shown in Screen Clip 4-18. For further discussion, the output screen's columns are numbered 1 through 11.

1 2 3 4 5 6 7 8 9 10 11



Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure		Future Damage %	Total Damage %
4.5(in) Asphalt	4.49	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	222		14.21		0.88	0.88%
			Summer	500	0.35	192		16.89		2.96	2.96%
			Fall	500	0.4	189		17.79		2.11	2.11%
			Winter	1,500	0.4	88.9		83.33		0.30	0.30%
								Total Damage:		6.25	6.25
6(in) Crushed Agg Base Course	4.51		Spring	30	0.4		28.20	0.48		25.89	25.89%
			Summer	35	0.4		22.50	1.67		30.01	30.01%
			Fall	35	0.4		22.20	1.74		21.54	21.54%
			Winter	50	0.4		15.30	18.74		1.33	1.33%
								Total Damage:		78.78	78.78
12(in) Subbase	10.51		Spring	500	0.4		19.20	16,264.98		0.00	0.00%
			Summer	50	0.4		12.30	38.17		1.31	1.31%
			Fall	50	0.4		12.20	39.20		0.96	0.96%
			Winter	50	0.4		9.24	96.99		0.26	0.26%
								Total Damage:		2.53	2.53
24(in) Select A	22.51		Spring	500	0.4		8.10	271,115.54		0.00	0.00%
			Summer	30	0.4		4.36	212.26		0.24	0.24%
			Fall	30	0.4		4.32	218.73		0.17	0.17%
			Winter	50	0.4		3.95	1,548.49		0.02	0.02%
								Total Damage:		0.42	0.42
S-Infinite Subgrade	46.51		Spring	100	0.4		1.21	701,928.79		0.00	0.00%
			Summer	6	0.4		0.74	179.81		0.28	0.28%
			Fall	6	0.4		0.73	183.83		0.20	0.20%
			Winter	6	0.4		0.57	416.83		0.06	0.06%
								Total Damage:		0.54	0.54

Screen Clip 4-18

Column 1. Identifies the material used for each layer.

Column 2. Identifies depth location where critical stresses or strains are evaluated (see section 4.3.2). The critical structural response parameter used in the TAI equation is tensile strain at the bottom of the layer. The critical structural response parameter used in the Per Ullidtz equation is compressive stress at the top of the layer. Note that the locations of tops and bottoms of layers indicated in column 2 are not exactly at the layer interfaces. For computational purposes, the ELSYM5 program defines, at layer interfaces, the top of the lower layer as being located slightly downward into that layer—and defines bottom of the upper layer as being located slightly upward into that layer.

Column 3. Lists asphalt concrete mix properties for each layer that was analyzed using the TAI fatigue-performance equation.

Columns 4, 5, and 6. These identify, for each season, the resilient modulus (M_R), and Poisson's ratio (μ) assigned to the material identified in column 1. Units used for M_R are ksi. Poisson's ratio is unitless.

Column 7. Lists tensile strains at the base of asphalt-cemented layer(s) calculated for various seasons. Values show up in this column only when the ***Use TAI*** box on the input screen near the material type designator (discussed in step 10) has been checked. The TAI equation uses this value, along with asphalt mix properties specified on the input screen, for calculating the load-cycles-to-failure indicated in column 9. Units used in this column are micro-strain (μ-ε).

Column 8. Lists compressive stresses at the top of unbound or lightly bound aggregates or soils, calculated for various seasons. Values show up in this column only when the ***Use TAI*** box on the input screen near the material type designator (discussed in step 10) has ***not*** been checked. The Per Ullidtz equation uses this value for calculating the load-cycles-to-failure indicated in column 9. Units used in this column are psi.

Column 9. Lists the number of design load cycles-to-failure for each material type and for each season of design load application. Cycles-to-failure (N_f discussed in section 4.3.2) are calculated for each material type using either the TAI or the Per Ullidtz equation, as applicable. The TAI equation is used if the ***Use TAI*** box is checked on the input screen—otherwise, the AKFPD program defaults to the Per Ullidtz equation. Units used in this column are 10^6 cycles.

Column 10. Lists "future damage," i.e., the percentage of life actually used up by the design ESAL applications. Values in this column are calculated by dividing the seasonal design ESAL value by the seasonal cycles-to-failure value in column 9.

> Example: Springtime design ESALS to be applied to the pavement structure are 125,000 as shown in the top, left portion of the output screen (Screen Clip 4-17). At the top of column 9, the springtime loads-to-failure is shown as 14,210,000. Therefore, the percent of springtime fatigue damage reported for the asphalt concrete at the top of column 10 is:
>
> $(125{,}000/14{,}210{,}000) \text{ x } 100 \approx 0.88\%$

In addition to listing the percent damage for each season, seasonal damage percents are summed, for each material type, within the column. This sum is blue if < 100% and red if it is ≥ 100%. For each material type, the sum predicts the total percent of the pavement structure's load capacity that will be exhausted by application of the design ESALs.

Column 11 is not used in this example. It repeats the listing of values shown in column 10. Column 11 is used in overlay designs that involve placing a new layer of asphalt concrete surfacing atop an existing pavement structure. In overlay designs, column 11 presents the sum of two damage types. The sum includes "future damage" used by the future design ESALs (as in column 10) plus damage done by past ESALs to the existing pavement structure prior to overlay placement.

Step 16. Interpreting the results of the analysis requires inspection of damage percents listed in column 10 of Screen Clip 4-18. In this case, damage sums for all material layers are less than 100% (note on your computer screen that each sum is shown in blue). Because all damage sums are less than 100%, the structural load capacity will not be exceeded for any of the layers due to application of the design ESALs. In other words, none of the layers will fail. The effect of the design ESALs on each layer is now assessed based on column 10 data:

1. Asphalt concrete layer: Design ESALs will exhaust about 6% of the structural load capacity (life). ESALs applied during summer and fall seasons contribute most to the percentage.
2. Crushed aggregate base: Design ESALs will exhaust about 80% of the structural load capacity. ESALs applied during spring and summer seasons contribute most to the percentage.
3. Subbase: Design ESALs will exhaust about 2.5% of the structural load capacity. ESALs applied during summer and fall seasons contribute most to the percentage.

4. Select: Design ESALs will exhaust about 0.4% of the structural load capacity. ESALs applied during summer and fall seasons contribute most to the percentage.
5. Subgrade: Design ESALs will exhaust about 0.5% of the structural load capacity. ESALs applied during summer and fall seasons contribute most to the percentage.

Based on this analysis, only the base course is “working” very hard during the ESAL design life of the pavement structure. The base course layer is therefore considered to be the critical one in this example—the critical layer is so called because it controls the design. Since 80% structural life of the critical layer will be consumed by the 1,250,000 design ESAL loading, the example pavement structure should be able to withstand the following number of ESALs before failure:

1,250,000 / 0.8 ≈ 1.5 million ESALs

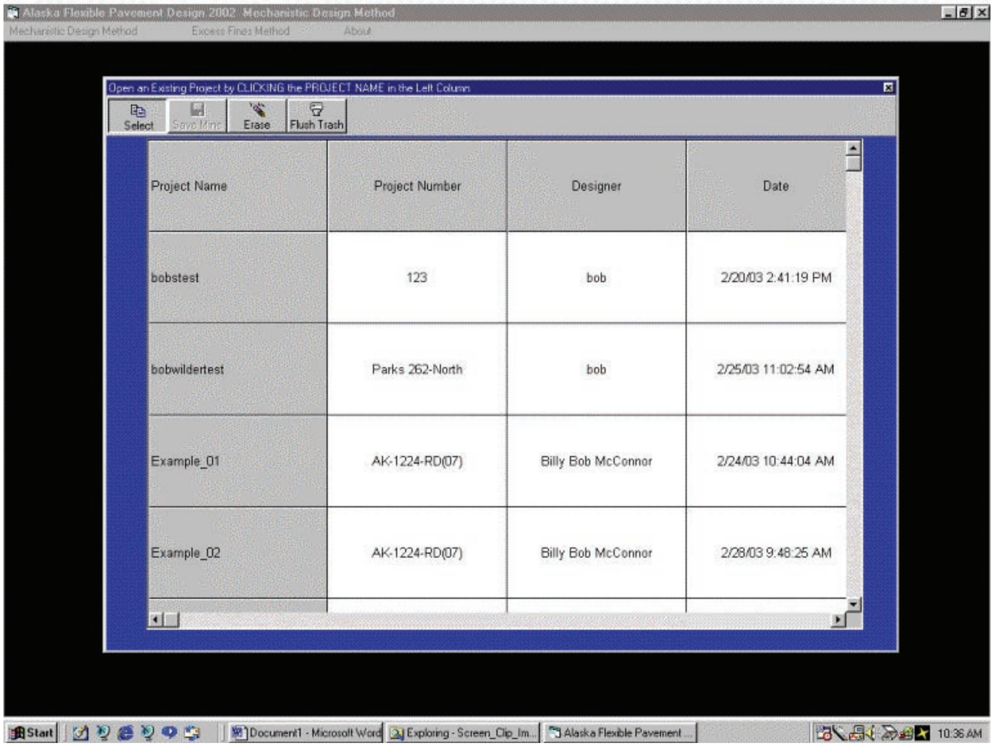
4.6.3 Saving, Recalling, and Modifying Files

Saving/Recalling the Input Screen

When you start the AKFPD program you can recall an existing data file (and modify it as necessary) instead of inputting new analysis data. Recall an existing file by accessing the ***Open Existing*** command on the ***Mechanistic Design Method*** pull-down menu from AKFPD’s opening screen as shown in Screen Clip 4-19.

Screen Clip 4-19

If you select the ***Open Existing*** option, a menu similar to the one shown in Screen Clip 4-20 appears. Click one of the data files to open it.



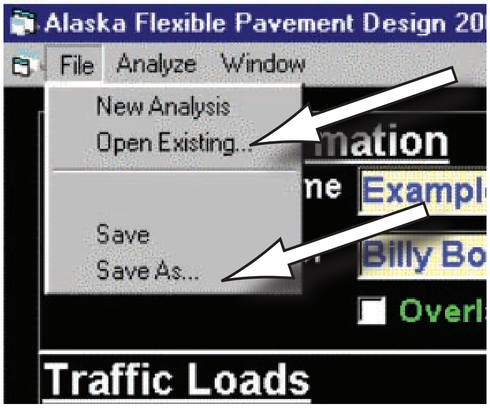
Open an Existing Project by CLICKING the PROJECT NAME in the Left Column

Project Name	Project Number	Designer	Date
bobstest	123	bob	2/20/03 2:41:19 PM
bobwildertest	Parks 262-North	bob	2/25/03 11:02:54 AM
Example_01	AK-1224-RD(07)	Billy Bob McConnor	2/24/03 10:44:04 AM
Example_02	AK-1224-RD(07)	Billy Bob McConnor	2/28/03 9:48:25 AM

Screen Clip 4-20

Using the menu shown in Screen Clip 4-20, you can remove a data file from the menu by clicking on the menu's ***Erase*** button. Then mark one or more of the menu selections for removal and click on the ***Flush Trash*** button to permanently remove them from the menu.

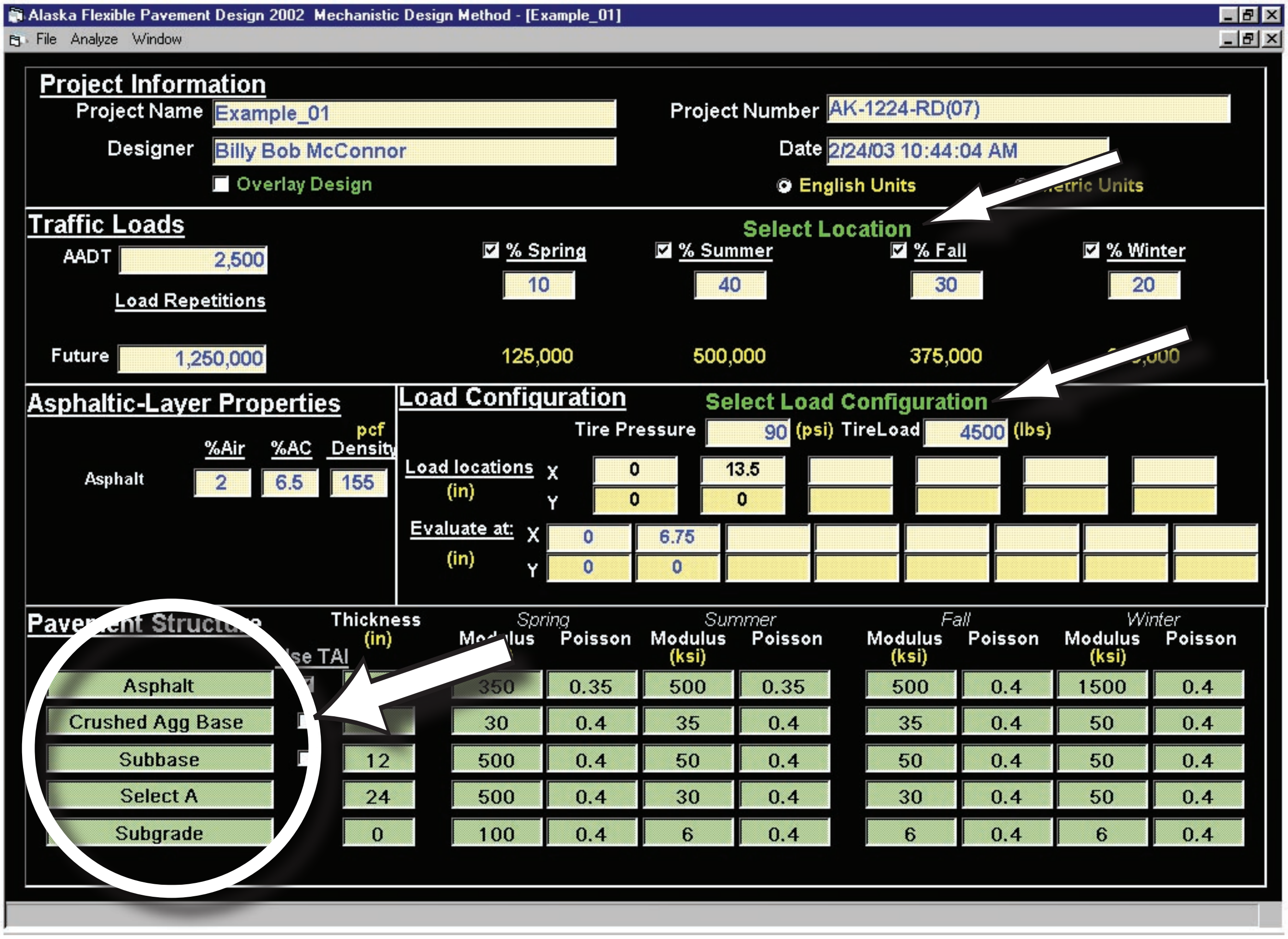
During the analysis you can save or open an existing data file. Save input screen data by accessing the ***File, Save As*** commands indicated in Screen Clip 4-21. Once saved, the input screen can be opened later using the ***File, Open Existing*** commands and analyzed as explained below. The input screen can also be opened and the data modified before analysis.



Screen Clip 4-21

Saving, Recalling, and Modifying Auxiliary Menu Data

For three types of variables, you can activate auxiliary menus and choose from a catalog of previously saved data. Pointers located on the input screen shown as Screen Clip 4-22 (using example 1 input data) indicate which of the variable types can be selected. Initiate menu selection by clicking on (a) ***Select Location,*** (b) ***Select Load Configuration,*** or (c) any one of the five material identification boxes at the bottom left of the screen. Instructions at the end of this section describe how to perform add or delete data contained in auxiliary menu files, i.e., how to customize the auxiliary menus.



Project Information

Project Name: Example_01

Designer: Billy Bob McConnor

Project Number: AK-1224-RD(07)

Date: 2/24/03 10:44:04 AM

☐ Overlay Design

● English Units ○ etric Units

Traffic Loads

		☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
AADT	2,500	10	40	30	20
Load Repetitions					
Future	1,250,000	125,000	500,000	375,000	,000

Asphaltic-Layer Properties

	%Air	%AC	pcf Density
Asphalt	2	6.5	155

Load Configuration

Tire Pressure 90 (psi) TireLoad 4500 (lbs)

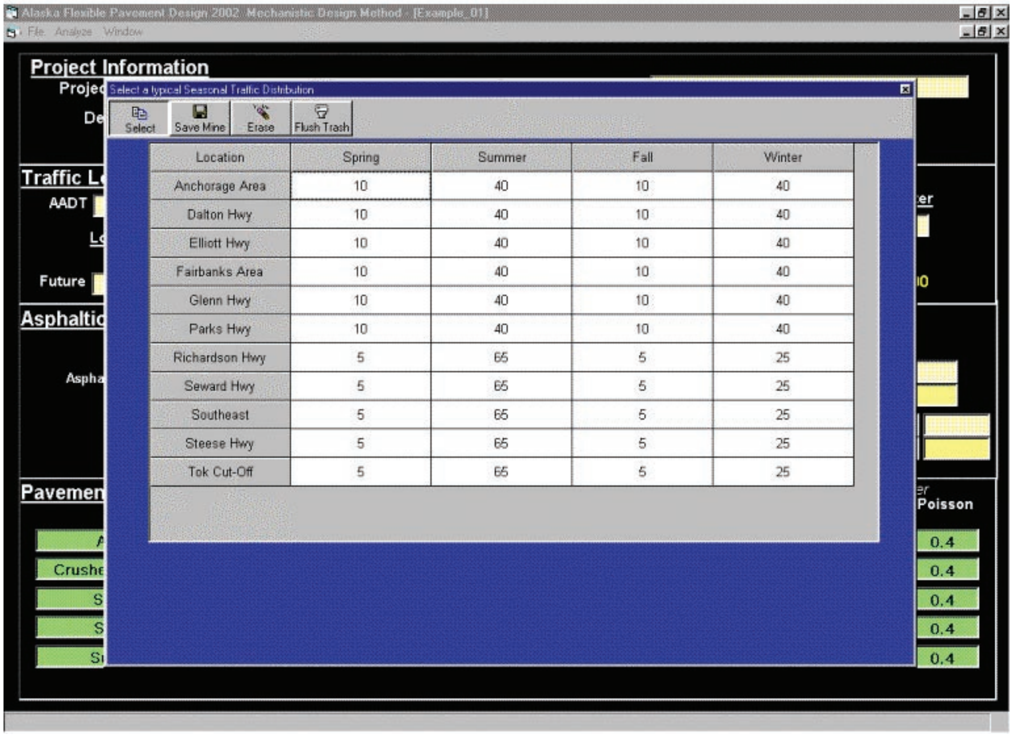
Load locations (in)	X	0	13.5						
	Y	0	0						
Evaluate at: (in)	X	0	6.75						
	Y	0	0						

Pave ent Structu e

	se TAI	Thickness (in)	Spring Mo lus	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑		350	0.35	500	0.35	500	0.4	1500	0.4
Crushed Agg Base	☐		30	0.4	35	0.4	35	0.4	50	0.4
Subbase	☐	12	500	0.4	50	0.4	50	0.4	50	0.4
Select A		24	500	0.4	30	0.4	30	0.4	50	0.4
Subgrade		0	100	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-22

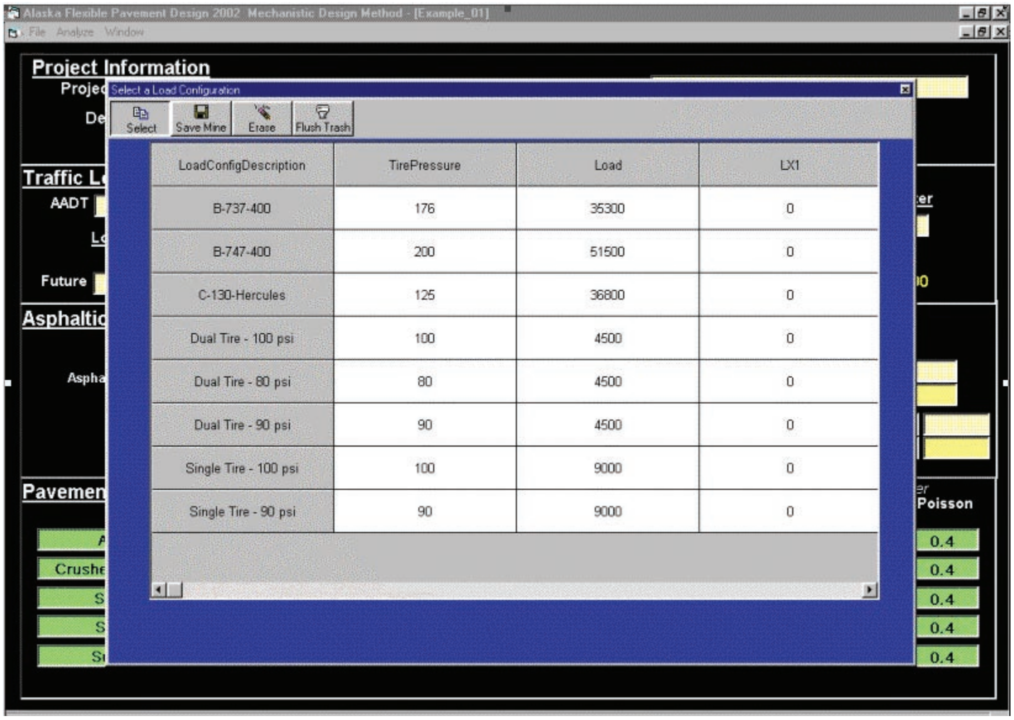
Point and click on ***Select Location*** and the menu shown in Screen Clip 4-23 will appear. From here you can select a particular set of seasonal ESAL distributions.



Location	Spring	Summer	Fall	Winter
Anchorage Area	10	40	10	40
Dalton Hwy	10	40	10	40
Elliott Hwy	10	40	10	40
Fairbanks Area	10	40	10	40
Glenn Hwy	10	40	10	40
Parks Hwy	10	40	10	40
Richardson Hwy	5	65	5	25
Seward Hwy	5	65	5	25
Southeast	5	65	5	25
Steese Hwy	5	65	5	25
Tok Cut-Off	5	65	5	25

Screen Clip 4-23

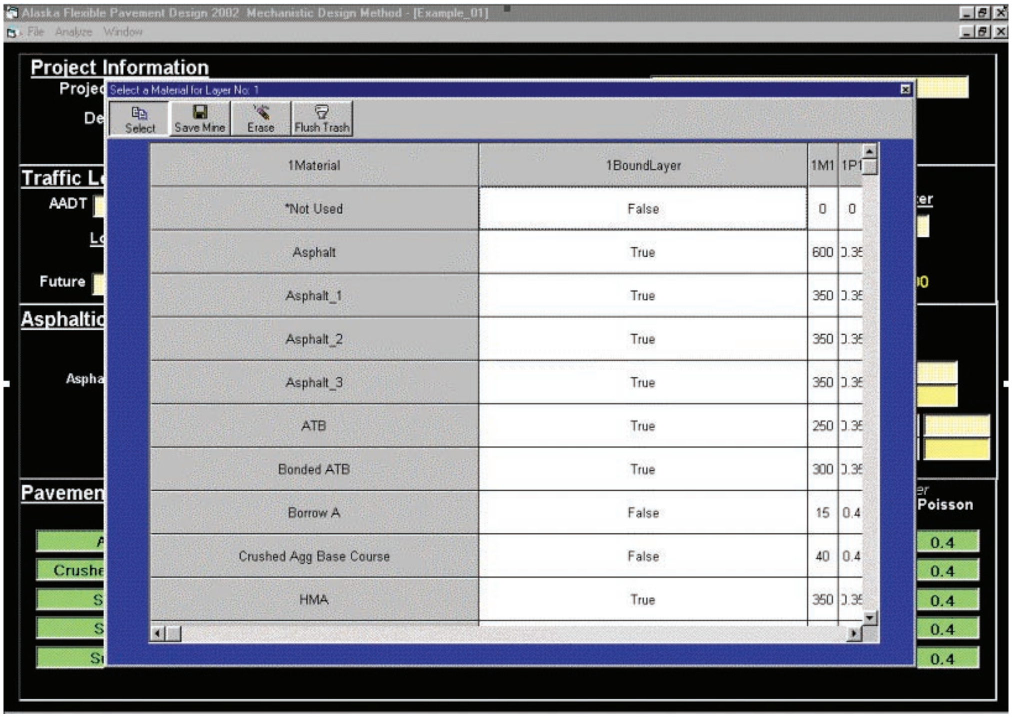
Click on ***Select Load Configuration*** and a menu as in Screen Clip 4-24 will appear. From this menu you can select a complete design load configuration. Each data set in the menu includes variables describing the design load in terms of wheel weight, tire pressure, and tire location. The data also specify plan view x, y coordinates designating where structural response will be calculated. For each menu selection, all data necessary to complete the ***Load Configuration*** section of the input screen are included.



