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 and policies for this design method.

There are many systems for mechanistically designing a flexible pavement structure. Although some Alaskan designers 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

DOT&PF adopted AKFPD which incorporated mechanistic design in 2004. 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. The computational engine, ELSYM5, had been used by DOT&PF since the 1980's. Unfortunately, the adoption of Windows 7 and above did not allow the continued use of ELSYM5.

The new software, AKFPD v 2.0, replaced ELSYM5 with WESLEA as the computational engine. The two engines yield the same results so the designer should see no differences in the computed stresses and strains nor a difference in predicted pavement life. However, the software has been rewritten to improve workflow and add life cycle costing. The principles employed have not changed.

If the designer requires a more in depth understanding of mechanistic design, textbooks by Yoder and Witczak,(15) Ullidtz,(16,17) and Huang(18) 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 WESLEA 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 WESLEA) into simple, empirical equations and thereby estimate the number of design load repetitions (N_f) that will cause the structure to fail (requires application of empirically derived transfer functions).

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

3. Pavement failure is the 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.

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

4.3.1 Calculating Stresses and Strains

The first computational step in Alaska's mechanistic design process is estimating stresses and strains, i.e., structural response, at selected locations within the pavement structural layers using layered system analysis.

In his 1983 publication,(19) 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 Alaska's mechanistic design procedures. After 37 years, WESLEA replaces ELSYM5 as the computational routine used in AKFPD v 2.0 to perform this same important computational function. Since both use the same underlying principles, they yield the same results.

In simplest terms, the designer supplies WESLEA with input values of thickness and stiffness (modulus and Poisson's ratio) for each layer. Input also includes vehicle load configuration and magnitude. WESLEA 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.

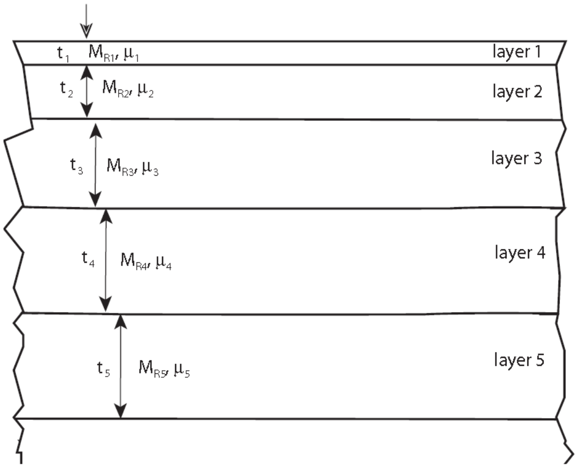


Figure 4-1 Typical Pavement Structure Showing Elastic Layers

The mathematical and programming details of how WESLEA 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 WESLEA as well as the principles and assumptions underlying WESLEA's stress and strain calculations.

Hicks covered this subject quite well in Chapter 2 of his 1983 publication.(19) 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 understand 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 WESLEA.

WESLEA 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 WESLEA, 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 and WESLEA. 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 "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.
- All loads are identical, uniform, and circular.
- All loads are placed at the surface of the elastic system and oriented normal to that surface.
- 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 WESLEA (see discussion below).
- The pavement structure modeled by WESLEA is an axisymmetric solid, which means that both load and pavement geometrics are symmetrical about a common centerline. Because of this axisymmetry, WESLEA cannot be used to analyze the effects of loads applied near the pavement edge, near cracks, or other edge-type boundaries.

WESLEA input requirements:

- One or more wheel loads must be specified at designer-selected locations at the surface of the pavement structure. The solution uses the principles of superposition to solve for stresses and strains due to application of multiple wheel loads. This means that WESLEA first calculates the stresses and strains caused by each load independently. Then, by applying the principles of 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 is defined as having semi-infinite thickness (a "bottomless" layer). As a result, the thickness must be left blank or a value of "0" entered.

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

Resilient modulus M_R (sometimes called the repeated-load or 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), or deviatoric stress, 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. This approximates traffic wheel loadings.

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 not be recovered. This nonrecoverable phenomenon is due to plastic deformation or some other form of permanent displacement.

Poisson's ratio (μ)

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

Where:

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

ε_{axial} = axial strain (parallel to the axial load direction) caused by application of the axial/vertical load

Chapter 5 provides specific information about appropriate modulus (M_R) and Poisson's ratio values that the engineer can use for designing pavements. It is important that the M_R value used as design input truly represents the modulus of the material after it has been placed and compacted.

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

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

The two output values of interest are:

1. Maximum horizontal tensile strain, ε_t, at the bottom of bound layers
2. Maximum vertical compressive stress, σ_v, at the top of each unbound layer

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 WESLEA analysis locations. As has been stated above, 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 tire configuration of the design load (wheel locations) determines where maximum stresses or strains will be found. In the simplest case of a single tire design load, the maximum value will be found directly under the center of the load. For design load configurations having two or more tires, 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 tire 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 multi-wheel 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 multi-wheel configurations can minimize the number of search locations.