LoadConfigDescription	TirePressure	Load	LX1
B-737-400	176	35300	0
B-747-400	200	51500	0
C-130-Hercules	125	36800	0
Dual Tire - 100 psi	100	4500	0
Dual Tire - 80 psi	80	4500	0
Dual Tire - 90 psi	90	4500	0
Single Tire - 100 psi	100	9000	0
Single Tire - 90 psi	90	9000	0

Screen Clip 4-24

Click on any of the five material types shown at the bottom of the input screen in Screen Clip 4-22 and a menu as shown in Screen Clip 4-25 will appear. From this menu the designer can select from one of the material types available. Except for layer thickness, each menu selection provides all data necessary to define the seasonal characteristics of a particular material type in the ***Pavement Structure*** section of the input screen.



1Material	1BoundLayer	1M1	1P1
*Not Used	False	0	0
Asphalt	True	600	0.3
Asphalt_1	True	350	0.3
Asphalt_2	True	350	0.3
Asphalt_3	True	350	0.3
ATB	True	250	0.3
Bonded ATB	True	300	0.3
Borrow A	False	15	0.4
Crushed Agg Base Course	False	40	0.4
HMA	True	350	0.3

Screen Clip 4-25

Adding Data to Auxiliary Menus: The auxiliary menu also allows you to save new data that you have entered on the input screen. To save new data, click on the auxiliary menu's ***Save Mine*** button. The new selection will show up on the auxiliary menu the next time it is activated. The described way of entering new menu data must be used because **you cannot enter new data by typing directly into an auxiliary menu screen**.

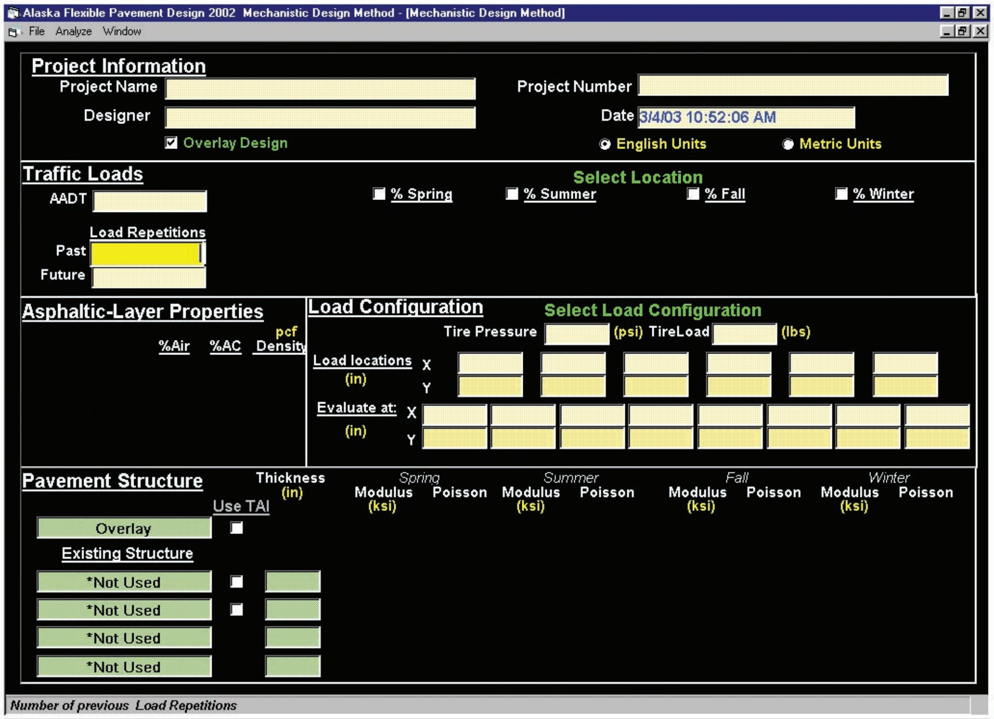
Deleting Data from Auxiliary Menus: You can remove data from the auxiliary menu by clicking on the menu's ***Erase*** button. Then mark one or more of the menu selections for removal, and click on the ***Flush Trash*** button.

4.6.4. Example 2—An Overlay Design

This example makes use of AKFPD's power to perform overlay design analyses. The concept of an overlay design is to determine how much pavement thickness needs to be added to an existing pavement to satisfy the requirements of future design ESALs. During the overlay design process, AKFPD accounts for the amount of structural life expended due to past ESAL applications. Past ESALs are those that were applied to the original pavement structure before the overlay placement.

You will gain cumulative experience by going through each design example because each example builds on information and tips contained in the previous one. This example uses many of the program operation techniques presented in Section 4.6.2, example 1. **If you have not thoroughly familiarized yourself with example 1, do so before proceeding with this example.**

Step 1. Begin this example design by initiating the ***Mechanistic Design Method, New Analysis*** input screen as described in example 1. When the input screen appears, click on the ***Overlay Design*** toggle. The input screen will appear as shown in Screen Clip 4-26.



Date 3/4/03 10:52:06 AM

☑ Overlay Design

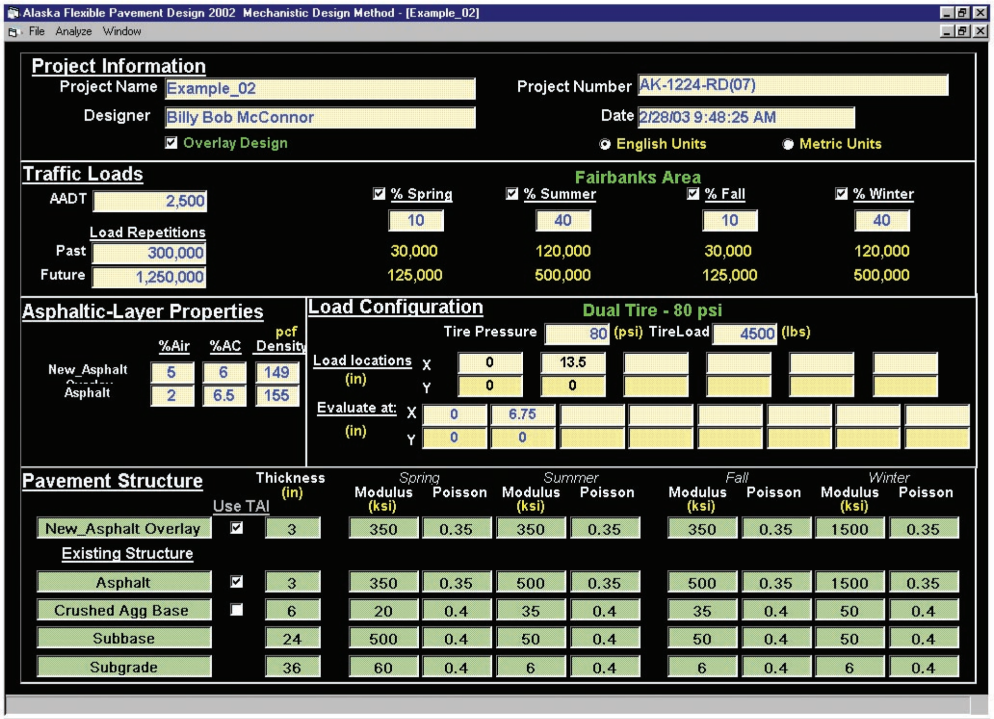
● English Units ○ Metric Units

	Use TAI
Overlay	☐
*Not Used	☐
*Not Used	☐
*Not Used	
*Not Used	

Number of previous Load Repetitions

Screen Clip 4-26

Step 2. Using mouse and keyboard, enter input data for the example until the input screen is filled as shown in Screen Clip 4-27.



Project Name Example_02

Project Number AK-1224-RD(07)

Designer Billy Bob McConnor

Date 2/28/03 9:48:25 AM

☑ Overlay Design

● English Units ○ Metric Units

Fairbanks Area

AADT 2,500

Load Repetitions		☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
		10	40	10	40
Past	300,000	30,000	120,000	30,000	120,000
Future	1,250,000	125,000	500,000	125,000	500,000

	%Air	%AC	pcf Density
New_Asphalt Overlay	5	6	149
Asphalt	2	6.5	155

Dual Tire - 80 psi

Tire Pressure 80 (psi) TireLoad 4500 (lbs)

Load locations (in)	X	0	13.5						
	Y	0	0						
Evaluate at: (in)	X	0	6.75						
	Y	0	0						

	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
New_Asphalt Overlay	☑	3	350	0.35	350	0.35	350	0.35	1500	0.35
Existing Structure										
Asphalt	☑	3	350	0.35	500	0.35	500	0.35	1500	0.35
Crushed Agg Base	☐	6	20	0.4	35	0.4	35	0.4	50	0.4
Subbase		24	500	0.4	50	0.4	50	0.4	50	0.4
Subgrade		36	60	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-27

Use mouse and keyboard to activate data input fields and input data as explained in example 1. However, the following tips may help expedite data entry within specific areas of the input screen:

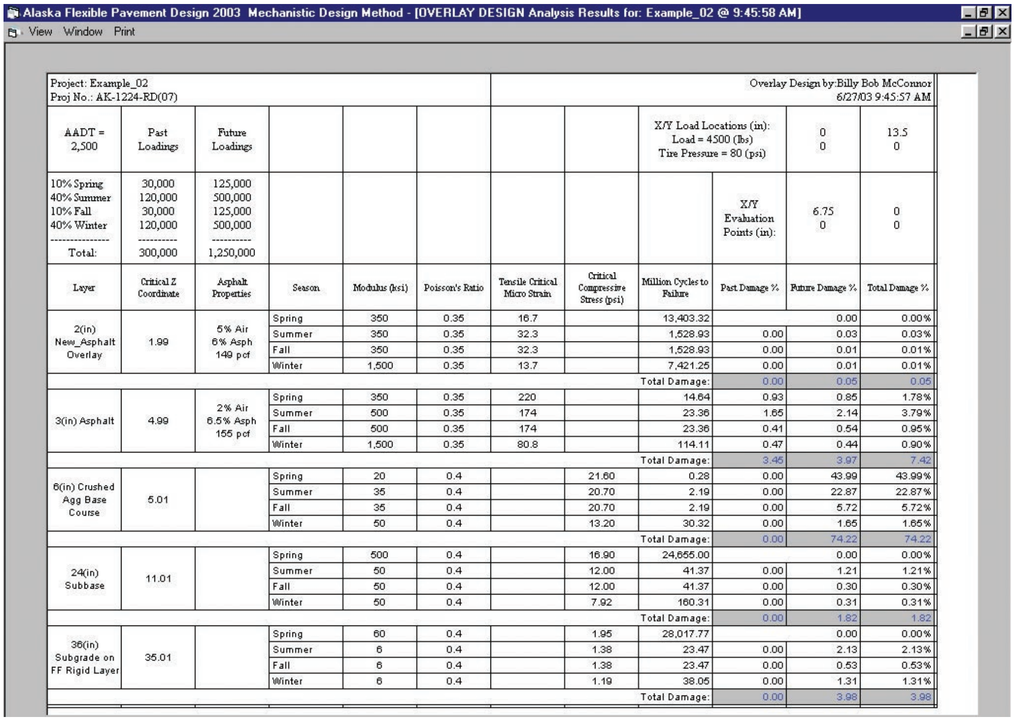
a. Tips for ***Traffic Loads*** section: As in the example, you can use an auxiliary menu to place data beneath the screen's ***Select Location*** designator. To do this, click on ***Select Location,*** and then select ***Fairbanks Area*** from the auxiliary menu. You do not need to use an auxiliary menu. You can click on each of the seasonal toggle boxes, and then type in the seasonal ESAL percents as shown in Screen Clip 4-27.

b. Tips for ***Load Configuration*** section: Click the left mouse button on the ***Select Load Configuration*** designator and then select from one of the choices on the auxiliary menu to fill applicable data boxes in the ***Load Configuration*** section. Alternatively, simply use mouse and keyboard to individually select and fill in the data entry fields exactly as shown in Screen Clip 4-27.

c. Tips for ***Pavement Structure*** section: Using auxiliary menus, select the material types shown in the example screen or use mouse and keyboard to select and fill in the data entry fields exactly as shown in Screen Clip 4-27. Be sure to use your mouse to activate the ***Use TAI*** toggle boxes for the top two materials. Both of these layers are asphalt concrete and must be analyzed using the TAI equation.

Step 3. Perform the analysis and print the results. Click on the ***Analyze*** button at the top of the screen. After the analysis is completed and the results screen appears, as in Screen Clip 4-28, use your mouse to point and click on the ***Print*** button at the top of the output screen.

Step 4. Interpret the results. All of the AKFPD output is contained on the output screen, as shown in Screen Clip 4-28. Example 1 identifies and generally explains the contents of each section and column of this screen. You should also have a printed copy of the output to follow along with the following interpretation.



Alaska Flexible Pavement Design 2003 Mechanistic Design Method - [OVERLAY DESIGN Analysis Results for: Example_02 @ 9:45:58 AM]

Project: Example_02 Proj No.: AK-1224-RD(07)						Overlay Design by:Billy Bob McConnor 6/27/03 9:45:57 AM					
AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 80 (psi)		0 0	13.5 0
10% Spring 40% Summer 10% Fall 40% Winter	30,000 120,000 30,000 120,000	125,000 500,000 125,000 500,000							X/Y Evaluation Points (in):	6.75 0	0 0
Total:	300,000	1,250,000									
Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure	Past Damage %	Future Damage %	Total Damage %
2(in) New_Asphalt Overlay	1.99	5% Air 6% Asph 149 pcf	Spring	350	0.35	16.7		13,403.32		0.00	0.00%
			Summer	350	0.35	32.3		1,528.93	0.00	0.03	0.03%
			Fall	350	0.35	32.3		1,528.93	0.00	0.01	0.01%
			Winter	1,500	0.35	13.7		7,421.25	0.00	0.01	0.01%
								Total Damage:	0.00	0.05	0.05
3(in) Asphalt	4.99	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	220		14.64	0.93	0.85	1.78%
			Summer	500	0.35	174		23.36	1.65	2.14	3.79%
			Fall	500	0.35	174		23.36	0.41	0.54	0.95%
			Winter	1,500	0.35	80.8		114.11	0.47	0.44	0.90%
								Total Damage:	3.45	3.97	7.42
6(in) Crushed Agg Base Course	5.01		Spring	20	0.4		21.60	0.28	0.00	43.99	43.99%
			Summer	35	0.4		20.70	2.19	0.00	22.87	22.87%
			Fall	35	0.4		20.70	2.19	0.00	5.72	5.72%
			Winter	50	0.4		13.20	30.32	0.00	1.65	1.65%
								Total Damage:	0.00	74.22	74.22
24(in) Subbase	11.01		Spring	500	0.4		16.90	24,655.00		0.00	0.00%
			Summer	50	0.4		12.00	41.37	0.00	1.21	1.21%
			Fall	50	0.4		12.00	41.37	0.00	0.30	0.30%
			Winter	50	0.4		7.92	160.31	0.00	0.31	0.31%
								Total Damage:	0.00	1.82	1.82
36(in) Subgrade on FF Rigid Layer	35.01		Spring	60	0.4		1.95	28,017.77		0.00	0.00%
			Summer	6	0.4		1.38	23.47	0.00	2.13	2.13%
			Fall	6	0.4		1.38	23.47	0.00	0.53	0.53%
			Winter	6	0.4		1.19	38.05	0.00	1.31	1.31%
								Total Damage:	0.00	3.98	3.98

Screen Clip 4-28

To interpret the results of this overlay design example, examine the three columns at the right side of the output. The column labeled ***Past Damage %*** lists the percent of structural life expended, for each layer and season, due to past traffic (ESALs applied prior to the overlay). The column labeled ***Future Damage %*** lists the percent structural life expended, for each layer and season, due to future traffic (design ESALs). Each line of the column labeled ***Total Damage %*** contains the sum of the other two columns (see further discussion of this sum in item "a" below). The last column, ***Total Damage %,*** is the principal one for interpreting this design analysis.

In the ***Total Damage %*** column, notice that the summation of seasonal damage for each material type (examine printout or screen to see sums listed in blue) is less than 100%. This shows that the structural life of none of the material layers has been exceeded in AKFPD's final design. At this point, stop and appreciate the fact that the AKFPD program has completed many steps of the overlay design process automatically—and it has saved you a *lot* of work. The automatic overlay design process is an iterative but simple one. AKFPD iterates through increasing thicknesses of overlay pavement until the final overlay thickness is enough to satisfy the structural requirements of past plus future ESALs. AKFPD knows when to stop the iterative process when the overlay thickness is great enough that summations in the ***Total Damage %*** column are all less than 100%.

Now examine the final overlay thickness (2 inches) listed at the top of the left column of your output screen or Screen Clip 4-28 labeled ***Layer.*** Assuming that other factors (factors not considered by the AKFPD program) do not require additional consideration, you may recommend an overlay design thickness of 2 inches.

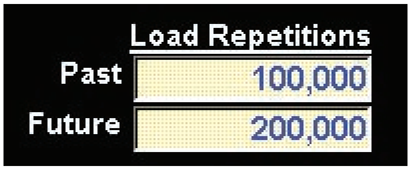
Although the main point of an overlay analysis is to determine the overlay thickness, you should consider a few additional points:

a. The overlay asphalt concrete pavement receives 0.05% damage only from future ESALs.

b. For asphalt concrete layers exposed to past ESALs and future design ESALs, the AKFPD program adds the percentage of structural life consumed by both past and future ESALs. This sum, 7.42%, is shown for the original 3-inch asphalt concrete layer. The sum includes 3.45% damage from past ESALs plus 3.97% damage from future ESALs. The TAI equation is used to calculate percent damage for these bound materials. For bound materials, past damage is added to future design ESAL damage because percent structural damage in bound materials is cumulative during the entire time those materials remain in the pavement structure. Miner's law accumulates damage for ESALs applied both before and after the overlay.

c. Soil and aggregate layers containing less than 4% asphalt cement are considered to be unbound materials and AKFPD uses the Per Ullidtz equation to calculate percent damage. For those materials, the ***Past Damage %*** column is re-zeroed when AKFPD begins to add overlay thickness (as in this example). Examine the ***Past Damage %*** column on your printout or the output screen and observe that any structural damage percentage accumulated because past ESALs have been set to zero. The Miner's law damage accumulation is reset by overlay repair work because, for unbound materials, the overlay process completely repairs roughness and rutting damage accumulated prior to the overlay.

d. If AKFPD determines that no overlay is required to handle past plus future ESALs (not the case in this example), a note will appear on the output screen. You can easily test this by returning to your input screen and replacing this example's ESAL data with the values in Screen Clip 4-29.



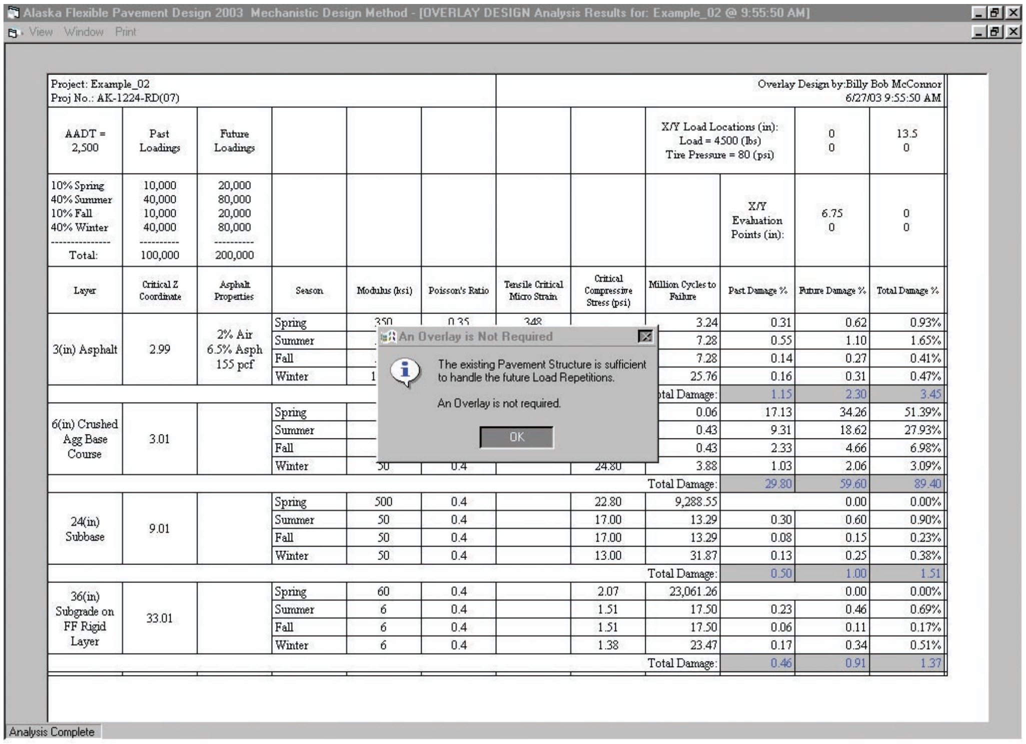
Load Repetitions

Past 100,000

Future 200,000

Screen Clip 4-29

Now click on the ***Analyze*** button at the top of the input screen. The output screen shown as Screen Clip 4-30 will appear when the analysis is complete.



Project: Example_02 Proj No.: AK-1224-RD(07)											Overlay Design by:Billy Bob McConnor 6/27/03 9:55:50 AM
AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 80 (psi)		0 0	13.5 0
10% Spring 40% Summer 10% Fall 40% Winter --------------- Total:	10,000 40,000 10,000 40,000 ---------- 100,000	20,000 80,000 20,000 80,000 ---------- 200,000							X/Y Evaluation Points (in):	6.75 0	0 0
Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure	Past Damage %	Future Damage %	Total Damage %
3(in) Asphalt	2.99	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	348		3.24	0.31	0.62	0.93%
			Summer					7.28	0.55	1.10	1.65%
			Fall					7.28	0.14	0.27	0.41%
			Winter	1				25.76	0.16	0.31	0.47%
								tal Damage:	1.15	2.30	3.45
6(in) Crushed Agg Base Course	3.01		Spring					0.06	17.13	34.26	51.39%
			Summer					0.43	9.31	18.62	27.93%
			Fall					0.43	2.33	4.66	6.98%
			Winter	50	0.4		24.80	3.88	1.03	2.06	3.09%
								Total Damage:	29.80	59.60	89.40
24(in) Subbase	9.01		Spring	500	0.4		22.80	9,288.55		0.00	0.00%
			Summer	50	0.4		17.00	13.29	0.30	0.60	0.90%
			Fall	50	0.4		17.00	13.29	0.08	0.15	0.23%
			Winter	50	0.4		13.00	31.87	0.13	0.25	0.38%
								Total Damage:	0.50	1.00	1.51
36(in) Subgrade on FF Rigid Layer	33.01		Spring	60	0.4		2.07	23,061.26		0.00	0.00%
			Summer	6	0.4		1.51	17.50	0.23	0.46	0.69%
			Fall	6	0.4		1.51	17.50	0.06	0.11	0.17%
			Winter	6	0.4		1.38	23.47	0.17	0.34	0.51%
								Total Damage:	0.46	0.91	1.37

The existing Pavement Structure is sufficient to handle the future Load Repetitions.

An Overlay is not required.

Screen Clip 4-30

You can examine the new output screen to see that: (1) no overlay was needed, and (2) the ***Past Damage %*** column has not been zeroed before future ESALs are applied. Note that damage due to past and future design ESALs for the aggregate base course are 29.8% and 59.6% respectively, for a total of 89.4%.

- Review the interpretation described for example 1 (step 16 of that analysis) as a guide for wringing additional information from the output screen.

4.6.5 Example 3—A Stabilized Base Design

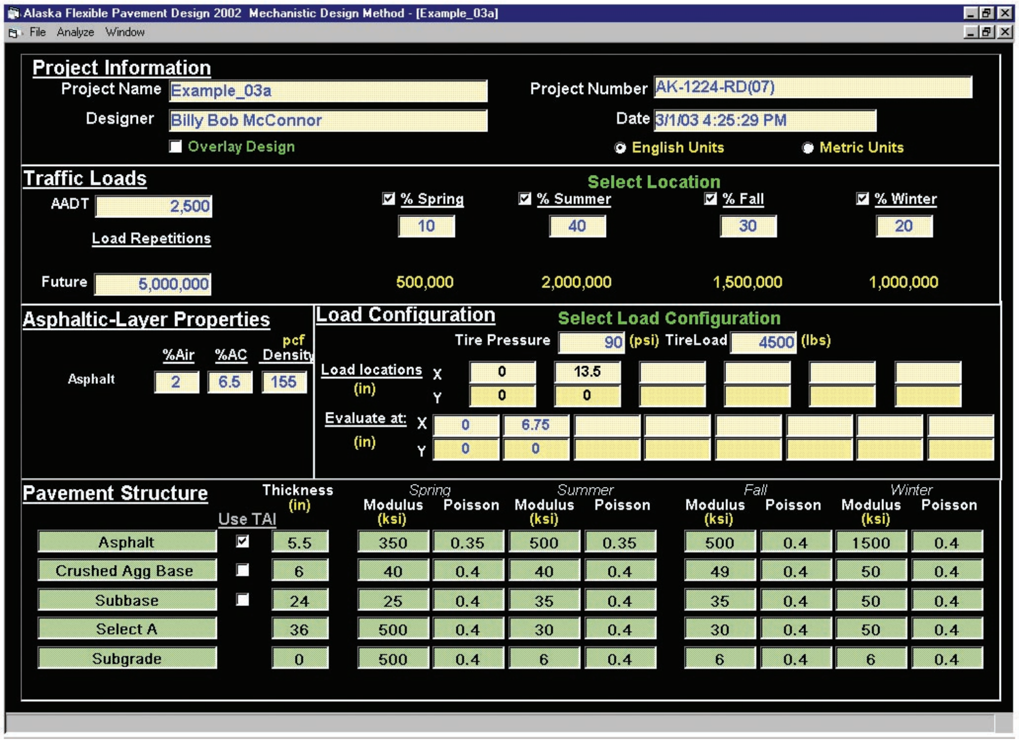
This example examines the use of stabilized base courses. Stabilized bases are now prescribed, by policy, for inclusion in most DOT&PF pavement designs. All else being equal, properly done base course stabilization does improve the ESAL capacity of any pavement structure. The stabilized base policy indirectly considers and compensates for unforeseen variables such as materials problems, construction-related problems, and future vehicle loadings that may exceed design ESALs.

A stabilized base course usually has a significantly more structural stiffness (higher M_R value) than a non-stabilized material. In Alaska, base stabilization is most often achieved by adding a bonding agent—usually asphalt cement—to an available base course material. Lately, mixtures of crushed, recycled asphalt pavement (RAP), with and without the addition of extra asphalt cement binder, have been used to satisfy the stabilized base policy. Life-cycle cost considerations not withstanding, it is your responsibility to comply with this policy to the extent possible.

You will gain cumulative experience in going through each design example in turn because each successive example builds on information and tips contained in the previous one. This example uses many of the program operation techniques presented in Section 4.6.2, example 1. **If you have not thoroughly familiarized yourself with example 1, do so before proceeding with this example.**

This example will compare the results of three analyses. In the first analysis you will determine the pavement thickness requirement of a pavement structure that contains a normal crushed aggregate base course. In the next analysis you will determine the pavement thickness required if the normal crushed aggregate base is replaced with the same thickness of lightly stabilized base course. In the third analysis you will determine the pavement thickness if a heavily stabilized base course is used.

Step 1. Begin this example by initiating the ***Mechanistic Design Method, New Analysis*** input screen. Using mouse and keyboard, enter data for the example until the input screen is as shown in Screen Clip 4-31.



Project Information

Project Name Example_03a
Designer Billy Bob McConnor
☐ Overlay Design
Project Number AK-1224-RD(07)
Date 3/1/03 4:25:29 PM
● English Units ○ Metric Units

Traffic Loads

AADT 2,500
Load Repetitions
Future 5,000,000

Select Location

☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
10	40	30	20
500,000	2,000,000	1,500,000	1,000,000

Asphaltic-Layer Properties

	%Air	%AC	pcf Density
Asphalt	2	6.5	155

Load Configuration

Select Load Configuration

Tire Pressure 90 (psi) TireLoad 4500 (lbs)

Load locations (in)	X	0	13.5
	Y	0	0
Evaluate at: (in)	X	0	6.75
	Y	0	0

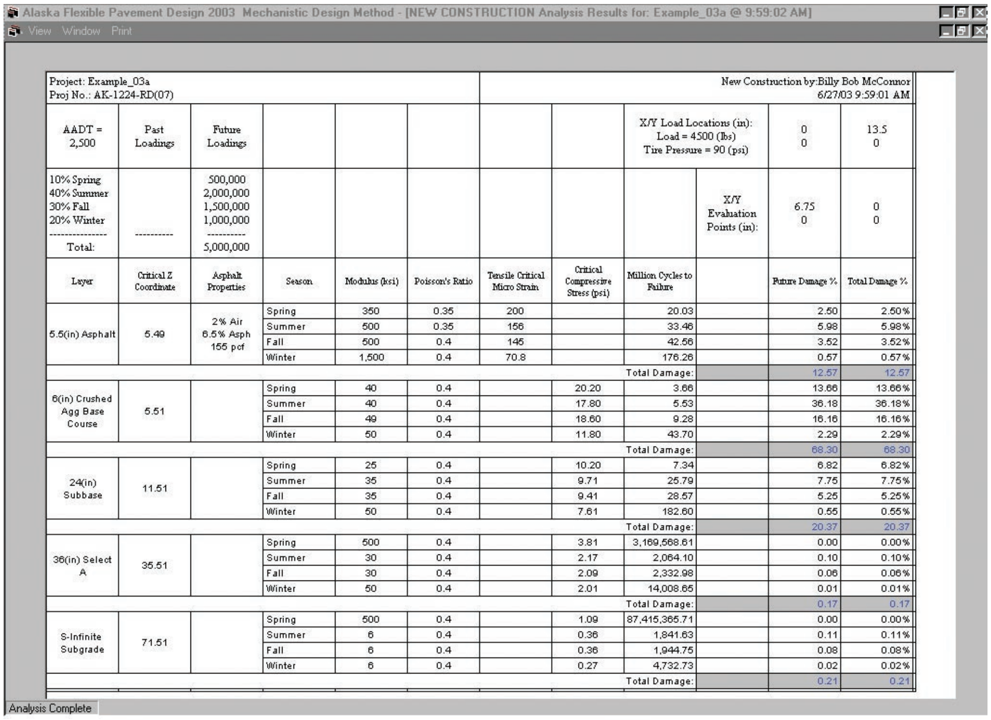
Pavement Structure

	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑	5.5	350	0.35	500	0.35	500	0.4	1500	0.4
Crushed Agg Base	☐	6	40	0.4	40	0.4	49	0.4	50	0.4
Subbase	☐	24	25	0.4	35	0.4	35	0.4	50	0.4
Select A		36	500	0.4	30	0.4	30	0.4	50	0.4
Subgrade		0	500	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-31

Step 2. Analyze, then print the results. Click on the Analyze button at the top of the input screen. After the results screen is displayed, click on the ***Print*** button at the top of the output screen shown as Screen Clip 4-32.

Step 3. Interpret the results. As you can see, the analysis requires 5.5 inches of asphalt concrete pavement over a crushed aggregate base course to handle the 5-million ESAL design load. Identify this thickness by analyzing increasing thicknesses of pavement until the seasonal damage sums for all of the material layers (see right column of Screen Clip 4-32) are less than 100%. You should now try pavement thicknesses less than 5.5 inches to verify that 5.5 inches are really required (see for yourself that 5 inches *almost* works).



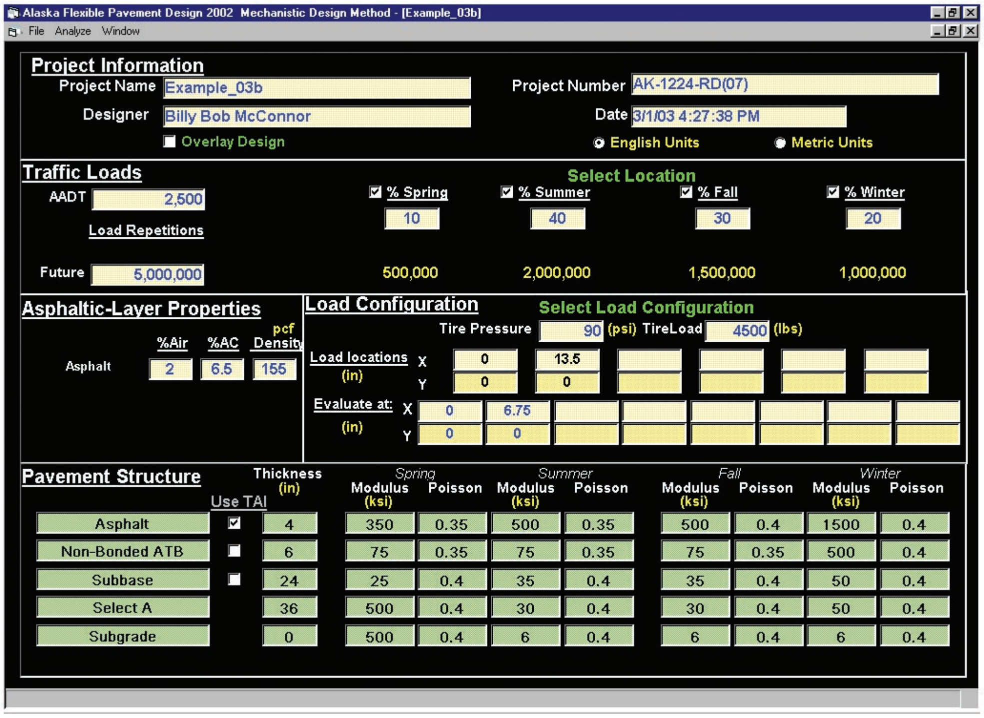
Project: Example_03a
Proj No.: AK-1224-RD(07)

New Construction by:Billy Bob McConnor
6/27/03 9:59:01 AM

AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 90 (psi)		0 0	13.5 0
10% Spring 40% Summer 30% Fall 20% Winter --------------- Total:	---------- 	500,000 2,000,000 1,500,000 1,000,000 ---------- 5,000,000							X/Y Evaluation Points (in):	6.75 0	0 0
Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure		Future Damage %	Total Damage %
5.5(in) Asphalt	5.49	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	200		20.03		2.50	2.50%
			Summer	500	0.35	156		33.46		5.98	5.98%
			Fall	500	0.4	145		42.56		3.52	3.52%
			Winter	1,500	0.4	70.8		176.26		0.57	0.57%
								Total Damage:		12.57	12.57
6(in) Crushed Agg Base Course	5.51		Spring	40	0.4		20.20	3.66		13.66	13.66%
			Summer	40	0.4		17.80	5.53		36.18	36.18%
			Fall	49	0.4		18.60	9.28		16.16	16.16%
			Winter	50	0.4		11.80	43.70		2.29	2.29%
								Total Damage:		68.30	68.30
24(in) Subbase	11.51		Spring	25	0.4		10.20	7.34		6.82	6.82%
			Summer	35	0.4		9.71	25.79		7.75	7.75%
			Fall	35	0.4		9.41	28.57		5.25	5.25%
			Winter	50	0.4		7.61	182.60		0.55	0.55%
								Total Damage:		20.37	20.37
36(in) Select A	35.51		Spring	500	0.4		3.81	3,169,568.61		0.00	0.00%
			Summer	30	0.4		2.17	2,064.10		0.10	0.10%
			Fall	30	0.4		2.09	2,332.98		0.06	0.06%
			Winter	50	0.4		2.01	14,008.65		0.01	0.01%
								Total Damage:		0.17	0.17
S-Infinite Subgrade	71.51		Spring	500	0.4		1.09	87,415,365.71		0.00	0.00%
			Summer	6	0.4		0.36	1,841.63		0.11	0.11%
			Fall	6	0.4		0.36	1,944.75		0.08	0.08%
			Winter	6	0.4		0.27	4,732.73		0.02	0.02%
								Total Damage:		0.21	0.21

Screen Clip 4-32

Step 4. Now analyze use of a lightly stabilized base course. Set up an input screen for this analysis by modifying the previous input screen to substitute new base course materials properties as shown in Screen Clip 4-33.



Project Information

Project Name: Example_03b

Project Number: AK-1224-RD(07)

Designer: Billy Bob McConnor

Date: 3/1/03 4:27:38 PM

☐ Overlay Design

● English Units ○ Metric Units

Traffic Loads

AADT: 2,500

Load Repetitions

Select Location

	☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
	10	40	30	20
Future 5,000,000	500,000	2,000,000	1,500,000	1,000,000

Asphaltic-Layer Properties

	%Air	%AC	pcf Density
Asphalt	2	6.5	155

Load Configuration

Select Load Configuration

Tire Pressure: 90 (psi) TireLoad: 4500 (lbs)

Load locations (in)	X	0	13.5
	Y	0	0
Evaluate at: (in)	X	0	6.75
	Y	0	0

Pavement Structure

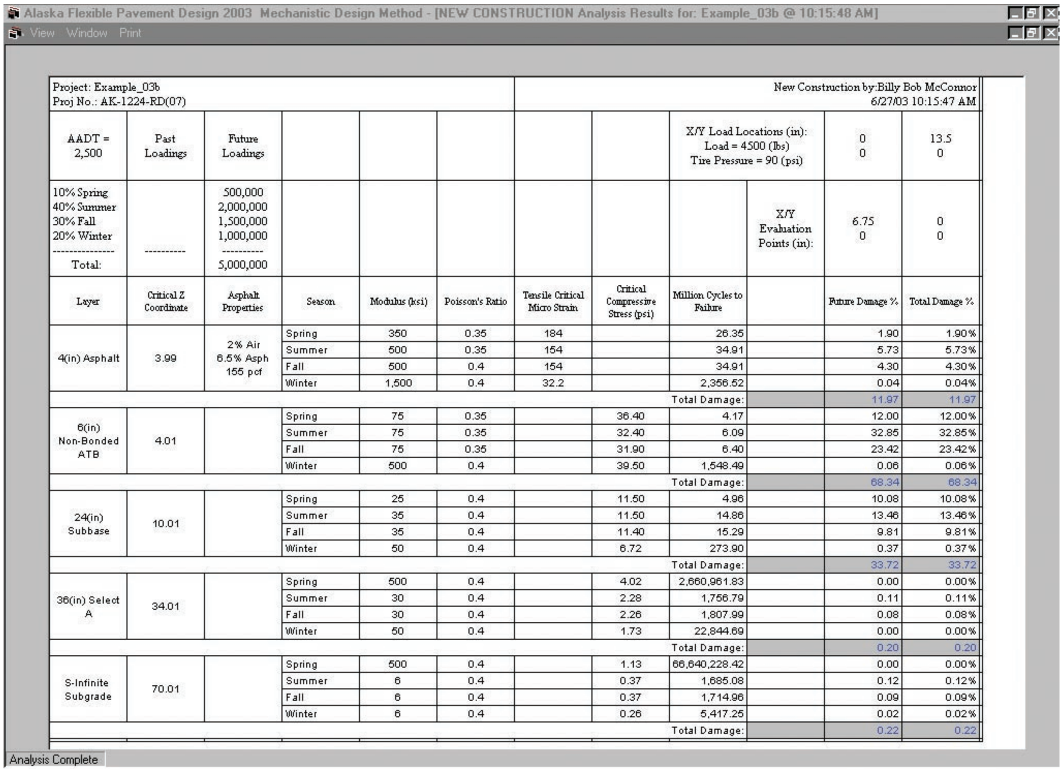
	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑	4	350	0.35	500	0.35	500	0.4	1500	0.4
Non-Bonded ATB	☐	6	75	0.35	75	0.35	75	0.35	500	0.4
Subbase	☐	24	25	0.4	35	0.4	35	0.4	50	0.4
Select A		36	500	0.4	30	0.4	30	0.4	50	0.4
Subgrade		0	500	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-33

Notice that the only changes to the base course properties involve raising the M_R values to 75 ksi, 75 ksi, 75 ksi, and 500 ksi for spring, summer, fall, and winter respectively.

Step 5. Perform the analysis and print the results.

Step 6. Interpret the results. The pavement thickness requirement is substantially reduced from that needed with normal base course (see Screen Clip 4-34). The lightly stabilized base requires only 4 inches of asphalt concrete pavement over the stabilized base to handle the 5-million ESAL design load. By using the lightly stabilized base (≈ 3% emulsion added to a crushed granular base), you have saved 1.5 inches of hot mix asphalt concrete pavement.



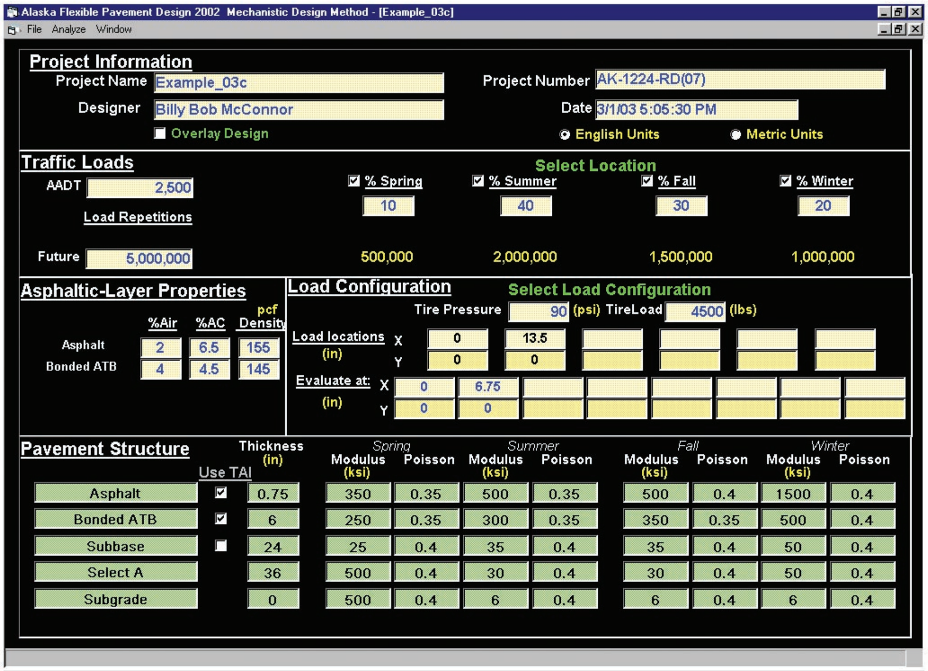
Project: Example_03b
Proj No.: AK-1224-RD(07)

New Construction by:Billy Bob McConnor
6/27/03 10:15:47 AM

AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 90 (psi)		0 0	13.5 0
10% Spring 40% Summer 30% Fall 20% Winter --------------- Total:	----------	500,000 2,000,000 1,500,000 1,000,000 ---------- 5,000,000							X/Y Evaluation Points (in):	6.75 0	0 0
Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure		Future Damage %	Total Damage %
4(in) Asphalt	3.99	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	184		26.35		1.90	1.90%
			Summer	500	0.35	154		34.91		5.73	5.73%
			Fall	500	0.4	154		34.91		4.30	4.30%
			Winter	1,500	0.4	32.2		2,356.52		0.04	0.04%
								Total Damage:		11.97	11.97
6(in) Non-Bonded ATB	4.01		Spring	75	0.35		36.40	4.17		12.00	12.00%
			Summer	75	0.35		32.40	6.09		32.85	32.85%
			Fall	75	0.35		31.90	6.40		23.42	23.42%
			Winter	500	0.4		39.50	1,548.49		0.06	0.06%
								Total Damage:		68.34	68.34
24(in) Subbase	10.01		Spring	25	0.4		11.50	4.96		10.08	10.08%
			Summer	35	0.4		11.50	14.86		13.46	13.46%
			Fall	35	0.4		11.40	15.29		9.81	9.81%
			Winter	50	0.4		6.72	273.90		0.37	0.37%
								Total Damage:		33.72	33.72
36(in) Select A	34.01		Spring	500	0.4		4.02	2,660,961.83		0.00	0.00%
			Summer	30	0.4		2.28	1,756.79		0.11	0.11%
			Fall	30	0.4		2.26	1,807.99		0.08	0.08%
			Winter	50	0.4		1.73	22,844.69		0.00	0.00%
								Total Damage:		0.20	0.20
S-Infinite Subgrade	70.01		Spring	500	0.4		1.13	66,640,228.42		0.00	0.00%
			Summer	6	0.4		0.37	1,685.08		0.12	0.12%
			Fall	6	0.4		0.37	1,714.96		0.09	0.09%
			Winter	6	0.4		0.26	5,417.25		0.02	0.02%
								Total Damage:		0.22	0.22

Screen Clip 4-34

Step 7. Finally, analyze using a heavily stabilized base course (>4% asphalt cement added to a crushed granular base). Set up an input screen for this analysis, as shown in Screen Clip 4-35, by first increasing the base course moduli to 250 ksi, 300 ksi, 350 ksi, and 500 ksi for spring, summer, fall, and winter respectively.



Project Information

Project Name: Example_03c

Project Number: AK-1224-RD(07)

Designer: Billy Bob McConnor

Date: 3/1/03 5:05:30 PM

☐ Overlay Design ● English Units ○ Metric Units

Traffic Loads

AADT: 2,500

Load Repetitions

Future: 5,000,000

Select Location

	☑ % Spring	☑ % Summer	☑ % Fall	☑ % Winter
	10	40	30	20
	500,000	2,000,000	1,500,000	1,000,000

Asphaltic-Layer Properties

	%Air	%AC	pcf Density
Asphalt	2	6.5	155
Bonded ATB	4	4.5	145

Load Configuration

Select Load Configuration

Tire Pressure: 90 (psi) TireLoad: 4500 (lbs)

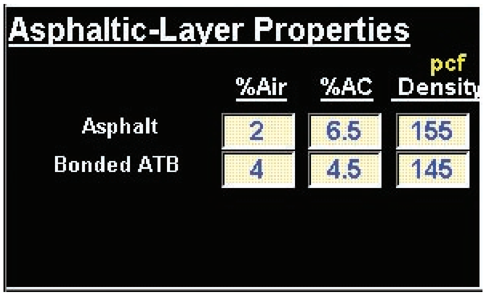
Load locations (in)	X	0	13.5					
	Y	0	0					
Evaluate at: (in)	X	0	6.75					
	Y	0	0					

Pavement Structure

	Use TAI	Thickness (in)	Spring Modulus (ksi)	Spring Poisson	Summer Modulus (ksi)	Summer Poisson	Fall Modulus (ksi)	Fall Poisson	Winter Modulus (ksi)	Winter Poisson
Asphalt	☑	0.75	350	0.35	500	0.35	500	0.4	1500	0.4
Bonded ATB	☑	6	250	0.35	300	0.35	350	0.35	500	0.4
Subbase	☐	24	25	0.4	35	0.4	35	0.4	50	0.4
Select A		36	500	0.4	30	0.4	30	0.4	50	0.4
Subgrade		0	500	0.4	6	0.4	6	0.4	6	0.4

Screen Clip 4-35

An additional change is also required on the input screen. Notice that the ***Use TAI*** toggle boxes in Screen Clip 4-35 now contain two checkmarks. The lower checkmark means that the heavily stabilized base will contain enough asphalt cement that the layer will require TAI analysis as a fully bound layer. The base course will be analyzed by assessing the tensile strain at the bottom of the layer. Because the second ***Use TAI*** toggle box is checked, you must also enter a second line of input values, as shown in Screen Clip 4-36, in the ***Asphaltic-Layer Properties*** section of the input screen, i.e., ***%Air*** = 4, ***%AC*** = 4.5, and ***pcf Density*** = 145.