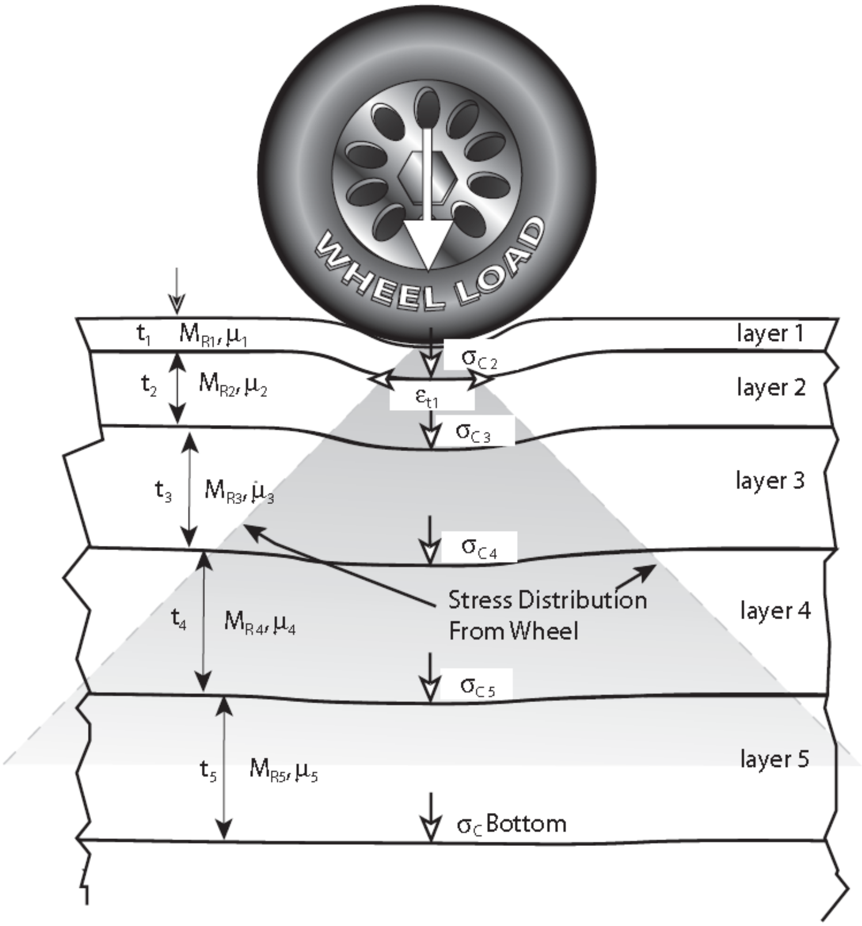


Figure 4-2 Analysis Data and Critical Load Analysis Points Used by WESLEA

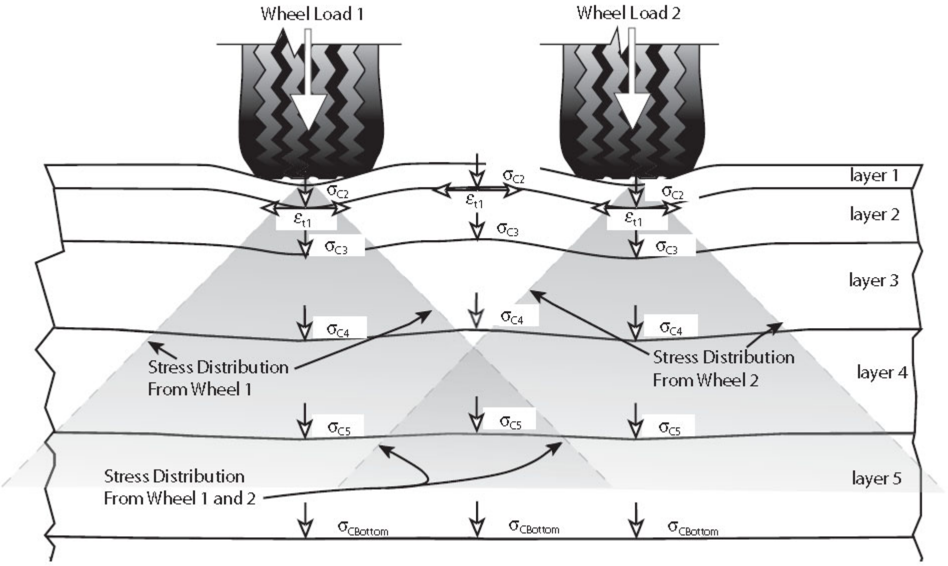


Figure 4-3 Elastic Pavement Layers Illustrating Superposition

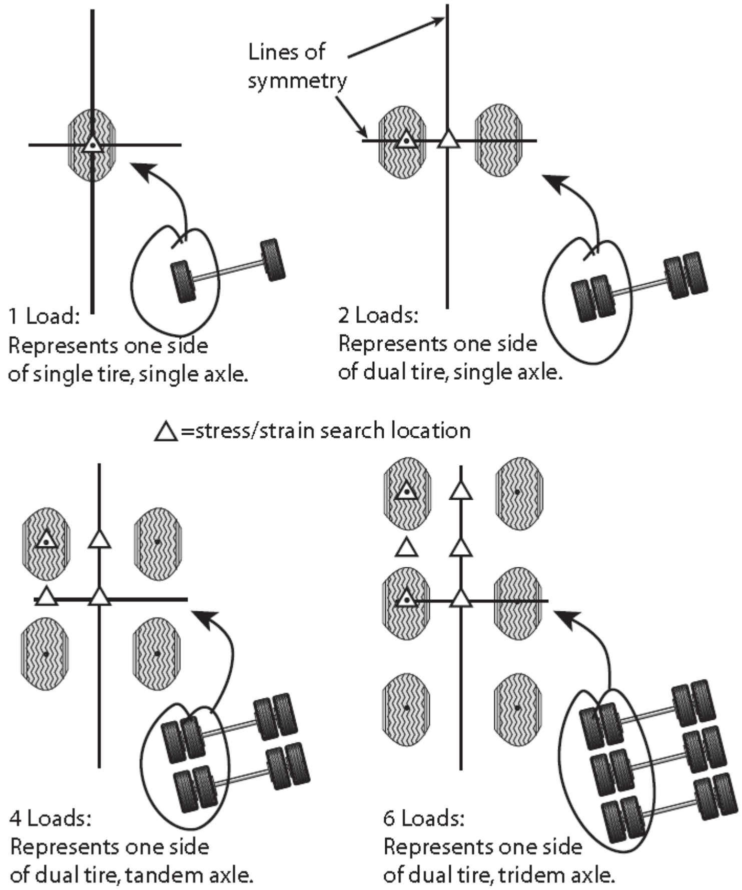


Figure 4-4 Plan View of Design Loads with Structural Response Search Locations

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 load repetitions that will cause the structure to fail. These equations are variously known as "damage equations" or "transfer functions." DOT&PF has selected two equations for application in the 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 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 Fatigue 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 response parameter used in the TAI equation for each layer is the maximum horizontal tensile strain (ε_h) at the bottom of that layer.

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

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

(for fatigue cracking over 45% of the wheel path area, equivalent to about 20% 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 load repetitions to fatigue failure)

ε_h = maximum horizontal tensile strain at the bottom of the bound layer, in /in

$|E^*|$ = modulus of the asphalt concrete material, psi

V_v = percent air voids volume in total mix

V_b = percent binder volume in total mix

$$V_b = \frac{(\gamma_{mix}) \times (\%AC)}{G_b \times \gamma_w}$$

where:

γ_{mix} = mix density, pcf

% AC = binder content, weight %

G_b = binder specific gravity

γ_W = water density, pcf (62.4 pcf)

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 Per Ullidtz equation—for functional failure(17) (applicable to unbound or lightly bound layers) is:

$$N_f = \frac{1}{R} \times 3.069x10^{10} \times \left(\frac{E}{E_0}\right)^{3.26b} \times \sigma_v{}^{-3.26} \text{ (for about 1-inch rut depth)}$$

where:

N_f = number of load repetitions to functional failure

R = regional factor = 2.75 for Alaska conditions

E = 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 WESLEA subroutine of the AKFPD program.

N_f values calculated using the above equations define the maximum number of 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 actual load repetitions (N_a) less than N_f ($N_a < N_f$) will consume a fraction of that life. Similarly, load repetitions $\geq N_f$ will fail 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 using 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 is the actual number of design vehicle loads applied during the i^{th}_t set of conditions

f N_f is 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 ith set of loads and materials conditions. The Miner's law concept can be explained 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.

4.3.4 A Simple Application of Miner's Law

In this example, first analyze the asphalt concrete pavement layer of a pavement structure using WESLEA 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. WESLEA 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 WESLEA 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.