Asphaltic-Layer Properties

	%Air	%AC	pcf Density
Asphalt	2	6.5	155
Bonded ATB	4	4.5	145

Screen Clip 4-36

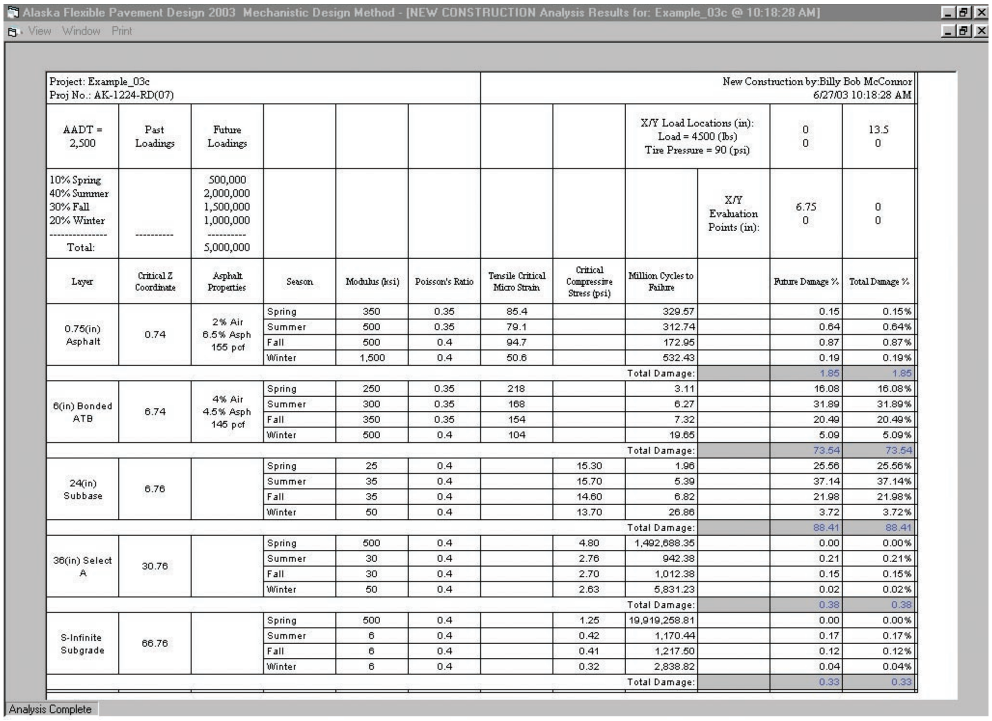
Step 8. Perform the analysis and print the results.

Step 9. Interpret the results. The pavement thickness requirement has now been drastically reduced from the 5.5 inches needed with normal base course (see output in Screen Clip 4-37). The heavily stabilized base requires only 0.75 inches of asphalt concrete pavement over the stabilized base to handle the 5-million ESAL design load! According to the mechanistic design method, you can do away with most of the pavement. The implication here is that an asphalt surface treatment, such as a double-layer AST or a high float AST, will be sufficient.

So, only 0.75 inches of pavement is theoretically required for a rather huge design loading of 5 million ESALs. However, other factors come into play in considering the final pavement thickness, not addressed in the mechanistic design. For example, a thin pavement may abrade away quickly from studded tire wear. Also, thin pavements contain small aggregates that may offer little resistance to rutting caused by simple plastic deformation. For these and other reasons, and considering the enormous ESALs, a minimum thickness of perhaps

2 inches or more may be necessary. Such considerations strongly suggest that you share the responsibility of your final design recommendations with your friendly pavement design experts located in regional and/or headquarters Materials sections.

As with all designs where there are several options, a cost analysis should be an important part of your decision.



Alaska Flexible Pavement Design 2003 Mechanistic Design Method - [NEW CONSTRUCTION Analysis Results for: Example_03c @ 10:18:28 AM]

Project: Example_03c Proj No.: AK-1224-RD(07)											New Construction by:Billy Bob McConnor 6/27/03 10:18:28 AM
AADT = 2,500	Past Loadings	Future Loadings						X/Y Load Locations (in): Load = 4500 (lbs) Tire Pressure = 90 (psi)		0 0	13.5 0
10% Spring 40% Summer 30% Fall 20% Winter --------------- Total:	----------	500,000 2,000,000 1,500,000 1,000,000 ---------- 5,000,000							X/Y Evaluation Points (in):	6.75 0	0 0
Layer	Critical Z Coordinate	Asphalt Properties	Season	Modulus (ksi)	Poisson's Ratio	Tensile Critical Micro Strain	Critical Compressive Stress (psi)	Million Cycles to Failure		Future Damage %	Total Damage %
0.75(in) Asphalt	0.74	2% Air 6.5% Asph 155 pcf	Spring	350	0.35	85.4		329.57		0.15	0.15%
			Summer	500	0.35	79.1		312.74		0.64	0.64%
			Fall	500	0.4	94.7		172.95		0.87	0.87%
			Winter	1,500	0.4	50.6		532.43		0.19	0.19%
								Total Damage:		1.85	1.85
6(in) Bonded ATB	6.74	4% Air 4.5% Asph 145 pcf	Spring	250	0.35	218		3.11		16.08	16.08%
			Summer	300	0.35	168		6.27		31.89	31.89%
			Fall	350	0.35	154		7.32		20.49	20.49%
			Winter	500	0.4	104		19.65		5.09	5.09%
								Total Damage:		73.54	73.54
24(in) Subbase	6.76		Spring	25	0.4		15.30	1.96		25.56	25.56%
			Summer	35	0.4		15.70	5.39		37.14	37.14%
			Fall	35	0.4		14.60	6.82		21.98	21.98%
			Winter	50	0.4		13.70	26.86		3.72	3.72%
								Total Damage:		88.41	88.41
36(in) Select A	30.76		Spring	500	0.4		4.80	1,492,688.35		0.00	0.00%
			Summer	30	0.4		2.76	942.38		0.21	0.21%
			Fall	30	0.4		2.70	1,012.38		0.15	0.15%
			Winter	50	0.4		2.63	5,831.23		0.02	0.02%
								Total Damage:		0.38	0.38
S-Infinite Subgrade	66.76		Spring	500	0.4		1.25	19,919,258.81		0.00	0.00%
			Summer	6	0.4		0.42	1,170.44		0.17	0.17%
			Fall	6	0.4		0.41	1,217.50		0.12	0.12%
			Winter	6	0.4		0.32	2,838.82		0.04	0.04%
								Total Damage:		0.33	0.33

Analysis Complete

Screen Clip 4-37

5. Design Input—Materials Properties for Mechanistic Design

In one way or another, moisture affects the mechanical properties of the pavement structure more than anything else. Control of moisture flow within, through, and around the pavement structure therefore influences the pavement structure design process more than any other consideration. In most cases, the moisture content of an unbound pavement layer is the chief determiner of strength. Both AKFPD design programs indirectly account for moisture contents of unbound layers. However, in addition to using the AKFPD program properly, the designer must ensure that the pavement's structural layers actually achieve and retain their intended strength properties. The designer must provide culverts, ditches, cross slopes, subdrains, and permeable layers as required to minimize water in the pavement structure. Good drainage design is critical to all pavement designs. Chapter 8 presents additional comments on drainage design.

5.1. Materials Properties—Recommended Presumptive Values for New Construction and Reconstruction Designs

5.1.1. Resilient Modulus (M_R) Values

M_R should not be confused with another measure of dynamic elastic modulus known as the complex modulus (E*). E* is not presently used in DOT&PF mechanistic design methods. Usually the layer resilient modulus values (M_R) for materials used in new construction are not known. You may use presumptive modulus values as shown in Tables 5-1 and 5-2. Material containing excess fines may cause significant thaw weakening of the overlying pavement structure. As a design quality control measure, seek concurrence in the selected modulus values from regional or headquarters pavement design experts.

Table 5-1. Pavement Layer Moduli (ksi)

Material Type	P_{200}	Spring	Summer & Fall	Winter
Asphalt Concrete	—	755	510	1,500
Aggregate Base	<6%	45	50	100
Selected Material Type A	<6%	25	35	90
Selected Material Type B	<10%	15	30	80
Selected Material Type C & Subgrade	<30%	50	10	10

Table 5-2. Pavement Layer Moduli (with excess fines) (ksi)

Material Type	P_{200}	Spring	Summer & Fall	Winter
Asphalt Concrete	—	755	510	1,500
Aggregate Base & Selected Material Type A	<10%	20	40	95
Selected Material Type B	<10%	15	30	80
Selected Material Type C	<18%	5	10	50
Subgrade	>30%	45	10	10

Another resource is available for quickly estimating the M_R for asphalt concrete materials. Install and run Paveinfo03 from the CD containing AKPFD, and follow the on-screen example regarding necessary input values. The equation that Paveinfo03 uses for calculating the modulus is explained in Witczak and Fonseca, 1996.[14]

5.1.2. Resilient Modulus Values for Stabilized Base Course Materials

Table 5-3 contains typical modulus values for stabilized base course materials.

Table 5-3. Stablized Base Course Moduli (ksi)

Material Type	Spring	Summer & Fall	Winter
RAP (50:50)[1]	80	80	115
CAB, 3% Emulsion[1]	75	75	115
CAB, 4% Asphalt[2]	250	250	1500

1. lightly bound: use Ullidtz
2. heavily bound: use TAI

Design with lightly bound asphalt-treated base courses (using CSS-1 emulsion additive) using the mechanistic design procedure and by controlling the vertical compression stress at the top of the treated base and horizontal tensile strain at the bottom of the asphalt concrete pavement layer.

Design with heavily bound asphalt-treated base courses (containing ≥ 4% asphalt cement) using the mechanistic design procedure and by controlling the horizontal tensile strain at the bottom of the asphalt-treated base course and the asphalt concrete pavement layer.

Verify the validity of presumptive modulus values with regional or headquarters Materials section personnel.

5.1.3. Handling Stress Sensitivity

Stress sensitivity need not be accounted for in mechanistic pavement designs for the Alaska DOT&PF.

5.1.4. Poisson's Ratio Values

Table 5-4 contains recommended Poisson's ratios for various pavement structure materials. As a design quality control measure, seek concurrence in the selected Poisson's ratio values from regional or headquarters pavement design experts. Slight variations will not alter the design.

Table 5-4. Poisson's Ratio Values

Material Type	**Poisson's Ratio (μ)**
Asphalt Concrete	0.30
Aggregate Base	0.35
Selected Material Types A and B	0.40
Selected Material Type C	0.45
Subgrade Materials	0.45

5.2. Materials Properties—Laboratory Testing to Determine Values for New Construction and Reconstruction Designs

Much of the mechanistic pavement design work done for DOT&PF relies on presumptive M_R Poisson's ratio values (see Section 5.1), although backcalculated values for M_R are often obtained based on deflection test data for overlay design work (see Section 5.3). This section provides guidance for those rare design situations where laboratory testing may be required. Testing might be required, for example, for designs involving unusual or experimental material types not listed in the Section 5.1 tables.

5.2.1. Resilient Modulus Values

For determining M_R of unbound soils (including subgrade soils) or unbound or lightly bound bases or subbase materials, use AASHTO T 292-97 (2000) *Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Material*.

For determining M_R of asphalt-bound materials such as asphalt concrete or other heavily asphalt-cemented pavement or base materials, use ASTM D4123-82 (1995) *Standard Test Method for Indirect Tension test for Resilient Modulus of Bituminous Mixtures.*

For heavily bound pavement, base, or subbase materials with a cementing agent other than asphalt, consult regional or headquarters Materials personnel for a recommended test method.

5.2.2. Resilient Modulus Values for Stabilized Base Course Materials

Use test methods indicated in 5.2.1.

5.2.3. Handling Stress Sensitivity

Stress sensitivity need not be accounted for in mechanistic pavement designs for the Alaska DOT&PF.

5.2.4. Poisson's Ratio Values

For all normal pavement design work the designer will use presumptive Poisson's ratio values. Table 5.3 contains recommended Poisson's ratios for common pavement structure materials. As a design quality control measure, the designer should seek concurrence in the selected Poisson's ratio values from regional or headquarters pavement design experts. Also solicit materials expertise for determining Poisson's ratio values for unusual materials.

5.3. Materials Properties—Values Determined From Field Tests for Overlay Designs

5.3.1. Backcalculation Program

DOT&PF recommends the backcalculation program ELMOD, developed by Dynatest Consultants Inc. Backcalculation of layer modulus values should be done only by personnel with experience in performing backcalculations—regional pavement design engineers or equivalent.

Poisson's ratios for various pavement structure layers are those shown in Table 5-4.

The minimum asphalt concrete thickness for which a modulus can be backcalculated is 3.5 inches, because of the plate size on the falling weight deflectometer. For thinner layers, the asphalt concrete pavement must be cored and tested in the laboratory, or suggested moduli in Table 5-1 can be used. Adjust the measured or backcalculated moduli to the seasonal field temperature using an equation such as on page 16 of The Asphalt Institute Research Report No. 82-2, *Research and Development of Thickness Design Manual.*

5.3.2. Selection of Design Moduli

Select the design modulus for a given pavement structure layer at the 84th percentile ranking value. Most soil properties follow a log normal distribution. This corresponds to a 95th percentile confidence level of a normal distribution. This is done by sorting the modulus values with the lowest ranked as zero and the highest 100%. Select the closest value to the 84th percentile ranking.

5.3.3. Deflection Testing

DOT&PF currently uses a falling weight deflectometer to measure the dynamic deflection for pavement rehabilitation design.

If deflection test data will be used in back-calculating modulus values for highway designs, the deflectometer should be set to deliver a 9,000-pound test load that corresponds to one half of an 18,000-pound standard dual axle load (ESAL).

Selecting Test Locations

When possible, select test locations as an average representation of the present surface condition and where the original pavement structure is free from patching. If alligator cracking is not prevalent, adjust test locations to avoid the cracking. If alligator cracking cannot be avoided, note it in the data. If alligator cracking is prevalent, assume a reduced modulus (contact your regional materials engineer). Select a test section to represent each type of terrain the project passes through.

Choose a minimum of 20 evenly spaced deflection test locations within a selected mile. If you suspect a pavement structure is frost-susceptible, consider increasing the number of tests. It is preferable to mark the test locations with paint for repeated testing of exact points in subsequent weeks. White painted markings on the centerline have been found to last longer and are easier to locate by field crews.

When to Test

Perform deflection testing during the spring thaw period when pavement strength is at a minimum. A weekly set of deflection tests should begin when the pavement structure begins to thaw and must continue through the period when peak deflections occur. Perform at least one set of readings in the summer and another in the fall. A rough guide showing when to begin deflection testing is offered below.

Table 5-5. Guide for Period of Deflection Testing

Maintenance Region	**Begin Testing**
Interior	2nd week in April
Central	1st week in April
Southcentral	South of Thompson Pass = 1st week in March
Southcentral	North of Thompson Pass = 1st week in April
Southeastern	Indeterminate; thaw must be closely monitored.

Base the decision of when to begin testing on actual field evidence, such as small test pits, frost tubes, or soil temperature data, if available. If you cannot perform deflection testing during the peak period, contact the regional materials engineer for a seasonal adjustment factor.

Testing during periods when night temperatures are below freezing should not begin before late morning. This is to prevent the bridging effect of the temporarily frozen surface layer from depressing the true rebound deflection readings.

Testing Procedure

See the falling weight deflectometer operation manual.

Safety Equipment and Precautions

Because of frequent stops, take all necessary safety precautions. Use appropriately attired flaggers as necessary to control traffic. High-level warning devices, such as vehicle-mounted arrow boards, are best (see the FHWA manual part VI, *Standards and Guides for Traffic Controls for Street and Highway Construction, Maintenance, Utility,* for detailed procedures). One or two vehicles with warning signs will be required, depending on traffic levels and sight distances.

5.4. Miscellaneous Materials Requirements

5.4.1. Required Asphalt Concrete Mix Design Properties (Marshall Method)

The following asphalt concrete Marshall Mix Design properties are required based on highway design ESAL levels.

Table 5-6. Mix Design Requirements

Marshall Mix Design Test Property	**ESALs >1,000,000**	**ESALs <1,000,000 & >10,000**	**ESALs <10,000***
	Class A	**Class B**	**Class C**
Compaction Blows	75 Blows/Face	50 Blows/Face	35 Blows/Face
Stability (lbs), min.	1,800	1,400	1,000
Voids Total Mix (%)	2–5	2–5	1–5
Flow (0.01 in)	8–14	8–16	8–16

* Includes parking areas, bike paths, etc.

6. Design Input—Equivalent Single Axle Loads

6.1. Introduction

This chapter applies to designing normal pavement structures for highway projects. Highway pavement structures are designed to withstand a specific number of standardized loadings derived from a known mix of truck-type traffic. Standardized vehicle loadings used in highway design are termed “equivalent single axle loads” (ESALs), i.e., the pavement structure will be subjected to a specific number of ESALs during its design life. This chapter describes how to calculate standardized ESAL loadings for your project. To facilitate the ESAL computation, planning personnel will provide you, the designer, with information concerning vehicle loadings as well as traffic growth rate and traffic lane distribution data. Similar concepts involving standardized vehicle loadings are used to calculate design aircraft loadings for aviation projects, although the methodology is not presented here.

Highway design designations provide information used for geometric and traffic design. The designer must obtain this information separately from planning.

With every application of an ESAL loading to the surface of a pavement structure, that structure receives a specifically quantifiable amount of structural damage. In other words, every ESAL application subtracts a finite amount from the pavement structure’s “life.” If the project involves construction of a new pavement structure or replacing an old one, one ESAL value will be needed for design, i.e., future ESALs (ESALs estimated for the design life of the new pavement structure). If the project involves placing an overlay on an existing pavement layer, two ESAL values will be required: (1) historical ESALs (ESALs accumulated on the existing pavement structure during its past service life), and (2) future ESALs.

For determining design ESALs, only various categories of truck-type vehicles are defined in terms of standard ESAL loadings. Only medium and large trucks are assigned ESAL equivalency for design purposes. Automobiles, pickup trucks, and other relatively small vehicles have such small ESAL loadings that they do negligible damage to the pavement structure. An old rule-of-thumb is that pavement structural damage done by the passage of a single large truck is equivalent to that done by about 9,000 automobiles.

ESAL Defined: One ESAL represents a single standardized load application. Each ESAL is known to cause a quantifiable and standardized amount of damage to the pavement structure equivalent to one pass of a single 18,000-pound, dual-tire axle with all four tires inflated to 110 psi.

ESAL Truck Classification and Load Factor Defined: Different sizes of truck are “pigeonholed” by size-category, known to DOT&PF as truck category. DOT&PF defines five truck categories (2-axle, 3-axle, 4-axle, 5-axle, and ≥6-axle). Trucks assigned to the 2-axle category have one front axle and one rear axle. Trucks assigned to the 3-axle category have one front axle and a tandem rear axle set. Trucks assigned to the 4-axle category are “semi” tractor/trailer combinations having one front axle on the tractor, a tandem set of driver axles on the tractor, and one axle at the rear of the trailer. Trucks assigned to categories higher than the 4-axle type are simply tractor/trailer or tractor/multi-trailer combinations having a total of two or more trailer axles.

Each of the five truck categories, according to scalehouse data, is assigned a specific ESAL equivalency. The assigned ESAL equivalency is termed the **load factor**—and every truck in that category is assigned that load factor. Assignment of a load factor to each truck category is specific to a particular scalehouse. Therefore, load factors generated at a particular scalehouse are valid only for those highway routes having truck load-weight characteristics similar to that scalehouse.

6.2. Calculate the Load Factor for Each Vehicle Category

This section provides a somewhat generalized description of how a load factor for each DOT&PF truck category is determined. Even though load factor data will be supplied to the designer, basic load factor computations are briefly discussed here to promote more thoroughly understanding of the concept of standardized loadings.

Load factor is defined as the average number of ESALs associated with each truck of a particular truck-size category. Load factors for all categories of truck size are usually calculated by regional planning sections and will be supplied to you when you request traffic data for your project. Planning provides load factor data on the truck classification table of the traffic data request form (see Figure 6-1). Load factors are necessary input data for the design ESAL calculations described in Section 6.3. One ESAL equivalent loading is defined for various axles or axle group configurations loaded as shown in Table 6-1.

Table 6-1. Standard Load Equivalencies

Type of Axle or Axle Group	Loading Equivalent to One ESAL (kips)
single tire single axle	12
dual tire axle	18
tandem axle group	32
tridem axle group	48
4 or more axle group	48

An axle is considered part of an axle group when it is less than 8 feet from another axle or group. For example, if two single axles are less than 8 feet apart, they are considered a tandem axle. If a single axle is less than 8 feet from a tandem axle, the three are considered a tridem axle.

Load factors are determined from scalehouse weight data obtained from many individual trucks. At the scalehouse, axle and axle group weights are sampled from a number of individual trucks representing each truck category. Each truck to be weighed is first assigned to a particular category. Then each axle and axle group (single, dual, tandem, etc.) for that truck is weighed individually. For each truck, an ESAL value is calculated for each axle and axle group (using the following ESAL equation).

The ESAL equation from truck axle weight and axle spacing for all axles or groups is:

$$ESAL = \left(\frac{W_1}{W_2}\right)^{4.3}$$

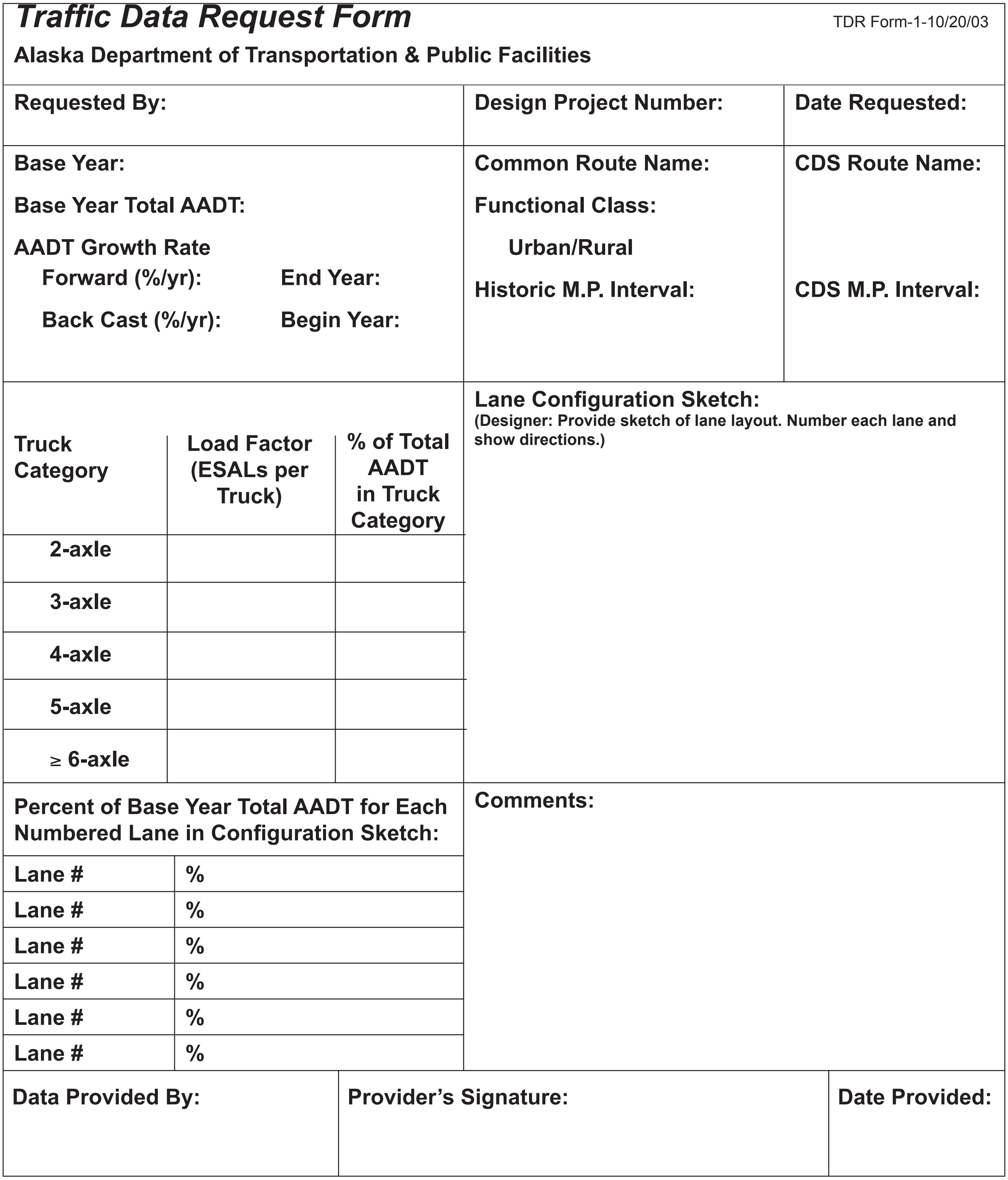
where:

W_1 = weight in kips of the loaded axle or axle group.

W_2 = weight in kips of the standard axle or axle group (see Table 6-1)

The total ESAL value, i.e., load factor, for that particular truck is the sum of ESAL values for all axles and axle groups of that truck.

The load factor for each truck category is determined by averaging the total ESAL values for all trucks in that category.



Traffic Data Request Form

TDR Form-1-10/20/03

Alaska Department of Transportation & Public Facilities

Requested By:	**Design Project Number:**	**Date Requested:**
Base Year: **Base Year Total AADT:** **AADT Growth Rate** **Forward (%/yr):** **End Year:** **Back Cast (%/yr):** **Begin Year:**	**Common Route Name:** **Functional Class:** **Urban/Rural** **Historic M.P. Interval:**	**CDS Route Name:** **CDS M.P. Interval:**

Truck Category	Load Factor (ESALs per Truck)	% of Total AADT in Truck Category
2-axle		
3-axle		
4-axle		
5-axle		
≥ 6-axle		

Lane Configuration Sketch:
(Designer: Provide sketch of lane layout. Number each lane and show directions.)

Percent of Base Year Total AADT for Each Numbered Lane in Configuration Sketch:

Lane #	**%**
Lane #	**%**
Lane #	**%**
Lane #	**%**
Lane #	**%**
Lane #	**%**

Comments:

Data Provided By:	**Provider's Signature:**	**Date Provided:**

Figure 6-1. Traffic Data Request (TDR) Form

6.3. Calculate Design ESALs

Estimate total ESALs for the design period by projecting forward the construction year ESALs for each truck category.

6.3.1. Outline of Computation Steps

1. Obtain basic information from planning personnel. These data are based on studies of scalehouse data, weigh-in-motion data, traffic counts, administrative studies/projections, and miscellaneous observations.

   - AADTs for base year (both directions). Base year data is a best estimate of design data for a given design location and for a specific year—usually for the year that the project is being designed. Using compound growth calculations, a past year or future year, AADT may be calculated from the base year AADT. The base year must be identified by whoever supplies the AADT data.
   - Traffic growth rate (% per year) from base year
     - forward
     - backcast (if applicable for historical ESAL calculations)
   - Number of driving lanes
   - Directional split
     - Determine design lane as lane having highest portion of directional split
   - Load factor information for each truck category
   - Percent of AADT in each truck category

To facilitate collecting previously indicated data, submit the Traffic Data Request (TDR) Form (shown as Figure 6-1) to your regional planning section. You may need to submit more than one copy of Figure 6-1 for a particular project because large projects may require more than one pavement structural design. Exercise engineering judgment to determine if more than one pavement design is required for your project. In general, road segments within a project that are expected to have significantly different traffic volumes and/or vehicular mix may warrant separate pavement designs.

2. For the year of construction, determine number of ESALs in each truck category based on AADT of the design lane.

   a. Calculate total AADT for year of construction using $i_{\text{B to D}}$ and "single payment" compound amount factor $\left(1+i_{\text{B to D}}\right)^n$

      where: n = year of construction – base year

      $i_{\text{B to D}}$ = growth rate from base year to last year of design period

      Construction year total AADT = (base year AADT) × (compound amount factor)

      (values for *i* and *n* are obtained from TDR form (see Figure 6-1))

   b. Calculate construction year AADT in the design lane.

      Construction year AADT in design lane = (construction year total AADT) × (*% AADT in design lane/100)

      * usually select highest % shown in TDR form (see Figure 6-1)

c. For each truck category, calculate the construction year ESALs in the design lane. Use the following equation for each truck category.

Construction year ESALs for specific truck category = (construction year AADT in design lane) × (*% of total AADT in truck category/100) × (*load factor for truck category) × 365

* obtained from TDR form (see Figure 6-1)

d. Calculate the total of construction year ESALs for all truck categories.

Total construction year ESALs = Σ construction year ESALs for every truck category

3. Calculate total number of ESALs for each truck category accumulated from the year of construction through the end of the design period.

a. Calculate total ESALs for design. Project total construction year ESALs for all truck categories (calculated in step 2d) forward to end of design period using $i_{\text{B to D}}$ and "uniform series," compound amount factor $\left[\left(1+i_{\text{B to D}}\right)^{n}-1\right]/i_{\text{B to D}}$

where: n = last year of design period – construction year

Total design ESALs = (total construction year ESALs) × (compound amount factor)

(values for i and n are obtained from TDR form (see Figure 6-1))

6.3.2. An Example (Calculate Design ESALs Forward in Time)

Input Data:

The project will be constructed in 2005 and has a 15-year design life (end year of design period = 2020).

Design work was done in 2003, the base year chosen for estimating the AADT growth rate.

For this example, Figure 6-2 shows an example of basic traffic data obtained, on TDR form (see Figure 6-1), from the regional planning section.

Calculations:

Design ESAL computations for this example follow the Section 6.3.1 outline.

Step 1

Already completed with the collection of the indicated input data (use Figure 6-2).

Step 2

a. Construction year total AADT = (base year total AADT) × $\left(1+i_{\text{B to D}}\right)^{n}$ = (1600) × $\left(1+0.025\right)^{2}$ = 1,681

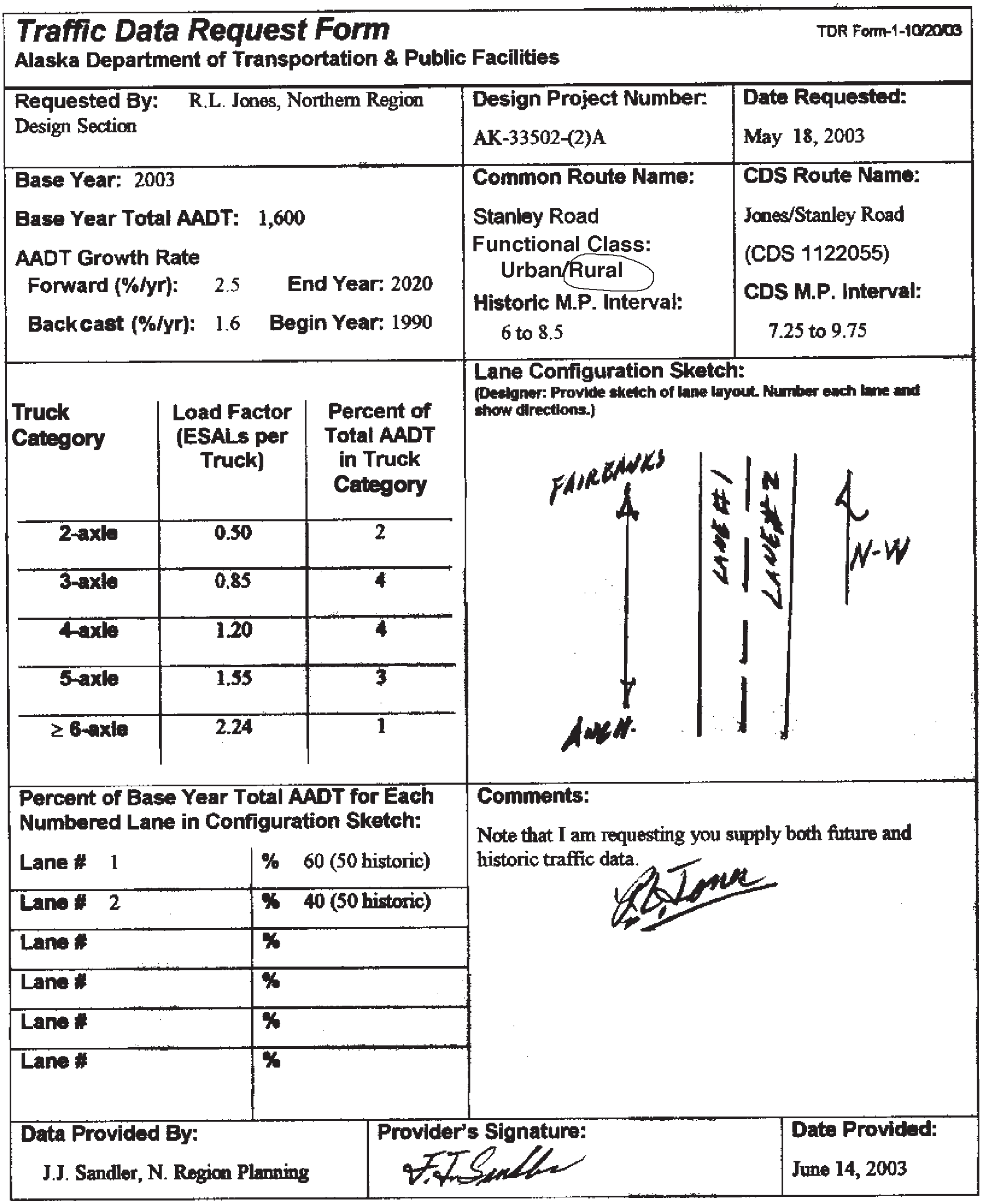
b. Construction year AADT in design lane = (construction year total AADT) × (% AADT in design lane/ 100) = (1681) × (0.6) = 1,009

c. Construction year ESALs for specific truck category = (construction year AADT in design lane) × (% of total AADT in truck category/100) × (load factor for truck category) × 365

See rows of computations in Table 6-2.

d. Total construction year ESALs = Σ of construction year ESALs for all truck categories = 3,683 + 12,522 + 17,678 + 17,125 + 8,250 = 59,258

See summation in Table 6-2.



Traffic Data Request Form

TDR Form-1-10/20/03

Alaska Department of Transportation & Public Facilities

Requested By: R.L. Jones, Northern Region Design Section

Design Project Number: AK-33502-(2)A

Date Requested: May 18, 2003

Base Year: 2003

Base Year Total AADT: 1,600

AADT Growth Rate

Forward (%/yr): 2.5 **End Year:** 2020

Backcast (%/yr): 1.6 **Begin Year:** 1990

Common Route Name: Stanley Road

Functional Class: Urban/ [✓ Rural]

Historic M.P. Interval: 6 to 8.5

CDS Route Name: Jones/Stanley Road (CDS 1122055)

CDS M.P. Interval: 7.25 to 9.75

Truck Category	Load Factor (ESALs per Truck)	Percent of Total AADT in Truck Category
2-axle	0.50	2
3-axle	0.85	4
4-axle	1.20	4
5-axle	1.55	3
≥ 6-axle	2.24	1

Lane Configuration Sketch:
(Designer: Provide sketch of lane layout. Number each lane and show directions.)

FAIRBANKS

ANCH.

LANE #1

LANE #2

N-W

Percent of Base Year Total AADT for Each Numbered Lane in Configuration Sketch:

Lane # 1	% 60 (50 historic)
Lane # 2	% 40 (50 historic)
Lane #	%
Lane #	%
Lane #	%
Lane #	%

Comments:

Note that I am requesting you supply both future and historic traffic data.

R.L. Jones

Data Provided By: J.J. Sandler, N. Region Planning

Provider's Signature: J.J. Sandler

Date Provided: June 14, 2003

Figure 6.2. Completed Traffic Data Request (TDR) Form for Examples

Table 6-2. Construction Year ESAL Calculations

Truck Category	(1) Construction Year Design Lane AADT	(2) % of Total AADT in Truck Category	(3) Load Factor for Truck Category	(1) × (2) × (3) × 3.65 Construction Year ESAL
2-axle	1009	2	0.50	3,683
3-axle	1009	4	0.85	12,522
4-axle	1009	4	1.20	17,678
5-axle	1009	3	1.55	17,125
≥6-axle	1009	1	2.24	8,250
		Total construction year ESALs =		59,258

Step 3

$$\text{Total design ESALs} = (\text{total construction year ESALs}) \times \left[(1+i_{\text{B to D}})^n - 1\right] / i_{\text{B to D}}$$

$$= (59258) \times \left[(1+0.025)^{15} - 1\right] / 0.025 = 1{,}062{,}610 \text{ Total design ESALs}$$

6.4. Historical ESALs

For rehabilitation projects, the historical ESALs are required for the analysis of the remaining pavement life. If historical AADTs exist for each year since the last pavement construction project, calculate ESALs for each year to the present—using methods in Section 6.3. The total historical ESAL is the sum of the past yearly ESALs. If load factors for past years are not available, use base year (present) load factors, and perhaps adjust based on careful consideration and judgment. Past growth rate information must be obtained from planning personnel. Request that historical traffic data be added to the TDR form (see Figure 6-1) if historical ESALs need to be calculated. After obtaining the historical growth rate from planning and collecting or estimating the other input data, calculate historical ESALs using the same steps outlined in Section 6.3.1.

6.4.1. An Example (ESAL Calculation Extended Backwards and Based on Previous Example)

Input Data

Input data for calculating historical ESALs are similar to those used for calculating future ESALs (see Section 6.3.2 example) except that data come from the construction year and years prior to that time.

The project will be constructed in 2005 and the backward (backcast) projection of ESALs will extend to the previous surfacing application in 1990, i.e., the historical construction year.

Use data pertaining to historical ESAL calculations from the TDR form used in the previous example (see Figure 6-2).

Construction work will be done in 2005. This now becomes the “base” year for estimating the AADT in 1990.

AADT for (2005) = 1,681 (from previous example)

Figure 6-2 shows that the traffic growth rate from the last historical construction event (1990) to the original base year (2003) of design period was 1.6% (this historical growth rate is identified as $i_{\text{H to C}}$)

Load factors and percent of AADT in each truck category are shown in Figure 6-2. Notice that these are the same data used in the previous example for projecting ESALs into the future (a simplification for this example). For historical ESAL projections, use actual historical truck category data if they are available. If available, planning would include historical truck category data, as separate numbers, to the “truck related table” of the TDR form.

Calculations

Historical ESAL computations generally follow the method outlined in Section 6.3.1.

Step 1

Already completed with the collection of the indicated input data (use Figure 6-2).

Step 2

a. Historical construction year total AADT = (construction year AADT) × $\frac{1}{(1+i_{\text{H to C}})^n}$
= (1681)/(1+0.016)^{15} = 1,325

where: $i_{\text{H to C}} = 0.016$

n = construction year – historical construction year = 2005 – 1990 = 15

b. Historical construction year AADT in design lane = (historical construction year total AADT) × (historical % of total AADT in truck lane/100) = (1325) × (0.5) = 663

c. Historical construction year ESALs for specific truck category = (historical construction year AADT in design lane) × (historical % of total AADT in truck category/100) × (historic load factor for truck category) × 365

See rows of computations in Table 6-3.

d. Total construction year ESALs = Σ of construction year ESALs for all truck categories
= 2,420 + 8,228 + 11,616 + 11,253 + 5,421 = 38,938

See summation in Table 6-3.

Table 6-3. Historical Construction Year ESAL Calculations

Truck Category	(1) Historical Construction Year Design Lane AADT	(2) % of Total AADT in Truck Category	(3) Load Factor for Truck Category	(1) × (2) × (3) × 3.65 Historical Construction Year ESAL
2-axle	663	2	0.50	2,420
3-axle	663	4	0.85	8,228
4-axle	663	4	1.20	11,616
5-axle	663	3	1.55	11,253
≥6-axle	663	1	2.24	5,421
		Total historical construction year ESALs	=	38,938

Step 3

Total historical ESALs = (total historical construction year ESALs) × $\left[(1+i_{\text{H to C}})^n - 1\right] / i_{\text{H to C}}$

= (38,938) × $\left[(1+0.016)^{15} - 1\right] / 0.016$ = 654,247 Total historical ESALs.

7. Surface Course and Pavement Layers Selection Guide

7.1. General Considerations

The selection of the surface course for a road or highway project should be based on initial cost, annual costs, embankment stability, and other considerations. Variables to consider for initial cost include mobilization, materials, materials availability, and other design and construction costs. Variables for annual costs include maintenance and user costs. Also, consider traffic speed and volume, truck volume, rural versus urban, severity of roughness, embankment stability, expected life, rainfall, temperature, and type of maintenance equipment available. Consult the regional maintenance section when selecting surface courses.

7.2. Unstable Embankments

The thawing of ice-rich permafrost foundation soils is the main cause of embankment instability in Alaska. Consolidation of thick organic soils that have not been adequately surcharged can also cause instability. Because frozen soils consolidate during thawing, thaw settlement instability problems progress at a varying rate from year to year. Sometimes an embankment can take more than 50 years to stabilize. The severity of the consolidation depends on the depth and volume of ice in the soil. Variations in ice content lead to inconsistent consolidation, resulting in differential settlement of the driving surface.

The life of a surface course on unstable embankments should closely match the life of the embankment and foundation. In rural areas, this almost always results in the selection of a double-layer asphalt surface treatment or a high-float asphalt surface treatment.

In urban areas, the selection of a surface course depends on traffic volume and speed, severity of the pavement roughness, possibility of vehicle damage due to airborne aggregate, and the possibility that vehicles will be coated with emulsified asphalt. When a hot mix asphalt concrete surface is used in an urban area with unstable soils, the thickness should be 2 inches, the minimum allowable thickness.

If a project has well-defined sections of unstable and stable embankment, consider selecting two types of surface courses, each appropriate to a particular level of embankment stability. Variables affecting this decision include the length and number of unstable areas, the percentage of the project with unstable embankment, the increased costs of multiple equipment spreads, and the variables discussed above in General Considerations.

7.3. Available Surfacing Types

Hot Mix Asphalt Concrete (HMA): HMA consists of a mixture of asphalt cement and well-graded aggregate. HMA provides the smoothest asphalt surface, the longest life, and contributes to the structural strength of the entire pavement structure. HMA generally requires less maintenance than other surfaces, and it is recommended for use in all stable embankment areas with AADTs greater than 1,000 or significant truck volumes. Consider HMA as an alternate for AADTs less than 1,000, based on the variables given in General Considerations.

Double-Layer Asphalt Surface Treatment (Double-Layer AST): Double-layer ASTs are typically made of two applications of asphalt emulsion and a single-sized aggregate. Double-layer ASTs are usually placed on a granular base. Design the pavement structure, including the base, to provide all of the required strength, since the double AST provides no structural strength. The aggregate for a double-layer AST is more expensive than aggregate for a HMA or high-float AST, because more material is wasted making the single-sized aggregate. Double-layer ASTs are a good alternative for unstable foundations and should be considered as an alternative to HMA for projects with AADTs less than 1,000. A double-layer AST is not recommended for high-speed, high-traffic urban areas.

Single-Layer Asphalt Surface Treatment (Seal Coat AST): A seal coat AST is constructed by spraying emulsified asphalt material followed immediately by a thin stone covering. An aggregate seal is typically used to extend the life of pavement. It produces an all-weather surface, renews weathered and cracked pavements, improves skid resistance, seals pavement, and gives no additional strength to pavement. An aggregate seal typically has a longer life in dry climates. An aggregate seal of imported, higher-quality aggregate may be designed for a new pavement if local aggregate wears poorly.

High-Float Asphalt Surface Treatment (High-Float AST): A high-float AST consists of one application of high-float emulsified asphalt followed by a single application of crushed gravel, and it is usually placed on a granular base. A high-float AST provides a less expensive alternative to double-layer AST, because it uses a single layer of aggregate with a less restrictive gradation and provides the same design life. Because of the aggregate gradation and properties of the high-float emulsified asphalt, a high-float AST surface is rougher than a double-layer AST—this is especially true for the first few years following construction. As with double-layer ASTs, high-float ASTs are not considered to be structural layers. That is, a high-float AST does not contribute to the load capacity of the pavement structure. High-float ASTs may have a significant P_{200} content, an undesirable trait for use in areas with high rainfall. In wet conditions, it is difficult to keep the P_{200} fraction dry. Wet aggregate clumps in the distributor and makes uniform spreading nearly impossible. High-float AST is a good alternative in areas with unstable foundations.

Sand and Slurry Emulsion Seals: A sand emulsion seal is comprised of sand and emulsified asphalt. A slurry seal is usually comprised of fine, dense-graded aggregate and emulsified asphalt and is placed using specialized slurry seal equipment. Fine-grained seal coats increase skid resistance, seal against water intrusion, and correct minor surface irregularities.

Stone Mastic Asphalt Concrete (SMA): SMA is a coarse-graded HMA mix that resists rutting caused by studded tires. SMAs do not have good fatigue properties and should only be used as a surface layer on top of an HMA. Consider SMA as an alternative for projects with an AADT greater than 10,000.

Stabilized Base Course: Stabilized bases are composed of aggregate and a stabilizing (bonding) material. The aggregates are generally well graded but can be open graded. Bonding materials include asphalt cement, asphalt emulsion, Portland cement, lime, various proprietary chemical products, and even recycled asphalt concrete. Use stabilized bases as required in chapter 2.

Reclaimed Asphalt Pavement (RAP): Create RAP by removing and crushing old asphalt concrete pavement. The RAP often contains a substantial portion of normal base course material picked up during removal of the old pavement surface (sometimes as high as 25% to 30% by weight). RAP can be used as a component in recycled asphalt pavement or as a substitute for base course. A base course can be constructed exclusively from RAP or with a mixture of RAP and virgin crushed aggregate. Always consider the use of RAP in the design of a pavement rehabilitation project.

Recycled Asphalt Pavement: Recycled asphalt pavement is processed from reclaimed asphalt pavement by crushing and mixing it with additional components such as aggregate, asphalt cement, or recycling agents. It is then re-laid and compacted. Hot recycling of pavement is usually processed in a plant, while cold recycling of pavement is usually done in place. Always consider recycling existing asphalt as an alternative on a pavement rehabilitation project.

Gravel Surface: For very low-volume roads, always analyze the cost of grading and replacing gravel versus the cost and maintenance of any other surface. Consider the continual loss of the crushed gravel surface (through maintenance operations and wind erosion) in the cost analysis. Calcium chloride or other dust palliatives may be used, especially for higher traffic volumes. These usually last only a year or two. Also consider the cost of future applications in the maintenance costs. Gravel surface courses require a higher P_{200} content than base courses for hot mix asphalt surfaces (10 to 15% versus less than 6% for HMA). If a road is to be paved in the future, the surface course will need to be replaced. Gravel surfacing is applicable for AADTs less than 50.

Portland Cement Concrete (PCC): Because of the high cost of PCC and the necessity of a thick, non-frost-susceptible base, PCC is rarely used in Alaska. PCC pavement sections have seen limited use at some Alaska airports. Consider PCC as an alternative to HMA. Local conditions may result in PCC being cost-effective. However, this manual does not cover PCC design.

An NHI course is available for anyone interested in developing expertise in PCC design. See basic reference materials in reference.[15]

7.4 Stabilized Layers

Use the following in conjunction with policies detailed in Chapter 2.

7.4.1. Stabilized Base

Bound stabilized base is a typical granular base course material that has been stabilized with a binder component. No minimum amount of additive is required, although bound stabilized base material must (1) achieve a M_R value ≥ 80,000 psi, and (2) exhibit some other form of improvement that is directly applicable to improving the structural design of the pavement, e.g., reduced frost susceptibility. The modulus value improvement and/or other improvement(s) gained through the addition of the binder must be documented or otherwise verified by regional or statewide materials personnel with pavement design expertise. Acceptable documentation will cite previous experience with similar materials or will be based on test data using test method(s) accepted by the DOT&PF Statewide Materials Section.

Bound stabilized bases are normally defined as standard base course materials containing one or more of the following components:

- Emulsion
- Asphalt cement
- Foamed asphalt cement
- Lime
- Portland cement
- Recycled asphalt concrete pavement *
- A mixture of recycled asphalt concrete pavement and base course material *

** These bound stabilized base materials, incorporating recycled asphalt concrete, are usually created through an unheated, mechanical mixing process. Such mixtures may require a significant period of time after construction (perhaps a year or more) before the expected stabilization effect is fully achieved.*

A stabilized base is considered a lightly bound material. Therefore, use the Per Ullidtz equation as the failure criterion for bound stabilized base material (see Section 4.3.2).

7.4.2. Asphalt-Treated Base

Asphalt-treated base (ATB) is defined as a typical granular base course material that has been stabilized with a minimum of 4% asphalt cement (residual asphalt cement) binder additive. The minimum amount of asphalt cement additive required is that necessary to achieve an M_R value ≥ 150,000 psi. The modulus value used for mechanistic design must be justifiably based on experience or on M_R test method(s) accepted by the DOT&PF Statewide Materials Section. Achievement of the 150,000-psi minimum modulus value, whether by test or presumption, must be documented or otherwise verified by regional or statewide materials personnel with pavement design expertise. Acceptable documentation will cite previous experience with similar materials or will be based on test data using test method(s) accepted by the DOT&PF Statewide Materials Section.

Asphalt-treated base is considered a heavily bound material. Therefore, use The Asphalt Institute (TAI) fatigue equation as the failure criterion for asphalt-treated base material (see Section 4.3.2).

7.4.3. Alaska Renewable Pavement

Alaska Renewable Pavement (ARP) is a pavement layering system that provides an acceptable alternative to stabilized base or can be used to amplify the benefits of a stabilized base. ARP can also be combined with a bound stabilized base or asphalt-treated base to satisfy requirements for pavement designs involving very high ESALs. The ARP system is similar to normal asphalt concrete pavement except that it is thicker and is actually composed of two sub-layers. Figure 7-1 illustrates ARP layering and examples of applications both with and without a stabilized base course.