Table 4-1 Miner's Law Example

Season	N_a	N_f	Na/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 $\sum Na/N_f$:	0.83

Miner's law states that the failure will not occur unless:

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

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 110 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)

Table 4-2 Example 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 Table 4-2.

e. Asphalt concrete mix properties:

i. density of asphalt concrete = 150 pcf;

ii. % asphalt cement by total weight of mix = 5.5

iii. % air voids = 4

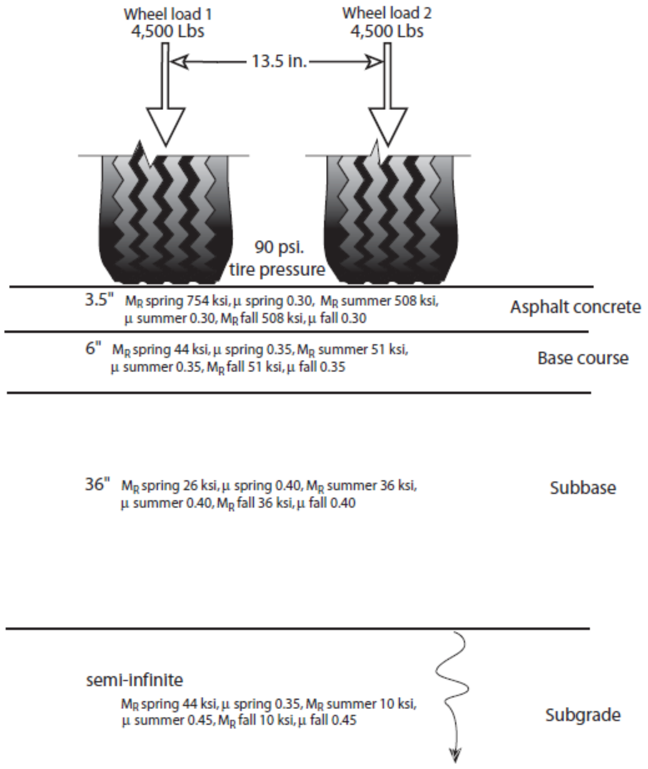


Figure 4-6 Pavement Structure Example Problem

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.

Table 4-3 Calculated Stresses and Strains

	Tensile Strain (micro-strain) at Critical Location	Compressive Stress (psi) at Critical Locations		
Season	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 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).

Table 4-4 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.

Table 4-5 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
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.

Table 4-6 Using Miner's Law to Sum Damage

Season	Sum Damage: $(N_a/N_f)_{spring} + (N_a/N_f)_{summer} + (N_a/N_f)_{fall}$ Based on Analyses at Critical Locations			
	Asphalt Concrete	Base Course	Subbase	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	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. $\sum_{i=1}^{i=total} \left({}^{N_a}\!/_{N_f} \right)_i \geq 1$.

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.

4.4.1 Overlaying an Existing Asphalt Concrete Layer

Pavement overlay involves placing an additional (new) asphalt concrete 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 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 minimum required overlay thickness.

The process of determining an overlay thickness for an existing paved structure uses essentially the same series of 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 asphalt concrete layer required to satisfy the structural requirements of future traffic. The minimum overlay thickness is 1.5 inch.

Refer to Chapter 2's GP-11 and Section 2.2.3 for overlay design guidelines.

4.5 Mechanistic Design Using the AKFPD Computer Program

4.5.1 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 repetitions 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 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 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 applies Miner's law to each layer to determine **total amount** of layer life expended by adding together the seasonal fractions. According to Miner's law, the layer (and pavement) has failed if this "total damage summation" is ≥ 1.
7. If the total damage summation is ≥ 1, the pavement structure is not adequate 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 asphalt or aggregate materials, thicker asphalt concrete layer, etc., until the total damage summation is less than 1.

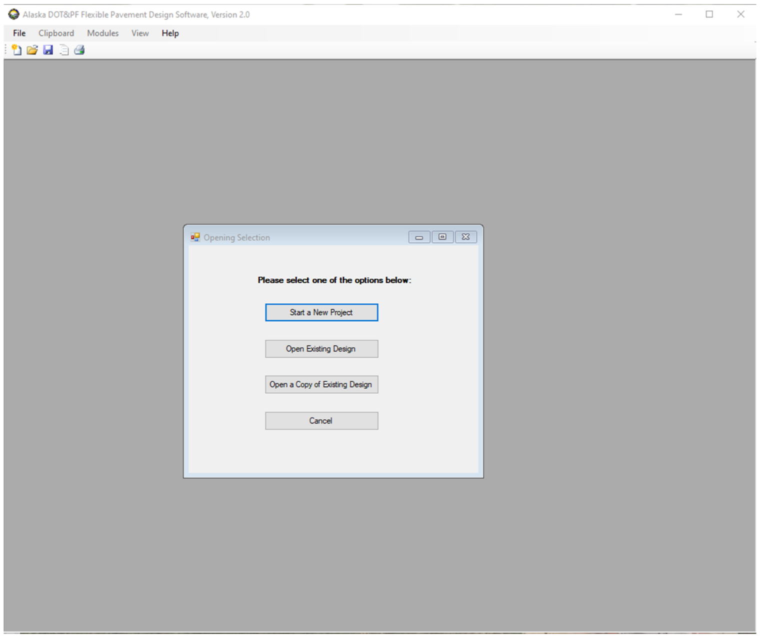
4.5.2 Example 1—Getting Started and Performing a Simple Design

The following steps lead you through a simple example of AKFPD-2 mechanistic pavement design analysis and interpretation of the results.

This design example does not use a previously saved input data file. In other examples, the use and modification of previously saved input data files are explored.

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.

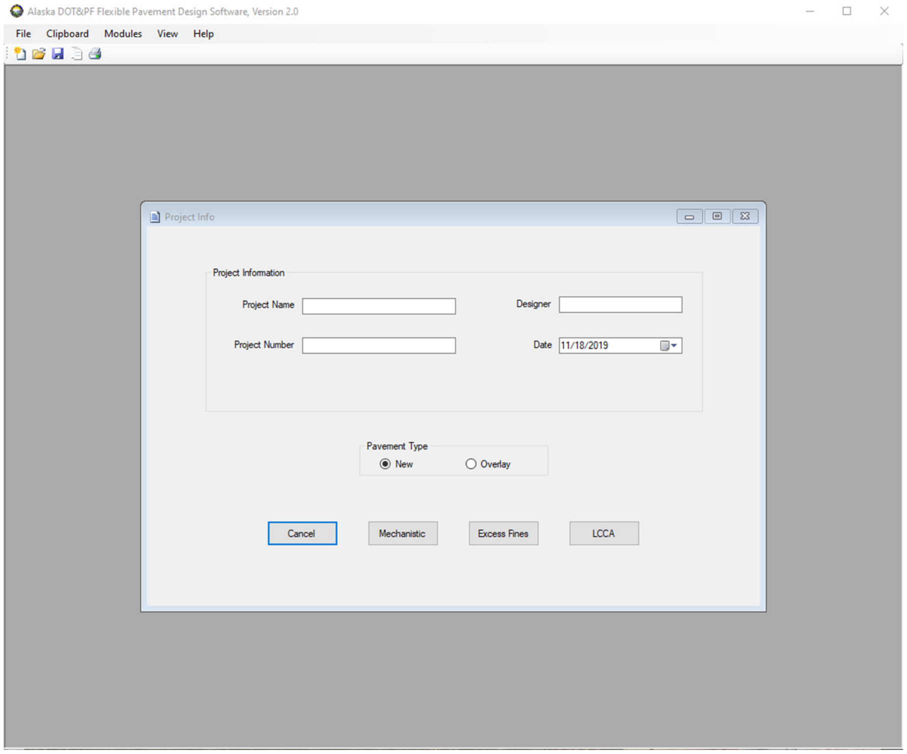
Step 1. Start the AKFPD software using the Start Menu. This varies slightly for each operating system. The AKFPD title screen will briefly appear and the landing page will then appear. (Screen Clip 4-1)



Please select one of the options below:

Screen Clip 4-1

Step 2. Start a new project for this example click on ***Start a New Project***. The Project Info page will appear. (Screen Clip 4-2)



Project Information

Project Name

Project Number

Designer

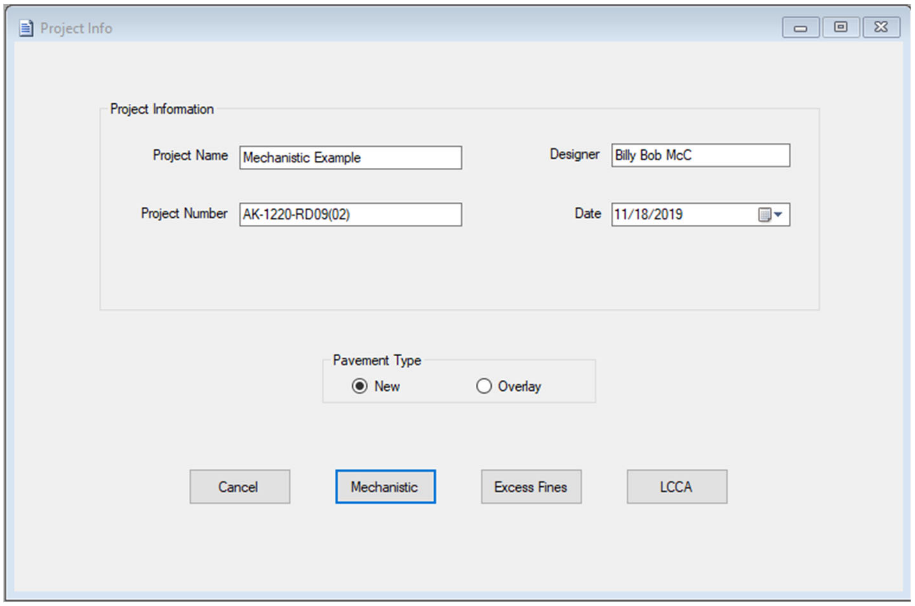
Date 11/18/2019

Pavement Type

● New ○ Overlay

Screen Clip 4-2

Step 3. Fill in the appropriate data and click ***New*** which will tell the software that this pavement structure is new. Then click ***Mechanistic*** to save the project information. (Screen Clip 4-3)



Project Information

Project Name Mechanistic Example

Project Number AK-1220-RD09(02)

Designer Billy Bob McC

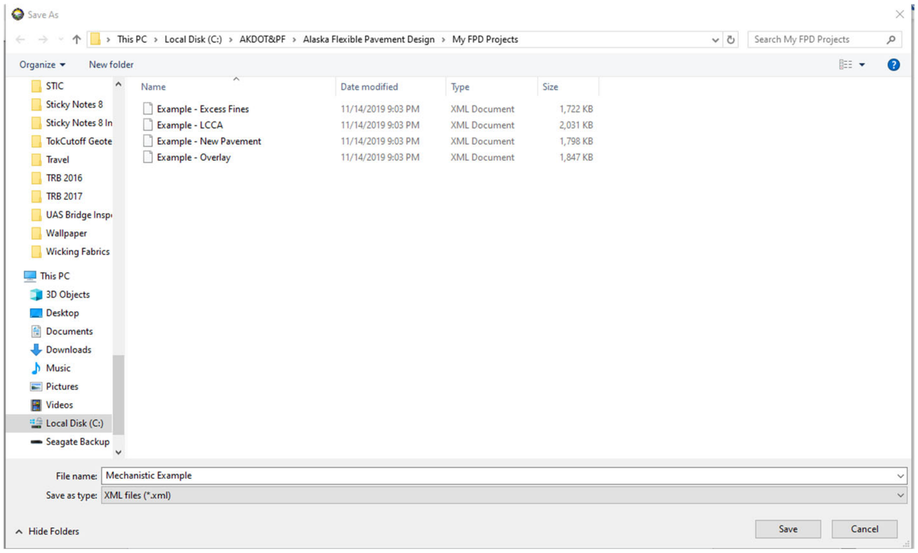
Date 11/18/2019

Pavement Type

● New ○ Overlay

Screen Clip 4-3

Step 4. Enter a filename tied to the project. In this case "Mechanistic Example". Click ***Save.*** (Screen Clip 4-4)



Name	Date modified	Type	Size
Example - Excess Fines	11/14/2019 9:03 PM	XML Document	1,722 KB
Example - LCCA	11/14/2019 9:03 PM	XML Document	2,031 KB
Example - New Pavement	11/14/2019 9:03 PM	XML Document	1,798 KB
Example - Overlay	11/14/2019 9:03 PM	XML Document	1,847 KB

File name: Mechanistic Example
Save as type: XML files (*.xml)

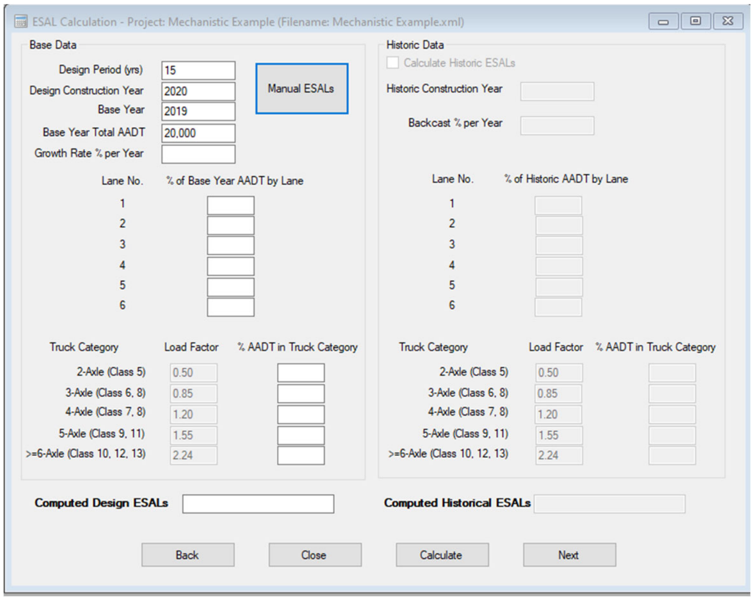
Screen Clip 4-4

Step 5. You have two choices based on the information supplied by the Regional Traffic/Planning Section:

a. Manually enter ESALs as provided by the Traffic Section. The design period, design construction year, base year, and base year total AADT must still be entered (Screen Clip 4-5). After entering required data click ***Manual ESALS***. Note the ***Manual ESALs*** button changes to ***Computed ESALs*** and the ***Computed Design ESALs*** box at the bottom left of the data input form changes to ***Manual Design ESALs*** (Screen Clip 4-6). Click "***Next***". Go to Step 6.