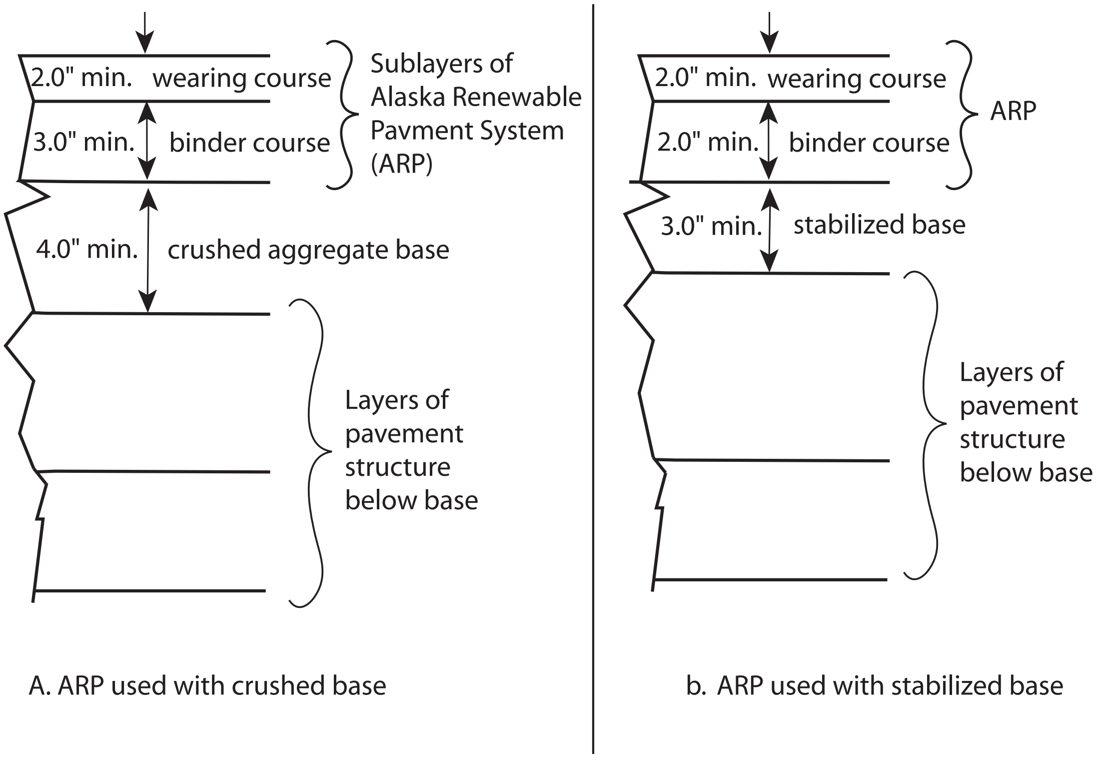


Figure 7-1. Pavement Structures Showing ARP Layers

The upper layer of the ARP, called the *wearing course*, consists of asphalt concrete containing components that: maximize resistance to abrasion wear (addresses tire-stud rutting), minimize surface roughness (addresses ride quality), minimize plastic deformation (addresses displacement rutting), and minimize permeability (addresses premature weathering and aging of the asphalt concrete).

The lower layer of the ARP, called the *binder course*, consists of asphalt concrete containing components that maximize fatigue resistance (addresses fatigue cracking) and minimize plastic deformation (addresses displacement rutting).

The ARP design provides for a minimum 30-year service life because the ARP concept anticipates periodic replacement of the upper ARP layer by mill-and-fill construction methods. Periodic mill-and-fill reconditioning can be done without ever penetrating the lower ARP layer. Therefore, vehicle traffic will never be subjected to an unpaved surface during future reconditioning events. Because of these objectives, apply an extended design life (30 years minimum) when considering an ARP pavement system.

Details regarding selection of materials and mix design requirements for ARP wearing and binder layers are outside the scope of this manual. However, the following points generally apply:

- The same mix design procedure and mix design class should be used for upper and lower layers.
- Aggregate gradation type need not be the same for both layers.
- Minimum thickness for wearing course is 2 inches.

Minimum thickness for binder course is 2 inches (if stabilized base is used) and 3 inches (if stabilized base is not used).

8. Pavement Drainage Design

Avoid premature pavement failures by providing proper drainage. Refer to the *Alaska Preconstruction Manual,* Chapter 11, Section 1120.4, Drainage, for basic guidelines. DOT&PF's *Highway Drainage Manual* is also available via Internet at http://www.dot.state.ak.us/stwddes/dcspubs/manuals.html. 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 sufficient to cause hydroplaning and skidding. Provide 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 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.

General references concerning drainage design are available through federal government publications *Pavement Subsurface Design Manual,* NHI Course No. 13126, and *Pavement Subsurface Drainage Systems,* Transportation Research Board, NCHRP Report No. 239, 1997.

9. Life-cycle Cost Analysis

To be developed.

10. Glossary

The definitions for the following terms are those commonly used in the transportation industry and particularly by the Alaska DOT&PF. Although some of these terms may seem fundamental, we provide them so that everyone, regardless of field experience, can develop an understanding of this nomenclature from this quick reference guide.

AASHTO: The acronym for the American Association of State Highway and Transportation Officials. A "T" designates AASHTO tests (example: AASHTO T195). An "M" designates AASHTO specifications (example: AASHTO M156).

Abrasion Testing: Aggregates break and erode as moved around by heavy equipment, plant machinery, and lay-down equipment. The Los Angeles abrasion machine tumbles the aggregate in a standard way to determine if the aggregate is hard enough to be made into processed aggregate. Refer to the current *Standard Specifications for Highway Construction*.

Absorption: Refers to the amount of asphalt absorbed into the aggregate in a mix, expressed as a percentage of aggregate.

Adhesion: The asphalt's ability to stick to the aggregate in the paving mixture.

Affinity (Attraction) for Asphalt: An aggregate's affinity, or attraction, for asphalt is its tendency to accept and retain an asphalt coating. Limestone, dolomite, and traprock have high affinities for asphalt and are referred to as hydrophobic (water-hating) because they resist the efforts of water to strip asphalt from them. Hydrophilic (water-loving) aggregates, such as quartz, have low affinities for asphalt. They tend to separate from asphalt films when exposed to water.

Aggregate: Any combination of one or more hard granular mineral materials, either natural or crushed, from very fine to large rocks. It is selected because of its characteristics for a specific purpose, such as sand, gravel, crushed stone, ballast, etc., used for mixing in graduated fragments. Types include:

> **Blended Aggregate:** The combination of coarse and fine aggregates meeting gradation requirements for the material specified.
>
> **Coarse Aggregate:** Typically, aggregate retained on the No. 4 sieve, but the designation is dependent on the specification requirements.
>
> **Coarse-Graded Aggregate:** Aggregate having a continuous grading in sizes of particles from coarse through fine with a predominance of coarse sizes.
>
> **Dense-Graded Aggregate:** An aggregate that has a particle size distribution near the maximum density line when plotted on a 0.45 power gradation chart.
>
> **Fine Aggregate:** Aggregates passing the No. 4 or other specified sieve, but the designation depends on the specification requirements.
>
> **Fine-Graded Aggregate:** Aggregate having a continuous grading in sizes of particles from coarse through fine with a predominance of fine sizes.
>
> **Mineral Filler:** Very fine aggregate, predominantly P_{200} and free of organics.
>
> **Natural Aggregates:** Aggregates in their natural form, with little or no processing.
>
> **Open-Graded Aggregate:** One containing little or no mineral filler, in which the void spaces in the compacted aggregate are relatively large.
>
> **Poorly Graded Aggregates:** An aggregate gradation with high variability in the amounts passing each successive sieve, having angles when plotted on a gradation chart.

Processed Aggregates: Aggregates that have been crushed and screened in preparation for use.

Synthetic Aggregates: Artificial aggregates that are the byproduct of industrial production processes such as slag from ore refining. The most common form is the lightweight aggregate used in concrete.

Well-Graded Aggregate: Aggregate graded from the maximum size down to filler with a smooth curve when plotted on a gradation chart.

Aggregate Loss: Refers to undesirable loss of aggregates in an asphalt pavement or surface treatment. The most common causes of aggregate loss from a pavement are lack of compaction, too little asphalt binder, lack of antistripping agents, poor quality aggregate, and dirty aggregate. In mixes using emulsified asphalt, aggregate loss may result from use of an inappropriate ionic grade.

Aggregate Storage Bins: Bins that store the necessary aggregate sizes for feeding to an asphalt plant in substantially the same proportions as are required in the finished mix. Also called **Cold Bins**.

Alaska Renewable Pavement (ARP): Pavement layering system that is an acceptable alternative to stabilized base or can be used to amplify the benefits of a stabilized base. ARP can also be combined with a bound stabilized base or asphalt-treated base to satisfy requirements for pavement designs involving very high ESALs. The ARP system is similar to normal asphalt concrete pavement except that it is thicker and is actually composed of two sublayers. The ARP design provides for very long service life because the ARP concept anticipates periodic replacement of the upper ARP layer by mill-and-fill construction methods.

Anionic: A material with a negative electrical charge (see **Emulsified Asphalt**).

Antistripping Agents: Antistripping agents are usually blended with asphalt binders to improve bonding between the binder and the aggregate. Lime and cement are among the most common antistripping agents. Chemical antistripping agents such as PaveBond or Arr-Maz are also commonly used in Alaska. Asphalt cement suppliers usually add the chemical antistripping agents.

Arctic-Grade Asphalt: Refers to paving asphalt cement that has been modified, usually by rubber derivative materials such as latex or polymer, for enhancing low-temperature characteristics. Arctic-grade asphalt has been used, with varied success, to reduce thermal cracking of pavement in cold climates. A standard grading system has not yet been developed for arctic grades.

Asphalt: A dark brown to black cementitious material in which the predominating constituents are bitumens that occur in nature or are obtained as residue in petroleum distillation. Asphalt imparts controllable flexibility to mixtures of mineral aggregates, with which it is usually combined. It is highly resistant to most acids, alkalis, and salts. Although it is a solid or semisolid at ordinary atmospheric temperatures, asphalt may be liquefied by applying heat, dissolving it in petroleum solvents of varying volatility, or emulsifying it.

Asphalt Blocks: Asphalt concrete molded under high pressure. The type of aggregate mixture composition, amount and type of asphalt, and the size and thickness of the blocks are varied to suit usage requirements.

Asphalt, Blown or Oxidized: Asphalt that is treated by blowing air through it at an elevated temperature to give it desired characteristics for special uses such as roofing, pipe coating, undersealing Portland cement concrete pavements, membrane envelopes, and hydraulic applications.

Asphalt, Catalytically Blown: An air-blown asphalt produced by using a catalyst during the blowing process.

Asphalt Cement: Asphalt that is refined to meet specifications for paving, industrial, and special purposes. The term is often abbreviated to AC or referred to as binder when used in an asphalt hot mix.

Asphalt Cement Grade: See **Binder Classification**.

Asphalt Concrete: Also referred to as asphalt concrete pavement (ACP), hot mix asphalt (HMA), flexible pavement, and hot bituminous pavement. It is the material most commonly used for surfacing roadways and airports in Alaska that are subject to high traffic. It is a high-quality, controlled, hot mixture of asphalt cement and graded aggregate, thoroughly compacted into a uniform dense mass.

Asphalt Content: Refers to the content of asphalt cement in an asphalt concrete paving mixture. Asphalt content is currently always expressed as a percentage of the total mix weight. In the 1970s and earlier, the Alaska DOT&PF expressed asphalt contents as a percentage of the aggregate weight.

Asphalt, Cutback: See **Cutback Asphalt**.

Asphalt Distributor: A truck-mounted asphalt tank including heating elements, a pump, and a spray bar on the back for spraying asphalt on a prepared surface. The asphalt distributor applies the desired volume of asphalt (liters /sq. m or gal./sq. yd.) for asphalt surface treatments, tack coats, and prime coats.

Asphalt Filler, Preformed: Premolded strips of asphalt mixed with fine mineral substances, fibrous materials, cork, sawdust, or similar materials; manufactured in dimensions suitable for construction joints.

Asphalt Joint Sealer (Filler): An asphalt product used for sealing cracks and joints in pavement and other structures.

Asphalt Leveling Course: A course (asphalt aggregate mixture) of variable thickness used to eliminate irregularities in an existing asphalt surface prior to placing the final wearing course.

Asphalt Plants: See **Batch Plant** and **Drum Mix Plant**.

Asphalt Soil Stabilization (soil treatment): Treatment of naturally occurring nonplastic or moderately plastic soil with cutback or emulsified soil mixture produces water-resistant base or subbase courses of improved load-bearing qualities.

Asphalt Surface Treatments: A broad term for several types of asphalt or asphalt-aggregate applications, usually less than 1 inch thick, to a road surface. The types range from a single application of emulsified asphalt followed by graded aggregate to multiple surface layers made up of alternating applications of asphalt and different-sized aggregates. See also **Single Surface Treatments** and **Multiple Surface Treatments**.

Asphalt-Treated Base: A base course constructed using hot asphalt cement as a binder, often referred to as ATB. See **Treated Base Courses** for further descriptions of types.

Asphaltenes: The high molecular weight hydrocarbon fraction of asphalt.

ASTM: The acronym for the American Society for Testing and Materials.

ATM: Stands for Alaska Test Methods. These tests were developed by the headquarters Materials section. ATM tests are designated with a “T” (Example: ATM T-4).

Automatic Cycling Control (batch plant): In a batch plant, a control system in which the opening and closing of the weigh hopper discharge gate, the bituminous discharge valve, and the pug mill discharge gate are actuated by self-acting mechanical or electrical machinery without any intermediate manual control. The system includes preset timing devices to control dry and wet mixing cycles.

Automatic Dryer Control (batch plant): In a batch plant, a system that automatically maintains the temperature of aggregates discharged from the dryer within a preset range.

Automatic Proportioning Control (batch plant): In a batch plant, a system in which proportions of the aggregate and asphalt fractions are controlled by gates or valves that are opened and closed by self-acting mechanical or electronic machinery without any intermediate manual control.

Annual Average Daily Traffic (AADT): The average volume for a 24-hour period. It is normally the annual total volume divided by 365, unless otherwise stated.

Axle Load: The total load transmitted to the pavement by all wheels of either a single or tandem axle, usually expressed in kips (1 kip = 1 kilo pound = 1,000 pounds of force).

Bag House: A contained fabric filter that removes dust from the exhaust gases of dryer drums on batch plants and drum plants. The fabric filters are sewn in the shape of cylindrical bags, several hundred of which are contained in the bag house. Bag houses are used to avoid air pollution during hot mix asphalt production. Bag houses are equipped with mechanical means of shaking and cleaning the filters during production of mix.

Bag House Fines: The dust that falls out of the bag house, off the filters. This material may be fed back in to the asphalt mix or wasted. Wasted bag house fines are often put into contained settling ponds.

Bank Gravel: Gravel found in natural deposits, usually intermixed with fine material such as sand or clay, or combinations thereof. Gravelly clay, gravelly sand, clayey gravel, and sandy gravel indicate the varying proportions of the materials in the mixture.

Base Course (BC): The layer or layers of specified material of designed thickness placed on a subbase or a subgrade to support a surface course. Most base courses are constructed with crushed aggregates and therefore called crushed aggregate base course.

Batch Plant: A stationary manufacturing facility for producing asphalt paving mixtures that proportions the aggregate constituents into the mix by screening and weighing batches, then adds asphalt material by either weight or volume in a pug mill. Batch plants make asphalt concrete one batch at a time. Measured quantities of aggregates are first run through a dryer drum and into hot bins for storage. A bag house filters dust emitted from the dryer drum. The aggregates are then sent through hot screens to control the gradation and dropped into a pug mill where they are mixed with hot asphalt. The batch is dumped from the pug mill and the process repeats. Dumped batches are either placed directly into trucks or conveyed to a silo for storage. Because batch plants are stationary facilities, they are usually only found in larger metropolitan areas where demand keeps them in operation. Batch plants are rated according to the maximum batch weight in tons they can produce and the weight they can produce per hour. Larger batch plants can produce five tons or more of mix with each batch and more than 300 tons per hour.

Binder: Material used to stabilize or cement together loose soil or aggregate. In hot mix asphalt and asphalt treated bases, the binder is asphalt cement.

Binder Classification (Grades): Refers to an asphalt cement's specification grade. The first developed grading system was penetration grading, followed by viscosity grading. Viscosity grading may be done on original asphalt (AC-grades–Note: AC-10 is seldom used), or on asphalt residue from the rolling thin film oven (AR-grades). Other grades include arctic grades, performance-based asphalt (PBA-grades), performance-graded (PG-grades), and modifications of the above.

Superpave Binder: See **Performance-Graded Asphalt**.

Binder Course: Where thick pavements are required, the asphalt concrete pavement is sometimes placed as two layers, each differing in composition but sharing approximately the same fatigue properties (see also **Wearing Course**). The binder course is the bottom portion of asphalt concrete pavement, "tuned" to provide maximum fatigue resistance (addresses fatigue cracking) and minimum plastic deformation (addresses displacement rutting).

Bitumen: A mixture of hydrocarbons that occur naturally or result from chemical processing. Asphalt and tar are examples.

Bituminous Surface Treatment (BST): See **Multiple Surface Treatments**.

Bleeding or Flushing: The upward movement of asphalt in an asphalt pavement or surface treatment, resulting in the formation of a film of asphalt on the roadway surface. The most common cause is too much asphalt in one or more of the pavement courses, resulting in asphalt coming to the surface under traffic and with heat expansion. Bleeding or flushing usually occurs in hot weather.

Block Cracks: See **Cracks**.

Blotter Material: Fine material (clean sand, crusher dust, etc.) sometimes spread on an uncured prime coat to allow traffic on the prime before it is cured and to protect the uncured prime from being washed off the grade by rain. You may use blotter sand less than four hours after applying the prime only with written permission. Blotter material may also be used to mitigate bleeding.

Breaking: The process of emulsified asphalt curing or setting by evaporation.

Break-Down Roller: The large roller that is the first to start compaction of freshly laid asphalt concrete pavement. Often vibratory rollers are used for the first few passes of break-down rolling.

Cape Seal: Cape seal combines a single-shot asphalt surface treatment with a slurry seal or microsurfacing. Done properly, it provides the rough, knobby surface of a chip seal to reduce hydroplaning, yet has a tough sand matrix for durability.

Cationic: A material testing positive in a particle charge test (see **Emulsified Asphalt**).

Check Marshall Test: *Alaska uses this test method*. The Check Marshall Test is made on the asphalt concrete that is produced on the project to determine if it has sufficient stability. (Stability is a measure of the pavement sample's diametral strength.) The Marshall method verifies the optimum asphalt content for a particular blend of aggregate. The method also provides information about the properties of the resulting asphalt hot mix, density, and void content that must be met during pavement construction. The job mix formula establishes optimum levels of density and void content. Check Marshall Testing is done by the Regional Laboratory.

Chips: Small angular fragments of stone containing little or no dust. They are used in asphalt surface treatments. See Table 7035 of the *Standard Specifications for Highway Construction,* 1988.

Chip Seal: See **Single Surface Treatments**.

Cohesion: The ability of the asphalt to hold the aggregate particles firmly in place in the finished pavement.

Cold Feed: Refers to the conveyors between the aggregate bins and the drum mixer or dryer drum in an asphalt plant that carry cold aggregates to the plant.

Cold-laid Plant Mixture: Plant mixes, using emulsified asphalt, that may be spread and compacted at atmospheric temperature.

Cold Mix: A mixture of emulsified asphalt and aggregate used for patching. This mixture is workable at temperatures above freezing.

Cold Recycling: Cold mix recycling may be done in place or at a central plant with a pug mill. Existing asphalt pavement is crushed to a specified maximum size and placed on the roadway with or without the addition of emulsified asphalt. When a train of equipment performs the crushing, treating, and relaying of the material, it is referred to as cold in place recycling (CIPR).

Compaction: Achieving density by compressing material into a smaller volume. The compaction process begins with break-down rolling, then intermediate rolling, and finally finish rolling. The percentage of compaction attained by the rolling of the hot mix can be estimated with a nuclear densometer, but is usually measured for acceptance by coring out samples whose density is measured in a laboratory and related to a maximum (Rice) density.

Composite Pavement: A pavement structure composed of an asphalt concrete wearing surface and Portland cement concrete slab.

Continuous Mix Plant: A manufacturing facility for producing asphalt paving mixtures that proportions aggregate and asphalt constituents into the mix by a continuous system without definite batch intervals. Also called a drum mix plant. See the definition for **Drum Mix Plant** for further details.

Coring Machine: Coring machines are used to remove core samples of the completed mix, which are tested to measure the level of pavement compaction and thickness for acceptance.

Cracks: Breaks in the surface of an asphalt pavement. The common types are:

> **Alligator cracks:** A slang term for fatigue cracking of asphalt concrete pavement that results in interconnected cracks forming a series of small shapes that resemble an alligator's skin. In some places outside Alaska, these are referred to as "turtleback" cracks. Traffic loads that exceed the structural strength of the roadway section cause these cracks.
>
> **Block cracks:** Interconnected cracks, sometimes called "shrinkage cracks," forming a series of large blocks, usually with sharp corners or angles. Shrinkage and daily temperature cycles cause them. Block cracking is a sign that the asphalt has aged and hardened significantly. It often occurs on older pavement with little or no traffic.
>
> **Construction Joint Cracks:** Longitudinal or transverse separations along the seam between two paving panels, caused by a weak bond between the panels and/or lack of compaction at the joint.
>
> **Edge Joint (Curb Line) Cracks:** The separation of the joint between the pavement and the shoulder, commonly caused by the wetting and drying beneath the shoulder surface. Other causes are shoulder settlement, mix shrinkage, and trucks straddling the joint. Longitudinal cracks between the traveled way and a paved shoulder may be caused by use of a different structural section of the shoulder or inadequate snow removal on the shoulders.
>
> **Fatigue Cracks:** Interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wire. They are caused by heavy traffic that is excessive for the given thickness of pavement and structural support provided by underlying layers.
>
> **Longitudinal Cracks:** Cracks that run in the direction of travel.
>
> **Reflection Cracks:** Cracks in asphalt overlays that reflect the crack pattern in the pavement structure underneath. They are caused by vertical or horizontal movements in the pavement beneath the overlay, brought on by expansion and contraction with temperature or moisture changes. Lack of support for an overlay over an existing crack also contributes to reflection.
>
> **Slippage Cracks:** Crescent-shaped cracks that are open in the direction of the thrust of wheels on the pavement surface. They result from braking and turning on pavement that lacks a good bond between the surface layer and the course beneath.
>
> **Thermal Cracks:** See **Transverse Cracks**.
>
> **Transverse Cracks:** Cracks that run perpendicular to the direction of traffic. Unless caused by a poor construction joint, these cracks are usually caused by longitudinal shrinkage of the pavement and the support layers when at very low temperatures.

Crack Sealing: Pavement maintenance operations, cleaning out cracks, and using asphalt materials to fill and seal cracks to impede infiltration of moisture into the supporting layers. Modern crack sealing compounds contain rubberized agents to help maintain flexibility even at very low temperatures.

Critical Fines Content (P_{cr}): The limiting fines content (P_{200}) above which frost action affects the strength of the pavement structure. The critical fines content (P_{cr}) varies with the depth below the surface course.

CRS-2: A cationic, rapid-setting emulsified asphalt, used primarily for fog seals, sand seals, and chip seals.

Crusher-Run: The unscreened product of a rock crusher.

Curing: In asphalt concrete, curing involves the chemical and physical changes the mix goes through as it cools and is initially subjected to traffic. See **Cutback Asphalt** and/or **Emulsified Asphalt**. Also see **Breaking**.

Cutback Asphalt: Cutback asphalt has been liquefied by blending with naphtha, kerosene, or fuel oil to allow mixing or spraying at lower temperatures than those for pure asphalt. Cutback asphalt cures by the evaporation of the solvent, which amounts to 33% to 50% by weight of the material. There are potential environmental problems with its use. Currently, cutback asphalt is only used for prime coat and some crack sealing. The following grades of cutback asphalt are standard:

> **Medium-Curing (MC) Asphalt:** Cutback asphalt composed of asphalt cement and kerosene-type diluent of medium volatility. Example: MC-30 is sometimes used for prime coat.
>
> **Rapid-Curing (RC) Asphalt:** Cutback asphalt composed of asphalt cement and a naphtha or gasoline-type dilutant that will evaporate quickly. Example: RC-800 has been used for crack sealing.
>
> **Road Oil:** A heavy petroleum oil, usually one of the slow-curing (SC) grades
>
> **Slow-Curing (SC) Asphalt:** Cutback asphalt composed of asphalt cement and oils of low volatility. Example: SC-250 has been used to control dust on gravel roads. However, it is no longer used due to concern that contaminated runoff may get into waterways.
>
> *Note:* The numbers following the acronyms above refer to the viscosity grade of the material. Higher numbers indicate higher viscosity cutbacks.