Or

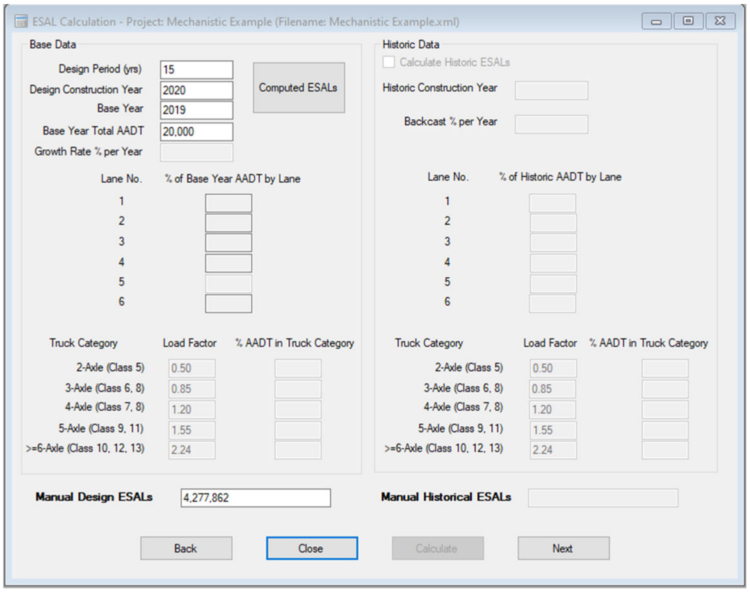
b. Enter requested data and compute ESALs by clicking ***Calculate.*** A detailed discussion of the input data is provided in Chapter 6. If the **Computed Design ESALs** appears reasonable, click "***Next***." Otherwise correct incorrect values and recalculate. (Screen Clip 4-7)



Design Period (yrs): 15
Design Construction Year: 2020
Base Year: 2019
Base Year Total AADT: 20,000
Growth Rate % per Year:

Truck Category	Load Factor
2-Axle (Class 5)	0.50
3-Axle (Class 6, 8)	0.85
4-Axle (Class 7, 8)	1.20
5-Axle (Class 9, 11)	1.55
>=6-Axle (Class 10, 12, 13)	2.24

Screen Clip 4-5

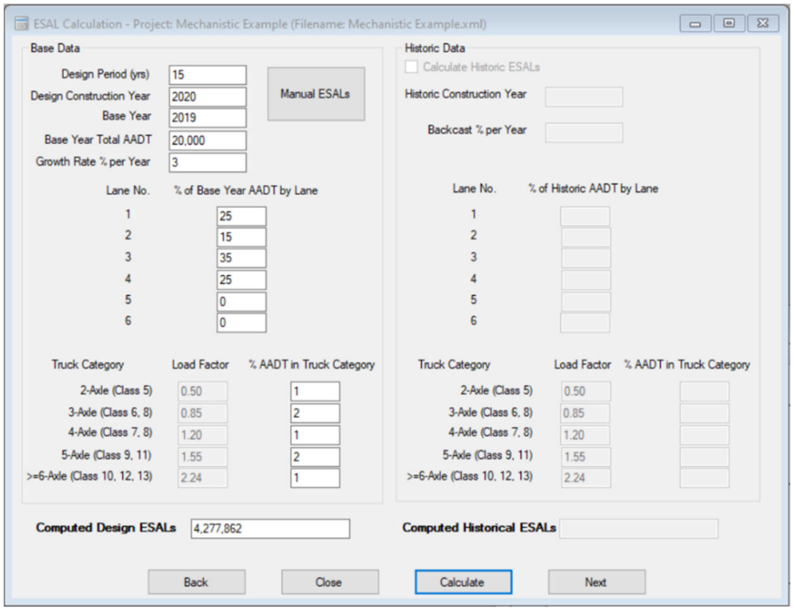


Design Period (yrs) 15
Design Construction Year 2020
Base Year 2019
Base Year Total AADT 20,000
Growth Rate % per Year

Truck Category	Load Factor	% AADT in Truck Category
2-Axle (Class 5)	0.50	
3-Axle (Class 6, 8)	0.85	
4-Axle (Class 7, 8)	1.20	
5-Axle (Class 9, 11)	1.55	
>=6-Axle (Class 10, 12, 13)	2.24	

Manual Design ESALs 4,277,862

Screen Clip 4-6



Design Period (yrs) 15
Design Construction Year 2020
Base Year 2019
Base Year Total AADT 20,000
Growth Rate % per Year 3

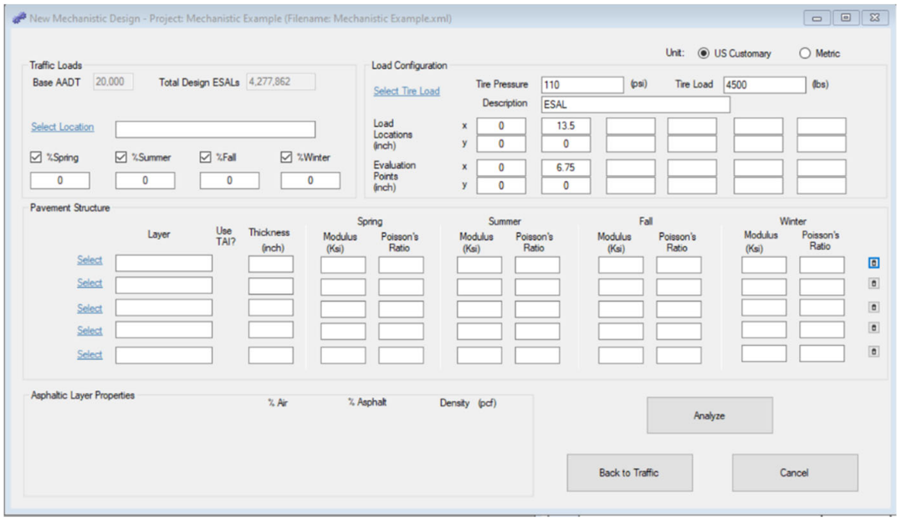
Lane No.	% of Base Year AADT by Lane
1	25
2	15
3	35
4	25
5	0
6	0

Truck Category	Load Factor	% AADT in Truck Category
2-Axle (Class 5)	0.50	1
3-Axle (Class 6, 8)	0.85	2
4-Axle (Class 7, 8)	1.20	1
5-Axle (Class 9, 11)	1.55	2
>=6-Axle (Class 10, 12, 13)	2.24	1

Computed Design ESALs 4,277,862

Screen Clip 4-7

Step 6. The Mechanistic design input screen will appear. Note the traffic inputs are brought forward. If the traffic data require changes, the user must go back to the traffic module by clicking on the ***Back to Traffic*** button. (Screen Clip 4-8)



Base AADT 20,000 Total Design ESALs 4,277,862

Unit: ● US Customary ○ Metric

Tire Pressure 110 (psi) Tire Load 4500 (lbs)

Description ESAL

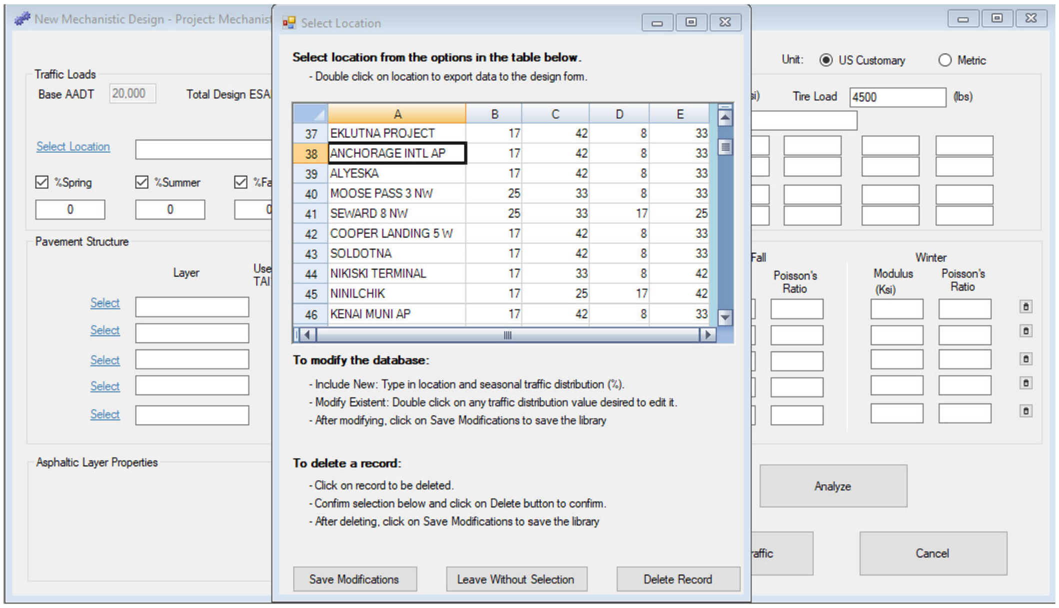
Load Locations (inch) x 0 13.5; y 0 0

Evaluation Points (inch) x 0 6.75; y 0 0

☑ %Spring 0 ☑ %Summer 0 ☑ %Fall 0 ☑ %Winter 0

Screen Clip 4-8

Step 7. The traffic data and calculated ESALs (Step 5-a/b) has been brought forward. Click on ***Select Location***.



Base AADT 20,000

Unit: ● US Customary ○ Metric

Tire Load 4500 (lbs)

☑ %Spring 0 ☑ %Summer 0

Select location from the options in the table below.

- Double click on location to export data to the design form.

	A	B	C	D	E
37	EKLUTNA PROJECT	17	42	8	33
38	ANCHORAGE INTL AP	17	42	8	33
39	ALYESKA	17	42	8	33
40	MOOSE PASS 3 NW	25	33	8	33
41	SEWARD 8 NW	25	33	17	25
42	COOPER LANDING 5 W	17	42	8	33
43	SOLDOTNA	17	42	8	33
44	NIKISKI TERMINAL	17	33	8	42
45	NINILCHIK	17	25	17	42
46	KENAI MUNI AP	17	42	8	33

To modify the database:

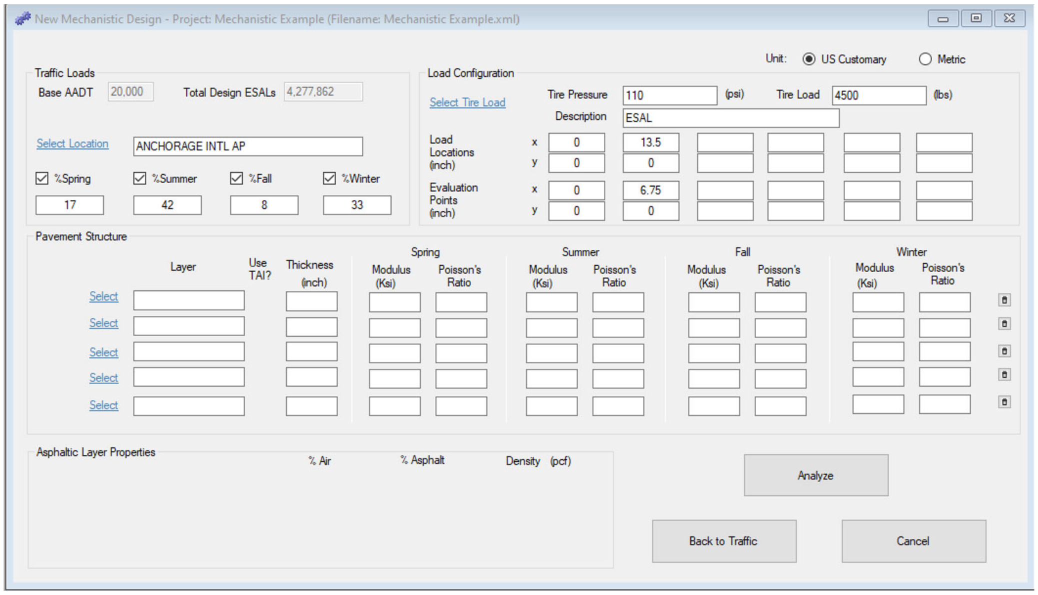
- Include New: Type in location and seasonal traffic distribution (%).
- Modify Existent: Double click on any traffic distribution value desired to edit it.
- After modifying, click on Save Modifications to save the library

To delete a record:

- Click on record to be deleted.
- Confirm selection below and click on Delete button to confirm.
- After deleting, click on Save Modifications to save the library

Screen Clip 4-9

Step 8. Screen Clip 4-9 allows the designer to input the percentage of the year in each season. The stiffness of the pavement layers varies with the seasons. Therefore, the amount of damage caused to the pavement structure by a given number of vehicle loads varies depending on the season the load is applied. The user may select one of the existing areas, modify one of the existing areas, create new areas or delete an area. Instructions are provided on the screen. For this example, double click on the ***Anchorage Area***. The user will be returned to the Mechanistic Design screen.