Degradation Test: The degradation test determines the durability of aggregate in the presence of water and agitation during construction. Degradation values of 20 to 45 may be susceptible to degradation. Below 20, the material will be susceptible to degradation.

Density: The unit weight of a material in terms of mass per unit volume, e.g., lbs/ft^3. The density of a compacted asphalt paving mixture is determined on laboratory-compacted specimens to:

- Provide a basis for computing the percentage of air voids and voids in the mineral aggregate in the compacted mixtures, an integral part of some asphalt paving mixture design procedures
- Provide an indication of the optimum asphalt content in some mix design procedures
- Establish a basis for controlling compaction during construction of the asphalt pavement
- Provide a basis for calculating the spread required for a given thickness of pavement
- Check density of pavement and effectiveness of rolling operations, on specimens obtained from pavements

Densification: Increasing the density of a mixture during the compaction process.

Design Lane: The lane on which the greatest number of equivalent 18,000-pound single-axle loads is expected. Normally this will be either lane of a two-lane roadway or an outside lane of a multilane highway.

Distortion: Change in the pavement surface.

Distributor: See **Asphalt Distributor**.

Double-Shot Seal Coat: See **Multiple Surface Treatments**.

Drainage: The ability of a structural section to allow moisture to be removed from its surface, subsurface, or roadway edges. The level of drainage provided by design, construction, and maintenance of a paved section is the most important factor in determining how long it will last.

Drainage Coefficients: Factors used to modify layer coefficients in the AASHTO pavement design process as an indicator of how well the pavement structure can handle the adverse effect of water infiltration.

Drum Mix Plant: Drum mix plants (sometimes called "dryer drum plants") combine and heat aggregate and asphalt cement continuously. May also be called a continuous mix plant. Measured amounts of different-sized aggregates are fed into the upper end of the dryer. The asphalt cement is added near the middle of the drum, where it mixes with aggregate that has already been heated and dried. The aggregate at a drum plant starts at a set of cold bins, just as it does at a batch plant. The hot asphalt storage tanks and pumping systems are also similar to those for batch plants. The drum mixer consists of a revolving cylinder lined with flites, a large burner, and a fan, like a batch plant dryer. Unlike batch plant dryers, asphalt cement is sprayed on the aggregate and mixed within the drum. The burner is at the upper end of the dryer, so the aggregate and the hot gases move down through the drum. This is known as "parallel flow." Parallel flow and a short flame are used so that the gases are cool enough by the time they reach the lower end of the drum that they will not burn the asphalt. Most drum-mix plants have an inlet, near where the asphalt is applied, to allow the addition of recycled asphalt pavement (RAP). Hot-mix asphalt that comes out the lower end of the drum is conveyed to truck loading facilities or a silo for storage. A bag house filters dust emitted from the lower end of the drum. Drum-mix plants are portable and are the most common type of asphalt plant used in Alaska, especially outside larger cities.

Dryer: An apparatus that dries the aggregates and heats them to the specified temperatures in batch plants.

Dry Mixing Time: Residence time of aggregate as it drops into the pug mill of a batch plant, before the addition of asphalt.

Ductility: The ability of a substance to be drawn out or stretched thin without breaking. Many types of asphalt grading use ductility tests.

Durability: Asphalt paving mixture's ability to resist disintegration with age, weathering, and traffic. Time and low traffic volumes affect pavement's durability. Included under weathering are changes in the characteristics of the asphalt, such as oxidation and volatilization, and changes in the pavement and aggregate due to water, including freezing and thawing.

Dust Control: Dust control operations use spray trucks equipped with stirring mechanisms and graders.

Dust Palliative: The use of a dilute asphalt emulsion (used motor oils are also an accepted form), sprayed directly on an unpaved road surface to control dust, is known as dust laying or the application of a dust palliative. The dilution depends on the condition of the surface. Some penetration is expected.

Dust Ratio: An asphalt mix property used for assessing acceptance during the mix design process. It is the number resulting from dividing the percentage P_{200} in the aggregate gradation by the percentage of asphalt as a percentage of mix. Typical acceptable values range from 0.6 to 1.2.

Effective Asphalt Content: The amount of asphalt in a paving mix not absorbed by the aggregates. It is the portion of asphalt available for coating and adhesion between aggregate particles.

Embankment Foundation: The material below the original ground surface whose physical characteristics affect the support of the embankment.

Emulsified Asphalt: Emulsified asphalt is made by combining ground asphalt, emulsifying agents, and water. It cures by "breaking," which is water removal by evaporation or steaming off. Asphalt emulsions fall into three categories: anionic, cationic, and nonionic. The first two types are ordinarily used in roadway construction and maintenance. The anionic (electronegatively charged) and cationic (electropositively charged) classes refer to the electrical charges surrounding the asphalt particles. With nonionic emulsions, the asphalt particles are neutral. Cationic emulsions are used with aggregates that are negatively charged. Anionic emulsions are used with positively charged aggregates. Opposite charges attract. The relative setting time of either slow setting (SS), medium setting (MS), or rapid setting (RS) emulsions further categorizes emulsified asphalts.

Emulsified Asphalt Specifications: AASHTO and ASTM have developed standard specifications for the following grades of emulsions:

Emulsified Asphalt	Cationic Emulsified Asphalt
RS-1	CRS-1
RS-2	CRS-2
MS-1	—
MS-2	CMS-2
MS-2h	CMS-2h
HFMS-1	—
HFMS-2	—
HFMS-2h	—
HFMS-2s	—
SS-1	CSS-1
SS-1h	CSS-1h

The “h” that follows certain grades means a harder base asphalt is used. The “HF” preceding some of the MS grades indicates high float. The “s” that follows certain grades means it contains solvent or other oil distillates intended to improve coating of aggregates. If a polymer additive is included in the emulsion, the letter “p” is added.

Emulsified Asphalt Treated Base: A product of mixing base course material with emulsified asphalt and sometimes a few percent Portland cement. It can be mixed on grade by heavy equipment or by specially made traveling plants. It can also be produced in a central mixing plant. Emulsified asphalt treated bases bind up P_{200} in base course material and reduce frost and high moisture. They also can create an effective structural support layer so that the otherwise required thickness of pavement or subbase can be reduced.

Emulsion: A suspension of solids in water.

Emulsion Slurry Seal: A mixture of emulsified asphalt, fine aggregate, and mineral filler with water added to produce a slurry that is applied to a previously paved surface.

Equivalent Single Axle Loads (ESAL): Traffic on highways and streets varies in the number of vehicles and in the magnitude of loading. The cumulative effects of traffic loads factor in the structural design of pavement. The effect on the pavement performance of any combination of axle loads is equated to the number of standard 18,000-pound, dual tired, single-axle loads required to produce an equivalent effect (i.e., the single axle load). In design of pavement structural sections, the total number of ESALs is a summary of equivalent 18,000-pound single-axle loads expected from the combination of all vehicle classes for the design period.

Excess Fines: The fines content above the critical fines content ($P_{200} - P_{cr}$).

Excess Fines Factor (EFF): A factor that includes the effects of the excess fines and the applied stress at a given depth $(\Delta\ \mathrm{SFR})(P_{200} - P_{cr})^{0.8}$.

Extraction: The procedure separating the asphalt from the mineral aggregates in an asphalt paving mixture using a chemical solvent, such as trichloroethylene. Extraction provides a basis for determining the asphalt content of a mixture and provides asphalt-free aggregates for a gradation analysis. Trichloroethylene and other chlorinated solvents are now considered hazardous and they are no longer used in Alaska DOT&PF laboratories. We now use ignition ovens and nuclear asphalt content gauges to determine asphalt contents. You may use a closed-system extraction method using toluene when gradation or asphalt recovery is necessary.

Falling Weight Deflectometer (FWD): A trailer-mounted device that drops a known weight from known heights on a pavement surface while automatically measuring the resulting peak stress and deflections. The drop stress is usually intended to simulate dynamic traffic loading. The data collected with the FWD back-calculates elastic moduli of the supporting layers. Once the elastic moduli are known, structural design can proceed to determine critical stresses and strains in the structure.

Fatigue Cracking: See **Cracking**.

Fatigue Resistance: The ability of asphalt pavement to withstand repeated flexing or slight bending caused by the passage of wheel loads. As a rule, the higher the asphalt content and the lower the air void content in an asphalt mix, the greater the fatigue resistance. However, a mix with too high an asphalt content or too low an air void content will tend to rut under traffic loading.

Fat Spots: Fat spots in an asphalt mixture are isolated areas where asphalt cement has come to the surface of the mix during the lay-down and compaction. These spots can occur erratically, or they may be numerous and regular. Excessive moisture in the mix or the accumulation of asphalt cement on the plant lay-down machines or rollers that drop the accumulation on the mat can also cause fat spots.

Fines Content (P_{200}): The average percentage by weight of material passing the No. 200 sieve.

Flash Point: Asphalt cement, if heated to a high enough temperature, will release fumes that flash in the presence of a spark or open flame. This temperature, the flash point, is well above the temperatures normally used in paving operations. The Cleveland Open Cup is a flash point test used in grading asphalt. The results ensure safety during mixing and handling of asphalt.

Flexibility: The ability of an asphalt pavement structure to conform to settlement of the foundation. It is also sometimes called the ability of asphalt pavements to heal themselves during warm weather. A high asphalt content can enhance flexibility of an asphalt paving mixture.

Flexible Pavement: Another term for asphalt concrete pavement.

Fog Line: A longitudinal white line delineating the edge of the traveled way on a road.

Fog Seal: A light application of asphalt emulsion, without mineral aggregate cover, on an existing pavement. Fog seals reduce oxidation on older pavement.

Fracture Test: The fracture test, ATM T-4, is a visual determination of whether the larger aggregate particles are sharp-edged or rounded, expressed as percent fracture. Samples for fracture testing ensure that crushed aggregates have at least the minimum specified percentage of fractured particles.

Gap-Graded Asphalt: A gap-graded asphalt mix is essentially the same as an open-graded mix; however, the amount of fine aggregate in the mix is usually greater than the amount used in the open-graded mix. Gap-graded can occur because of aggregate gradations but can also be a design feature. The production, placement, and compaction of a gap-graded HMA mix are similar to the processes used for an open-graded mix.

Gradation: The relative size distribution of the particles in an aggregate sample. The percentages passing various sieve sizes, from the largest (100% passing) to the smallest (No. 200 sieve) show the gradation of the material.

Gradation Chart: A chart where the percentage passing various sieve sizes can be plotted, giving a visual demonstration of an aggregate's size distribution. Gradation charts with the sieve sizes (in inches) raised to 0.45 power on the x axis are most commonly used with paving aggregates. A straight line plotted on a 0.45 power gradation chart is a maximum density line, which is usually avoided in asphalt mix production. Gradations near the maximum density line have little space for asphalt, making the optimum asphalt range small.

Grooves: Grooves cut into pavement increase traction and moisture runoff and make ice removal easier. They are usually transverse to the direction of traffic. In Alaska, grooves are common on runway pavements at larger airports.

Heavy Trucks: Two-axle, six-tire trucks or larger, including trucks with heavy-duty, wide-base tires. Pickup, panel, and light four-tire trucks are not included.

High-Float Emulsion: AASHTO high-float emulsion derives its name from the fact that asphalt residue from distillation must satisfy a minimum float test in water at 140°F. High-float emulsion has the capability of wicking up into fine materials, unlike CRS-2, that basically only allow embedment of clean aggregate (chips). Typically HFMS-2s grade emulsion is used, that is, high-float, medium setting, high viscosity with solvent emulsion. It is considered an anionic emulsion. This is a specific type of emulsion that may contain up to 7% oil distillates, which can result in a softer residue that is less sensitive to low-temperature construction than CRS-2. The addition of solvent also helps the material coat aggregates and wick upward. High-float emulsion tends to develop a weak gel structure immediately after spraying, which creates resistance to flow on banked and crowned surfaces. The Yukon Territory uses a slightly different specification for high-float emulsions based on penetration and other slight modifications to the AASHTO specification.

High-Float Asphalt Surface Treatment: See **Single Surface Treatment**.

Hot Asphalt Recycling: Reclaimed asphalt pavement (RAP) is combined with new asphalt cement and new aggregate in a central mixing plant. Carefully consider the amount of RAP to allow in a mix because its addition cools the mix, which may impede proper asphalt coating of aggregates and hamper lay-down operations.

Hot Aggregate Storage Bins: In a batch plant, bins that store the heated and separated aggregates prior to their final hot screening into the pug mill.

Hot-Laid Plant Mixture: See **Asphalt Concrete**.

Hot-Mix Asphalt (HMA): See **Asphalt Concrete**.

Hveem Method: Alaska does not use this method.

Ignition Oven: A furnace that determines estimated asphalt cement content of an asphalt concrete mixture by burning off and exhausting the asphalt cement out, leaving only aggregates. It heats weighed samples of mixture at approximately 1,100 degrees Fahrenheit for one hour and the remaining aggregate is weighed after cooling, producing an estimate of the asphalt content of the mix. Pollution control devices on ignition ovens' exhaust stacks make them much less hazardous to the environment than previously used chemical extraction methods.

Impermeability: A material's resistance to the flow of air and water through it.

In Situ: In the natural or original position.

Initial Traffic Number (ITN): The average daily number of equivalent 18,000-pound, single-axle load applications expected for the design lane during the first year.

Intermediate Course (sometimes called binder course): An asphalt pavement course between a base course and an asphalt surface course.

Job-Mix Formula: An acceptable product of an asphalt concrete mix design, including aggregate gradation, optimum percent asphalt content, and other data determined in the mix design process.

Lay-down Machine: Asphalt pavers are also called lay-down machines. These self-propelled machines place asphalt concrete pavement. They consist of a tracked or wheeled tractor unit that pulls an activated screed. The screed spreads the asphalt concrete and partially compacts it by using its weight and sometimes vibrators.

Layer Coefficient (a1, a2, a3): These are used in the AASHTO pavement design procedure, which Alaska does not use.

Layton Box: A box mounted on the tailgate of an end dump truck containing asphalt concrete mix. When the dump truck raises the bed, the hot mix slides into the Layton box, which allows paving in small areas such as trails and driveways.

Lift: A layer or course of paving material applied to a base or a previous layer.

Longitudinal Joint: Longitudinal joints run in the direction of paving. They are weak spots in the pavement and should be kept out of high-traffic areas. On highway projects, you must place them at lane lines or the centerline. In aviation projects, paving strips are normally at least 25 feet wide, which minimizes longitudinal joints. Placing hot asphalt concrete against cold pavement forms most longitudinal joints.

Lute (Asphalt Rake): A metal rake with triangular teeth that finishes hot asphalt overlays before rolling.

Manual Proportioning Control: In a hot or batch plant, a control system in which proportions of the aggregate and asphalt fractions are manually controlled by gates or valves. The system may include power-assist devices for the opening and closing of gates and valves.

Map Cracks: See **Cracks**, **Block Cracks**.

Marshall Method: Alaska uses this method. You may use the Marshall method for asphalt paving mixtures for laboratory design and field control of mixtures containing asphalt cement and aggregates not exceeding 1 inch. The test features density-voids analysis and stability-flow test on specimens of compacted asphalt paving mixtures. Equipment and procedures for the Marshall tests are outlined in AASHTO Method of Test T245 and ASTM Method of Test D1559.

Mastic: A mixture of asphalt and fine mineral material that may be poured into place and compacted by troweling to a smooth surface.

Maximum Density Line: A straight line, plotted on a 0.45 power gradation chart, that indicates a gradation with little void space for asphalt cement. An accepted way to illustrate the line is to connect the 0 point on the chart to the smallest sieve size with 100% of the material passing it.

Maximum Fines Content (P_{max}): The maximum allowable fines content of a material at a given depth below the surface course.

Maximum Size of a Gradation: The smallest sieve size with 100% of the material passing it.

Maximum Specific Gravity: A theoretical maximum specific gravity of a paving mixture, at the zero air voids state, as determined by AASHTO T-209. The Rice specific gravity of a mix helps in calculating the percentage of air voids in a mix and the percentage of compaction. It is the reference for acceptance of asphalt concrete pavement compaction. The percentage of Rice specific gravity a mix has is its percentage of compaction. If you take 100% minus the compaction percentage, you will find the percentage of the volume of air voids in the mix. Also called “Rice specific gravity.”

Medium-Setting Emulsions: See **Emulsified Asphalt**.

Mesh: The square opening of a sieve.

Mineral Dust: The dust portion of the fine aggregate (P_{200}).

Mineral Filler: A finely divided mineral product, at least 70% of which is P_{200}. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, Portland cement, and certain natural deposits of finely divided minerals are also used.

Mix Design Methods: See definitions for each of the following:

Marshall Methods

Superpave Procedures (Gyratory)

Hveem Methods (Stabilometer)

Mix Design Report: Contains information project materials inspectors need. On aviation and highway projects, the asphalt mix design becomes part of the contract. The asphalt content, aggregate, and temperature specifications listed on the mix design supersede the authority of the standard specifications.

Mixed-in-Place (Road-Mix): An asphalt course produced by mixing mineral aggregate and cutback or emulsified asphalt at the road site by travel plants, motor graders, or special road-mixing equipment.

Multiple Surface Treatment: Two or more surface treatments using asphalt and aggregate placed one on the other. The aggregate maximum size of each successive treatment is usually half that of the previous one, and the total thickness is about the same as the nominal maximum size aggregate particles of the first course. A multiple surface treatment is a denser-wearing and waterproofing course than a single surface treatment, and it adds some strength but is not assigned a structural coefficient. The following is a list of various MSTs:

Bituminous Surface Treatment (BST): Another term for an emulsified asphalt surface treatment (AST). A BST indicates a double-shot AST where the process of surface preparation, application of emulsified asphalt with a distributor, and application of graded aggregate chips with a chip spreader is done two or more times. In the Yukon Territory, BST is the name for high-float surface treatments.

Double-Shot Seal Coat: Similar to the chip seal but in a double application. It is durable, provides some leveling, and is available in a number of textures.

Triple Seal: Uses three applications of binder and three sizes of chips using CRS-2 or RS-2. It provides up to a 0.75-inch thick, flexible pavement. It provides a smooth, sealed, and tough-wearing surface.

Natural (Native) Asphalt: Naturally occurring asphalt derived from petroleum by evaporation of volatile fractions, leaving the asphalt fractions. The most important native asphalt is found in the Trinidad and Bermudas Lake deposits. Asphalt from these sources is often called Lake Asphalt.

Nominal Maximum Size of a Gradation: In geological terms, one sieve size smaller than the maximum size or the first sieve with any aggregate retained on it. In Superpave mix design technology, the nominal maximum size is the first sieve smaller than the maximum size, which retains at least 10% of the material.

Nuclear Gauges/Nuclear Density: Nuclear gauges are monitor compaction levels of mixes. The nuclear density gauge senses the reflection of gamma rays sent into the pavement; the greater the density, the more rays are reflected. The gauge must be calibrated for each paving mix.

Oil Content: See **Asphalt Content**.

Open-Graded Asphalt Mix (Friction Course): Open-graded hot-mix asphalt concrete creates friction surfaces to reduce hydroplaning, placed as overlays on new or existing pavements. Open-graded asphalt concrete contains a large proportion of coarse aggregate and a small proportion of fine aggregate. This leaves voids (openings) in the mix, which allow water to drain. This, combined with the coarse surface texture, provides a skid-resistant surface. The coarse material provides the structural strength of the pavement. The P_{200} size materials, combined with the asphalt cement, coat the coarse aggregate and cement it together. Open-graded asphalt concrete typically contains 20% or more air voids.

Optimum Asphalt Content: A term used in the Marshall design method. It is the design asphalt content at which the mix has a certain combination of stability, air voids, and density.

Overlay: A way to rehabilitate distressed asphalt concrete pavement. Overlays may be used to increase the design life before distress shows. They are best applied before the existing pavement has become too rough, cracked, and rutted. An application of emulsified asphalt tack coat is applied on the existing pavement prior to the overlay. The thickness requirement for the overlay is a function of the structural condition of the existing pavement and the predicted future traffic loading.

Patching: Mending or repairing a roadway surface, usually with asphalt and aggregates.

Pavement Design Methods:

- California Bearing Ratio (aviation) (FAA)
- Excess Fines Method (highway) (see Guide for Pavement Design, PCM 1180)
- Mechanistic Method (highway) (PCM 1180)
- AASHTO Pavement Design Methods (highway)

Pavement Design Period ("n"): The number of years that a pavement is expected to carry a specific traffic volume and retain minimum serviceability without rehabilitation. This is optimized by the Pavement Management System.

Pavement Performance: The trend of serviceability in relation to load applications.

Pavement Price Adjustment: See **Quality Level Analysis**.

Pavement Rehabilitation: Work to extend the service life of an existing facility. This includes placement of additional surfacing material or other work necessary to return an existing roadway, including shoulders, to structural or functional adequacy. This could include the removal and replacement of the pavement structure.

Pavement Structure: The combination of select material, subbase, base, and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed (42 inches below the asphalt concrete layer).

Pavement Structure Combination or Composite Type: When the asphalt pavement is on old Portland cement concrete pavement, a Portland cement concrete base, or other rigid-type base, or is on a granular base, the pavement structure is called a combination or composite-type pavement structure.

Penetration: The consistency of a bituminous material expressed as the distance in tenths of a millimeter (0.1 mm) that a standard needle vertically penetrates a sample of the material under specified loading, time, and temperature. It can also refer to the depth the prime coat penetrates the base.

Percent Trucks (PTT): The percentage of annual average daily traffic (AADT) that is heavy truck traffic.

Predicted Deflection (D_p): The predicted maximum probable deflection of a proposed pavement structure due to an 18,000-pound, single-axle load.

Performance-Graded Asphalt: A product of the SHRP research program, sometimes called Superpave or PG graded binder (asphalt). A new asphalt grading system based on temperature extremes that the design pavement is expected to withstand. The laboratory grading system subjects samples of the binder to various tests at the extremes. Performance-graded asphalt receives a PG grade. For example, a PG58-28 is a binder that is supposed to withstand temperatures from 135° F to –20° F. The high temperature is the maximum ambient temperature the mix is expected to withstand for any seven-day period during the design life. The low temperature is the one-day expected low pavement temperature during the design life of the pavement.

Performance Period: The time that an initially constructed or rehabilitated pavement structure will last before reaching its terminal serviceability; this is also referred to as the design period.

Performance-Related Specifications: Specifications that describe the desired levels of key materials and construction quality characteristics that correlate with fundamental engineering properties predicting performance. These characteristics—for example, air voids in asphaltic pavements and strength of concrete cores—are amenable to acceptance testing at the time of construction. True performance-related specifications not only describe the desired levels of these quality characteristics, but also employ the quantified relationships containing the characteristics to predict subsequent pavement performance. They provide the basis for rational acceptance and/or price adjustment decisions.—*TRB Circular #457. Glossary of Highway Quality Assurance Terms.*

Permafrost: Permanently frozen subsoil.

PG Grades: See **Performance-Graded Asphalt**.

Pickup Machines: Some contractors use belly dump trucks, which dump hot mix in windrows on the grade. Then a pickup machine, also called a windrow elevator, deposits the mix into the paver.

Pit-Run: Using aggregates from selected deposits as they exist naturally without further treatment such as screening.

Plant Mix: See **Asphalt Concrete**.

Plant Screens: In a hot or batch plant, the screens located between the dryer and hot bins that separate the heated aggregates into the proper hot bin sizes. Plant screens are also used with rock crushers and washing plants.

Pneumatic-Tired Roller: Self-propelled pneumatic rubber-tired rollers have two to eight wheels in front and four to eight wheels in the rear. The wheels oscillate (axles move up and down), and some may wobble. Self-propelled pneumatic-tired rollers vary in weight. Ballast can be added to the machines to increase the weight. Some machines have the ability to change tire inflation while the roller is operating.

Poise: A centimeter-gram-second unit of absolute viscosity. It is equal to the viscosity of a fluid in which a stress of one dyne per square centimeter is required to maintain a difference of velocity of 1 centimeter per second between two parallel planes in the fluid that lie in the direction of flow and are separated by 1 centimeter.

Prepared Roadbed: In-place roadbed soils compacted or stabilized according to applicable specifications.

Present Serviceability Index (PSI, p): A number that estimates the serviceability rating from measurements of certain physical features of the pavement.

Prime Coat (Highway and Aviation): A bituminous application used to prepare an untreated base for an asphalt surface. The prime penetrates into and seals the base and plugs the voids. It hardens the top, keeps the base from raveling, and helps bind the base to the overlying asphalt course. Highway Standard Specification 403-2.1 allows MC-30 liquid asphalt or CSS-1 emulsified asphalt as a prime coat. Aviation Standard Specification 600.2 allows MC-30 or CMS-2S emulsified asphalt. The contract special provisions may allow other materials.

Project Design Life (N): The total number of years a pavement will be in service before it will be reconstructed. This includes the years of life extended by asphalt overlays considered in the original design.

Pumping: The ejection of foundation material, wet or dry, through joints or cracks, or along edges of rigid slabs resulting from vertical movements of the slab under traffic.

Quality Level Analysis: This is also known as “pavement price adjustment,” “QC/QA,” “incentive/disincentive,” and “penalty/bonus.” The procedure provides a basis for deciding whether to accept, reduce payment for, or reject the paving material depending on its conformance with the specifications and its variability. A statistically random sampling plan is used for asphalt acceptance testing whenever the contract includes a price adjustment. Airport projects now always use pavement price adjustments.

Quality Control (Process Control) Tests: Tests done by the contractor to ensure the quality of the materials prior to use. The tests allow the contractor to correct deviations from specifications before placing the material.

Rapid-Setting Emulsions: The rapid-setting grades react quickly with aggregate and revert from the emulsion state to asphalt. The RS grades produce a relatively heavy film. They are used primarily for spray applications, such as aggregate (chip) seals, sand seals, surface treatments, and asphalt penetration macadam. The RS-2 and CRS-2 grades have high viscosities to prevent runoff.

Raveling: The loss or dislodgment of surface aggregate particles from the edges inward or the surface downward. It is caused by lack of compaction, construction of a thin lift during cold weather, dirty or disintegrating aggregate, too little asphalt in the mix, or overheating of the asphalt mix. Studded tires can also contribute to raveling.

Reclaimed Asphalt Pavement (RAP): The removed or processed materials containing crushed asphalt pavement. In reuse, the RAP can be used for hot or cold recycling, mixed with base course, or used as a pure RAP base.

Resilient Modulus (M_R): A measure of the repeated-load modulus, sometimes called "dynamic" modulus of elasticity of roadbed soil or other pavement material. Stresses and strains are generated on test equipment using repetitive loading conditions. M_R should not be confused with another measure of the dynamic modulus known as the complex modulus (E*). E* is not presently used in mechanistic design methods used by DOT&PF.

Rice Specific Gravity: Same as **Maximum Specific Gravity**.

Rigid Pavement: A pavement structure that distributes loads to the subgrade, having as one course a Portland cement concrete slab of relatively high bending resistance.

Roadbed: The graded portion of a highway within top and side slopes, prepared as a foundation for the pavement structure and shoulders. It extends to such a depth as to affect the support of the pavement structure.

Roadbed Material: Material used in construction of the roadbed.

Road Mix: A method of combining aggregates and asphalt by use of a grader.

Roadway Structure: A combination of select subbase, base course, and surface course materials placed on a subgrade that supports the traffic load and distributes it to the elements of the roadbed.

Rock Asphalt Pavements: Pavements made of rock asphalt, natural or processed, and treated with asphalt or flux if required for construction.

Ross Count: A visual determination of how well the asphalt is coating the aggregate. The Ross count is performed on asphalt concrete at the asphalt plant and is an acceptance test for batch plants and an informational test for dryer-drum plants.

Ruts: Ruts are depressions that develop in the wheel tracks of a pavement. Ruts may result from consolidation or lateral movement under traffic in one or more of the underlying courses or by displacement in the asphalt surface layer. They may also develop under traffic in new asphalt pavements that had too little compaction during construction or from plastic movement in a mix that does not have enough stability to support the traffic. Studded tire wear can also cause ruts.

Sand Asphalt: A mixture of sand and asphalt cement or cutback or emulsified asphalt. It may be prepared with or without special control of aggregate grading and may contain mineral filler. Employ either mixed-in-place or plant mix construction. Sand asphalt is used in construction of base and surface courses.

Sand Equivalent Test: The sand equivalent test indicates the relative proportion of detrimental fine dust or clay-like materials in mineral aggregates used for asphalt paving mixtures and mineral aggregates or soil used for base courses.

Sand Seal: A seal coat of spray-applied CRS-1 or RS-1 with a sand cover. It reduces raveling, restores uniform cover, and enriches dry, weathered pavement.

Scarify: To mechanically loosen the surface.

Screed Unit: The screed unit is attached to the tractor unit on a lay-down machine by long screed pull arms on each side of the machine. The screed pull arms provide the screed with a floating action as it travels along the road, automatically compensating for surface irregularities within the “wheel base” of the paver. As the tractor unit pulls the screed into the material, the screed seeks the level where the path of its flat bottom surface is parallel to the direction of the pull, planing up or down to the required paving thickness as the screed angle of attack is adjusted.

Seal Coat: See **Single Surface Treatment**.

Segregation: The separation of the coarse and fine aggregate particles in an asphalt mix. The segregation of the mix can occur at several locations during the mix production, hauling, and placing operation. Some mixes are more prone to segregate than others. Asphalt mixes that have large top-size coarse aggregates (1 inch or greater), low asphalt cement contents, and are gap graded will segregate more readily when handled than a dense-graded mix of optimum asphalt content and a smaller top-size coarse aggregate. Segregation lessens pavement durability by increasing the air void content of the mix, which increases the potential for moisture damage. Segregated locations are susceptible to raveling and, if bad enough, to disintegration under traffic.

Selected Material: A suitable native material obtained from a source such as a particular roadway cut or borrow area, having specific characteristics.

Serviceability: The ability, at time of observation of a pavement, to serve traffic that uses the facility.

Settlement Test: Detects the tendency of asphalt globules to settle during storage of emulsified asphalt. The procedures and equipment are prescribed in AASHTO Method of Test T59 and ASTM Method of Test D244.

Sheet Asphalt: A hot mixture of asphalt cement with clean, angular-graded sand and mineral filler. Its use is usually confined to surface course, and it is laid on an intermediate or leveling course.

Shoving: Displacement of a concrete asphalt layer in any direction. An unstable or tender mix can cause shoving. It can take place during the compaction operation or later, under traffic.

SHRP: The acronym for the Strategic Highway Research Program. It is a federally funded research program, begun in 1987 as a five-year operation with goals of improving methods of design, construction, and maintenance of asphalt concrete and Portland cement concrete pavements. SHRP research funds were partly used for the development of performance-based specifications to relate laboratory analysis with field performance. The program was completed in 1995, with only the portion on long-term pavement performance (LTPP) still ongoing.

Sieve: In laboratory work, an apparatus with square apertures that is used for separating sizes of material. Sieve sizes are given in two ways: large sizes (sieves with holes 1/4 inch or more) are named by the opening width, such as 1 inch, 3/8 inch. Smaller sieves are numbered, i.e. #4, #200. The number corresponds to the number of openings per linear inch of screen.

Sieve Analysis: A mechanical sieve shaker shakes a weighed quantity of aggregate over a set of sieves with various sizes of square openings. The sieve with the largest opening is on top and those with successively smaller openings are nested beneath. A pan below the bottom sieve collects the material as it passes through. The material retained on each sieve is weighed and expressed as a percentage of the weight of the original or total sample.

Sieve Test: The sieve test complements the settlement test and has a similar purpose. It determines the percentage of asphalt present in the form of relatively large globules. The procedure and equipment for the sieve test are found in AASHTO Method of Test T59 and ASTM Method of Test D244.

Single Axle Load: The total load transmitted by all wheels of a single axle extending the full width of the vehicle.

Single Surface Treatments: A single application of asphalt to any kind of road surface followed immediately by a single layer of aggregate of uniform size. The thickness of the treatment is about the same as the nominal maximum-size aggregate particles. A single surface treatment is a wearing and waterproofing course. The following is a list of SSTs:

> **Chip Seal:** A chip seal or "single-shot" asphalt surface treatment is the spraying of emulsified asphalt material (CRS-2 or RS-2) followed immediately by a thin stone cover. This is rolled as quickly as possible to create adherence between the asphalt and the aggregate cover. The chips (or stones) range from 3/4-inch aggregates to sand and are predominately one size. It produces an all-weather surface, renews weathered pavements, improves skid resistance and lane demarcation, and seals the pavement.
>
> **High-Float Asphalt Surface Treatment:** A single-shot asphalt surface treatment where one application of high-float emulsion is applied to the prepared surface followed by a single application of crushed gravel cover coat. The gradation of cover coat aggregate used in high-float emulsion surface treatments are typically similar to those used for crushed aggregate base course (D-1), except with 100% passing the 3/4-inch sieve rather than the 100% passing the 1-inch sieve as with D-1. The fine aggregates allowed in high-float operations may cause segregation of larger materials and blockage in the chip spreader if they are not very dry. Therefore, maintain strict moisture content control of cover coat materials. High-float asphalt surface treatments are more easily constructed in areas with dry climates, such as interior Alaska. In the Yukon, high-float asphalt surface treatments are called "BST."

Skid Resistance: The ability of an asphalt paving surface, particularly when wet, to offer resistance to slipping or skidding. The factors for obtaining high skid resistance are generally the same as those for obtaining high stability. Proper asphalt content and aggregate with a rough surface texture are the greatest contributors. The aggregate must not only have a rough surface texture, but also resist polishing. Aggregates containing nonpolishing minerals with different wear or abrasion characteristics provide continuous renewal of the pavement's texture, maintaining a skid-resistant surface.

Slow-Setting Emulsions: The slow-setting grades are designed for maximum mixing stability. They are used with high P_{200} content, dense-graded aggregates. The SS grades have long workability times to ensure good mixing with dense-graded aggregates. All slow-setting grades have low viscosities that can be further reduced by adding water. These grades, when diluted, can also be used for tack coats, fog seals, and dust palliatives. The SS type of emulsion depends entirely on evaporation of the water for coalescence of the asphalt particles. The SS emulsions are generally used for dense-graded aggregate-emulsion bases, soil asphalt stabilization, asphalt surface mixes, and slurry seals.

Slurry Seal: A slurry seal is a maintenance operation intended to fill minor depressions and provide an easily swept surface. It is made with fine crushed aggregate mixed with quick-set emulsified asphalt (RS grades). The liquid slurry is machine-applied with a sled-type box mounted on the back of a truck, containing a rubber-edged strike-off blade.

Snivey: A stainless steel nozzle attached to the spray bar on the back of a distributor that controls the shape and volume of asphalt being sprayed on the roadway.

Softening Point: The temperature at which asphalts reach an arbitrary degree of softening. The softening point is usually determined by the ring-and-ball test method.

Solubility: A measure of the purity of asphalt cement. It is that portion of the asphalt cement that is soluble in a specified solvent such as trichloroethylene. Inert matter, such as salts, free carbon, or nonorganic contaminants, is insoluble.

Specific Gravity: Specific gravity is the ratio of weight of any volume of material to the weight of an equal volume of water, both at a specified temperature. Thus, a specific gravity of 1.05 means that the material is 1.05 times as heavy as water at the indicated temperature. The specific gravity of asphalt is usually determined for two reasons: (1) to permit a calculation of voids of compacted asphalt paving mixes, or (2) to adjust quantities of aggregate components of a paving mix, where such components vary appreciably in specific gravity. The specific gravity is determined by the hydrometer method as prescribed in AASHTO Method of Test T227 and ASTM Method of Test D3142.

Stability: The ability of asphalt paving mixture to resist deformation from imposed loads. Stability depends on internal friction and cohesion.

Static Steel Wheel Roller: Static steel wheel rollers normally range in weight from 3 to 14 tons. The gross weight can be adjusted by adding ballast, but this adjustment cannot be made while the roller is operating and is not normally changed during the term of a paving project.

Stoke: A unit of kinematic viscosity, equal to the viscosity of a fluid in poises divided by the density of the fluid in grams per cubic centimeter.

Stone Mastic (Matrix) Asphalt Pavement (SMA): SMA is a product that is relatively new in America. It was developed by contractors in Western Europe who are subject to giving warranties for their work against rutting. It is often used to rehabilitate areas with premature rutting failure due to studded tire wear. SMA optimizes stone-on-stone contact in the mix. It is gap-graded, hot mix asphalt with a large proportion of coarse aggregates (amount passing 0.08 inch limited to approximately 20%) and a rich asphalt cement/filler mastic. The coarse aggregates form a strong structural matrix. Asphalt cement, fine aggregate, filler, and stabilization additive form a mastic that binds the structural matrix together. The coarse aggregates are highly fractured and roughly cubical stone. Relatively high asphalt contents (about 6.5% of the total mix) provide for a durable pavement. A stabilizing additive, usually 0.3% cellulose from ground newspapers, is included in SMA to prevent hot asphalt cement from draining down during hauls.

Stress Reduction Factor (SRF): The factor by which the stress of an applied load at the surface of a pavement is reduced at a given depth below the surface course.

Structural Number (SN): This is part of the AASHTO pavement design procedure that Alaska does not use.

Subbase (SB): The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course (or in the case of rigid pavements, the Portland cement concrete slab). If the subgrade soil is of adequate quality, it may serve as the subbase.

Subgrade: The top surface of a roadbed upon which the pavement structure and shoulders are constructed.

Subgrade, Improved: Subgrade, improved is a working platform achieved (1) by the incorporation of granular materials or stabilizers such as asphalt, lime, or Portland cement, prepared to support a structure or a pavement system, or (2) any course or courses of select or improved material placed on the subgrade soil below the pavement structure. Subgrade improvement does not affect the design thickness of the pavement structure.

Superpave Procedures: The term Superpave stands for Superior Performing Asphalt Pavements and is a product of the SHRP asphalt research. The Superpave system incorporates performance-based asphalt materials characterization with design environmental conditions to improve performance by controlling rutting, low temperature cracking, and fatigue cracking. The three major components of Superpave are the asphalt binder specification, the mix design and analysis system, and a computer software system.

The Superpave mix design process uses a gyration compactor to compact mixes. A gyratory compactor uses a rotating flat steel plate that is forced down upon the mix contained in a steel cylinder. The number of gyrations required for a mix design is determined from the expected equivalent single axle loads (ESALs) and the design seven-day maximum air temperature.

The Superpave mix design differs most significantly from the currently used Marshall mix design process in that it requires the designer to try various gradations in order to determine the one(s) that will meet the voids criteria at all three gyration levels.

Surface Course (SC): One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer of flexible pavements is sometimes called "wearing course."

Tack Coat: A tack coat is a thin application of asphalt material applied to a previously paved surface to ensure that an overlay will adhere to the existing surface. It is recommended to place a thin coat on any cold edges of new paving such as joints, gutter lines, and around manholes, etc. For application, a slightly damp (not wet) surface is preferable to a dry, dusty one.

Tandem Axle Load: The total load transmitted to the road by two consecutive axles extending across the full width of the vehicle.

Tar: A material resulting from the process of combusting coal, sugar, wood, or other organic material.

Test Categories: DOT&PF divides material tests into five categories:

> **Acceptance:** Project materials inspectors perform acceptance tests. They document whether a specific lot of a pay item (such as asphalt concrete) meets particular specifications for the item (such as gradation). DOT&PF accepts and pays for materials using acceptance tests.
>
> **Assurance:** The Regional lab usually performs assurance tests. These are used as checks on acceptance tests to ensure that procedures and test equipment are working correctly.
>
> **Information:** Information tests are made on samples taken during the production of materials prior to the point of acceptance. The gradation of aggregates, for example, is often checked as it is being crushed. Either project materials personnel or the regional laboratory may make information tests.
>
> **Quality:** State or Regional Materials Laboratory generally performs quality tests. They determine whether raw material has acceptable qualities. Gravel, for example, is tested for hardness and durability.
>
> **Quality Control:** The contractor performs these tests to ensure the materials meet the contract requirements and makes adjustments to the construction process if the materials begin going out of specifications.

Thin Film Oven Test: The thin film oven (TFO) test actually is not a test. It is a procedure intended to subject a sample of asphalt to hardening conditions approximating those in normal hot-mix plant operations. Viscosity or penetration tests made on the sample before and after the TFO test are considered a measure of the anticipated hardening.

Traffic Equivalence Factor (e): A numerical factor that expresses the relationship of a given axle load to another axle load in terms of their effect on the serviceability of a pavement structure.

Transverse Joint: Transverse joints are placed wherever paving is ended and begun again at a later time.

Travel Plant: Travel plants are self-propelled pug mill plants that mix the aggregates with asphalt, applied at a controlled rate, as they move along the road.

Traveled Way: The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Treated Base Courses: Asphalt treated bases may be divided into two categories: (1) hot asphalt treated, and (2) emulsified asphalt treated. These two categories may be further subdivided into dense graded and open graded (permeable) bases. Dense graded bases are the materials typically specified for highway construction. Open graded bases require special considerations. One purpose of any treated base is to provide improved structural support for paving. When using asphalt treated base course, you may substitute a portion of its thickness for the thickness of asphalt concrete pavement required by structural design.

Dense Graded Asphalt Base: Uses hot asphalt cement as a binder and is designed to be constructed much the same as asphalt concrete pavement. These are usually D-1 gradation with asphalt binder.

Open Graded Asphalt Base: Made from crushed porous aggregates treated with hot asphalt binder. This material's use is limited in particular applications. It is asphalt treated in order to provide stability during construction. Production and lay-down of open graded asphalt treated base is similar to asphalt concrete pavement except compaction requirements, in terms of number of roller passes required, are determined by a test strip.

Triple Seal: See **Multiple Surface Treatments**.

Truck Factor: The truck factor is the number of equivalent 18,000-pound single-axle load applications contributed by one passage of a single vehicle. Also see also **Equivalent Single Axle Loads (ESAL)**.

Unified Soil Classification System (USCS): USCS is a classification used in airport construction projects. The unified soil classification system is based on textural characteristics for those soils with such a small amount of P_{200} that the P_{200} does not affect soil behavior. It is based primarily on the characteristics that determine how a soil will behave when used as a construction material. The USCS places soils into three divisions:

- Coarse-grained
- Fine-grained
- Highly organic

The USCS is designed so that visual inspection and simple field tests can classify these primary group soils. Tests used in the field identification are dilatancy or shake test, dry strength, and toughness or consistency near the plastic limit. Unified soil classification symbols for components, gradation, and liquid limit are:

Component	Symbol
Boulders	None
Cobbles	None
Gravel	G
Sand	S
Silt	M
Clay	C
Organic	O
Peat	Pt
Well graded	W
Poorly graded	P
High Liquid Limit	H
Low Liquid Limit	L

Unit Weight: The ratio of weight to the volume of a substance. For example, the unit weight of water is 62.4 lbs/ft^3 at 40° F.

Vibratory (Vibrating) Roller: Vibrating rollers are made with one or two smooth-surfaced steel wheels. They vary in static weight. Vibratory rollers are used for compacting any type of asphalt mixture but should not be used in the vibratory mode when the mat thickness is 1.5 inch or less.

Vibratory Screed: The vibratory screed is highly effective in initially increasing the density of the asphalt mat placed by the paver. Its operation is similar to the tamping screed but the compaction effort generated by the screed is derived from electric vibrators, rotating shafts with eccentric weights, or hydraulic motors.

Viscosity: A measure of the resistance to flow. It is one method of measuring the consistency of asphalt.

Absolute Viscosity: A method of measuring viscosity using the poise as the basic measurement unit. This method uses a partial vacuum to induce flow in the viscometer.

Kinematic Viscosity: A method of measuring viscosity using the stoke as the basic measurement unit.

Viscosity Grading: A classification system of asphalt cements based on viscosity ranges at 140° F. A minimum viscosity at 275° F is also usually specified. The purpose is to prescribe limiting values of consistency at these two temperatures; 140° F approximates the maximum temperature of asphalt pavement surface in service in the U.S., and 275° F approximates the mixing and lay-down temperatures for hot asphalt pavements. There are five grades of asphalt cement based on the viscosity of the original asphalt at 140° F.

Voids/Voids in the Mineral Aggregate (VMA): Nearly all the volume of asphalt pavement is filled by aggregate particles. Asphalt or air fills the remaining spaces (voids).

Void Volume: Total empty space in a compacted mix.

Wearing Course: Where thick pavements are required, the asphalt concrete pavement is sometimes placed as two layers, each differing in composition but sharing approximately the same fatigue properties (see also **Binder Course**). The wearing course is the top portion of asphalt concrete pavement, “tuned” to provide maximum resistance to abrasion wear (addresses tire-stud rutting), minimum surface roughness (addresses ride quality), minimum plastic deformation (addresses displacement rutting), and minimum permeability (addresses premature weathering and aging of the asphalt concrete).

Wet Mixing Time: The interval between the beginning of application of asphalt material and the opening of the mixer gate.

Workability: The ease with which paving mixtures may be placed and compacted.

Yield: Refers to the quantity of asphalt concrete pavement that is laid in the paving operation. An estimating factor is calculated, based on the expected unit weight of the compacted mixture, the width of the screed, and the planned thickness of the mix. This estimating factor is in terms of weight per lineal measure of paving. Using this and net weights of mix from truck scale tickets, asphalt inspectors can see that the paving operation is proceeding properly toward the planned quantity of asphalt concrete mix and avoid overruns. Adjustments in the pavement thickness may be made, based on yield calculations, in order to match the planned tonnage of mix.

Zeta Potential: The measurement of zeta potential is a relatively new test for evaluating asphalt emulsions and is not an AASHTO or ASTM test. It measures stability in a colloid system with a laboratory device known as a zeta meter. The zeta meter measures the speed of move placed in an electrical field. This test has particular value in evaluating cationic emulsions. The level of zeta potential is a general indication of the setting characteristics of the emulsion.

11. References

1. Casagrande, A., *Discussion of Frost Heaving*, Proceedings, Highway Research Board, 1931.
2. McHattie, R. L., Connor, B. G., and Esch, D. C., *Pavement Structure Evaluation of Alaskan Highways*, FHWA-AK-RD-80-1, Alaska Department of Transportation and Public Facilities, Fairbanks, Alaska, 1980.
3. Esch, D. C., McHattie, R. L., and Connor, B. G., *Frost-Susceptibility Ratings and Pavement Performance*, Transportation Research Record 809, Transportation Research Board, 1981.
4. McHattie, R. L., *Asphalt Concrete Properties and Performance in Alaska*, FHWA-AK-RD-82-2, Alaska Department of Transportation and Public Facilities, Fairbanks, Alaska, 1982.
5. Esch, D. C., and McHattie, R. L., *Prediction of Roadway Strength from Soil Properties*, Transportation Research Record 918, Transportation Research Board, 1983.
6. *Guide for Flexible Pavement Design and Rehabilitation* (the “gold manual”), Alaska Department of Transportation and Public Facilities, Anchorage, Alaska, 1982.
7. *Asphalt Overlays and Pavement Rehabilitation*, Manual Series MS-17, The Asphalt Institute (TAI), 1977.
8. Hicks, R. G., *Use of Layered Theory in the Design and Evaluation of Pavement Systems*, FHWA-RD-83-8, Alaska Department of Transportation and Public Facilities, Fairbanks, Alaska, 1983.
9. *Alaska Overlay Design Program for Flexible Highway Pavements* (a guide developed by the Alaska overlay design committee) Alaska Department of Transportation and Public Facilities, Fairbanks, Alaska*, 1990.*
10. Yoder, E. J., and Witczak, M. W., *Principles of Pavement Design*, 2nd Ed., John Wiley and Sons, New York, 1975.
11. Ullidtz, P., *Pavement Analysis*, Developments in Civil Engineering, Vol. 19, Elsevier, Amsterdam, The Netherlands, 1987.
12. Ullidtz, P., *Modelling Flexible Pavement Response and Performance*, Polyteknisk Forlag, Narayana Press, Gylling, Denmark, 1998.
13. Huang, Yang H., *Pavement Analysis and Design*, 2nd Ed., Pearson Prentice-Hall, New Jersey, 2004.
14. Witczak, M., and Fonseca, O., *Revised Predictive Model for Dynamic (Complex) Modulus of Asphalt Mixtures*, Transportation Research Record 1540, 1996.
15. *Concrete Pavement Design Manual*, FHWA-HI-92-015.
16. *Pavement Subsurface Design Manual,* NHI Course No. 13126.
17. *Pavement Subsurface Drainage Systems,* Transportation Research Board, NCHRP Report No. 239, 1997.