Unit: ● US Customary ○ Metric

Traffic Loads

Base AADT: 20,000

Total Design ESALs: 4,277,862

Location: ANCHORAGE INTL AP

☑ %Spring: 17 ☑ %Summer: 42 ☑ %Fall: 8 ☑ %Winter: 33

Load Configuration

Tire Pressure: 110 (psi) Tire Load: 4500 (lbs)

Description: ESAL

Load Locations (inch)	x	0	13.5
	y	0	0
Evaluation Points (inch)	x	0	6.75
	y	0	0

Pavement Structure

Layer	Use TAI?	Thickness (inch)	Spring Modulus (Ksi)	Spring Poisson's Ratio	Summer Modulus (Ksi)	Summer Poisson's Ratio	Fall Modulus (Ksi)	Fall Poisson's Ratio	Winter Modulus (Ksi)	Winter Poisson's Ratio

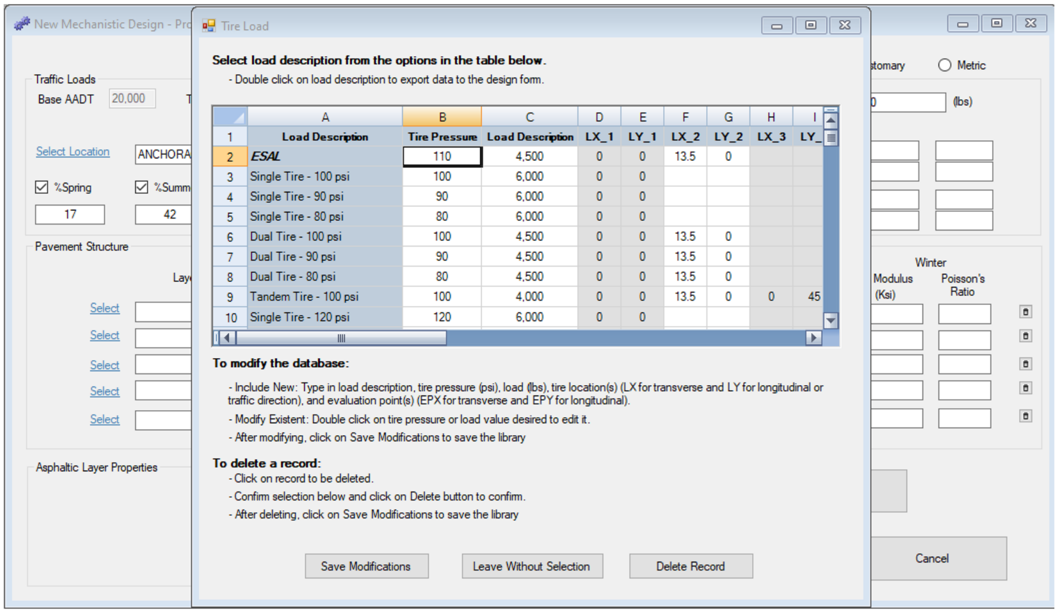
Asphaltic Layer Properties

% Air % Asphalt Density (pcf)

Screen Clip 4-10

Note the values for the seasons are inserted. (Screen Clip 4-10)

Step 9. The ***Load Configuration*** defaults to ***ESAL*** since this is the load configuration for which the traffic loadings were developed. However, there may be instances where you need to design for a specific load configuration. In this case select the appropriate load configuration by clicking on ***Select Tire Load*** and then select the desired load configuration (Screen Clip 11). Follow the instructions provided on the screen, to add or delete load configurations. Be sure to save modifications if appropriate.



Select load description from the options in the table below.

- Double click on load description to export data to the design form.

	A	B	C	D	E	F	G	H	I
1	Load Description	Tire Pressure	Load Description	LX_1	LY_1	LX_2	LY_2	LX_3	LY_
2	*ESAL*	110	4,500	0	0	13.5	0		
3	Single Tire - 100 psi	100	6,000	0	0				
4	Single Tire - 90 psi	90	6,000	0	0				
5	Single Tire - 80 psi	80	6,000	0	0				
6	Dual Tire - 100 psi	100	4,500	0	0	13.5	0		
7	Dual Tire - 90 psi	90	4,500	0	0	13.5	0		
8	Dual Tire - 80 psi	80	4,500	0	0	13.5	0		
9	Tandem Tire - 100 psi	100	4,000	0	0	13.5	0	0	45
10	Single Tire - 120 psi	120	6,000	0	0				

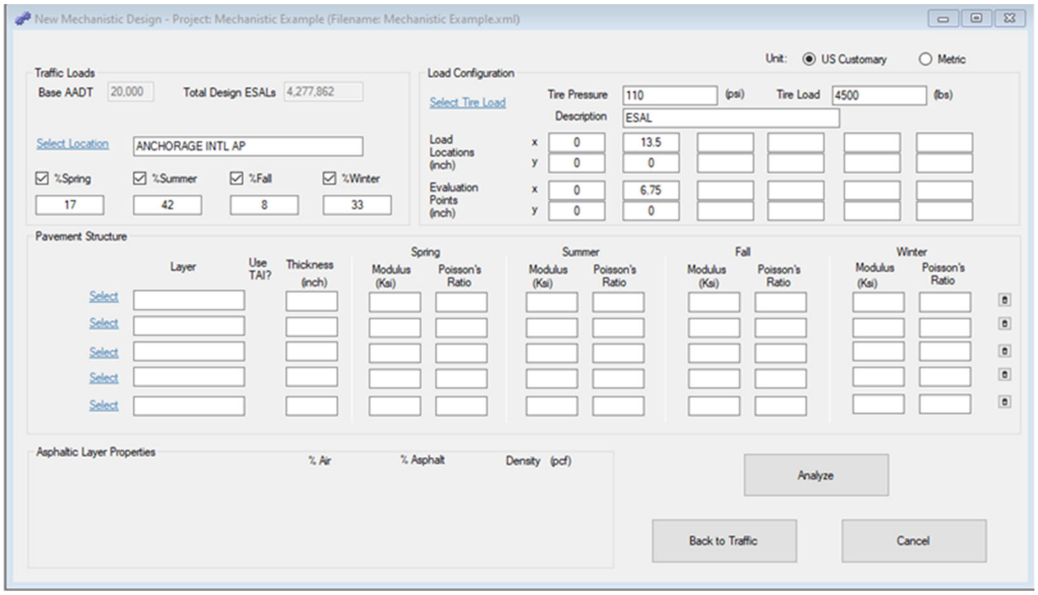
To modify the database:

- Include New: Type in load description, tire pressure (psi), load (lbs), tire location(s) (LX for transverse and LY for longitudinal or traffic direction), and evaluation point(s) (EPX for transverse and EPY for longitudinal).
- Modify Existent: Double click on tire pressure or load value desired to edit it.
- After modifying, click on Save Modifications to save the library

To delete a record:

- Click on record to be deleted.
- Confirm selection below and click on Delete button to confirm.
- After deleting, click on Save Modifications to save the library

Screen Clip 4-11



New Mechanistic Design - Project: Mechanistic Example (Filename: Mechanistic Example.xml)

Unit: ● US Customary ○ Metric

Traffic Loads

Base AADT: 20,000

Total Design ESALs: 4,277,862

Select Location: ANCHORAGE INTL AP

☑ %Spring: 17

☑ %Summer: 42

☑ %Fall: 8

☑ %Winter: 33

Load Configuration

Tire Pressure: 110 (psi)

Tire Load: 4500 (lbs)

Description: ESAL

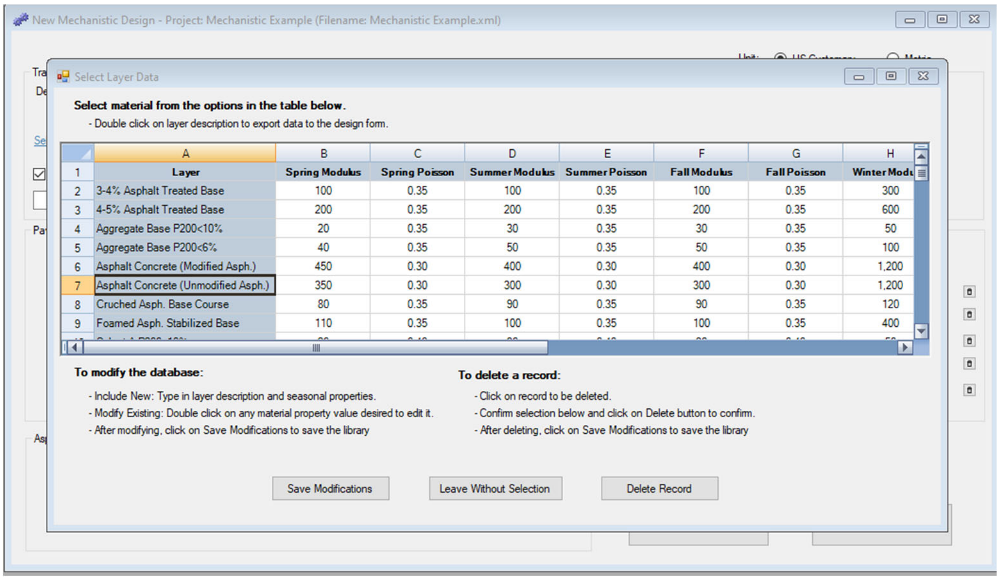
Load Locations (inch): x 0, 13.5; y 0, 0

Evaluation Points (inch): x 0, 6.75; y 0, 0

Screen Clip 4-12

Note that the Load Configuration has been entered. (Screen Clip 4-12)

Step 10. The Pavement Structure must now be defined in the box labeled "Pavement Structure." Up to 5 layers are available for analysis. As explained earlier, the properties (thickness, modulus, and Poisson's ratio) of each layer must be defined. Refer to Chapter 5 or work with your materials section to obtain appropriate values. You can either enter the values manually or click on ***Select*** to bring up a menu of materials. In most cases it is most efficient to go to the materials menu and use an existing material or modify an existing material. At this point click on ***Select*** for the first layer. The "Select Layer Data" dialog box will appear. (Screen Clip 4-13)



Select material from the options in the table below.

- Double click on layer description to export data to the design form.

	A	B	C	D	E	F	G	H
1	Layer	Spring Modulus	Spring Poisson	Summer Modulus	Summer Poisson	Fall Modulus	Fall Poisson	Winter Modu
2	3-4% Asphalt Treated Base	100	0.35	100	0.35	100	0.35	300
3	4-5% Asphalt Treated Base	200	0.35	200	0.35	200	0.35	600
4	Aggregate Base P200<10%	20	0.35	30	0.35	30	0.35	50
5	Aggregate Base P200<6%	40	0.35	50	0.35	50	0.35	100
6	Asphalt Concrete (Modified Asph.)	450	0.30	400	0.30	400	0.30	1,200
7	Asphalt Concrete (Unmodified Asph.)	350	0.30	300	0.30	300	0.30	1,200
8	Cruched Asph. Base Course	80	0.35	90	0.35	90	0.35	120
9	Foamed Asph. Stabilized Base	110	0.35	100	0.35	100	0.35	400

To modify the database:

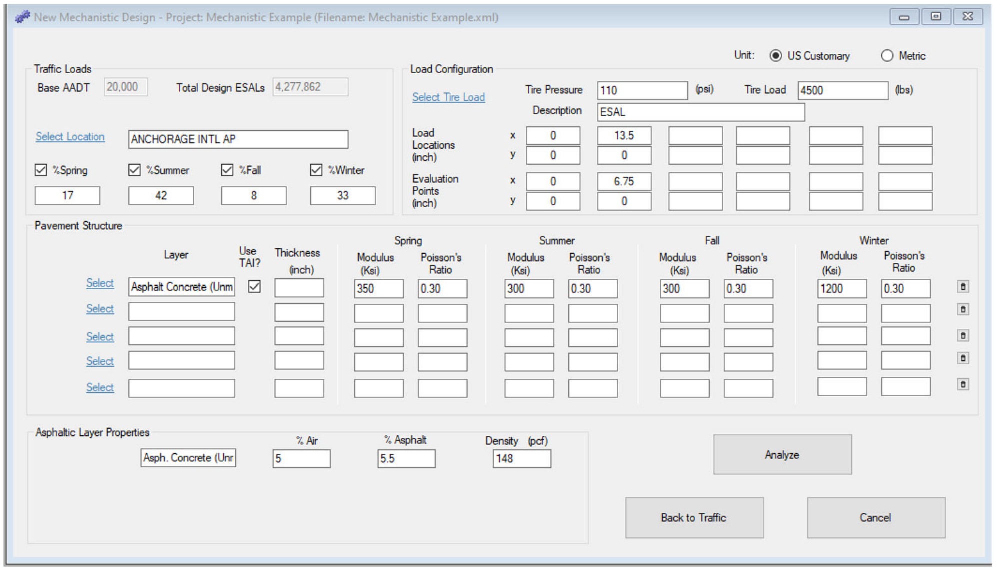
- Include New: Type in layer description and seasonal properties.
- Modify Existing: Double click on any material property value desired to edit it.
- After modifying, click on Save Modifications to save the library

To delete a record:

- Click on record to be deleted.
- Confirm selection below and click on Delete button to confirm.
- After deleting, click on Save Modifications to save the library

Screen Clip 4-13

In most cases, the first layer will be some form of Asphalt Concrete. The values shown here represent a typical set of properties. Note the properties vary with season. However, the properties for your project may be different. As before, follow the instructions provided to make changes. For this example, double click on "Asphalt Concrete (Unmodified Asphalt.)."



New Mechanistic Design - Project: Mechanistic Example (Filename: Mechanistic Example.xml)

Unit: ● US Customary ○ Metric

Traffic Loads

Base AADT 20,000 Total Design ESALs 4,277,862

Select Location: ANCHORAGE INTL AP

☑ %Spring 17 ☑ %Summer 42 ☑ %Fall 8 ☑ %Winter 33

Load Configuration

Select Tire Load

Tire Pressure 110 (psi) Tire Load 4500 (lbs)

Description ESAL

Load Locations (inch) x 0, 13.5; y 0, 0

Evaluation Points (inch) x 0, 6.75; y 0, 0

Pavement Structure

			Spring		Summer		Fall		Winter	
Layer	Use TAI?	Thickness (inch)	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio
Asphalt Concrete (Unm	☑		350	0.30	300	0.30	300	0.30	1200	0.30

Asphaltic Layer Properties

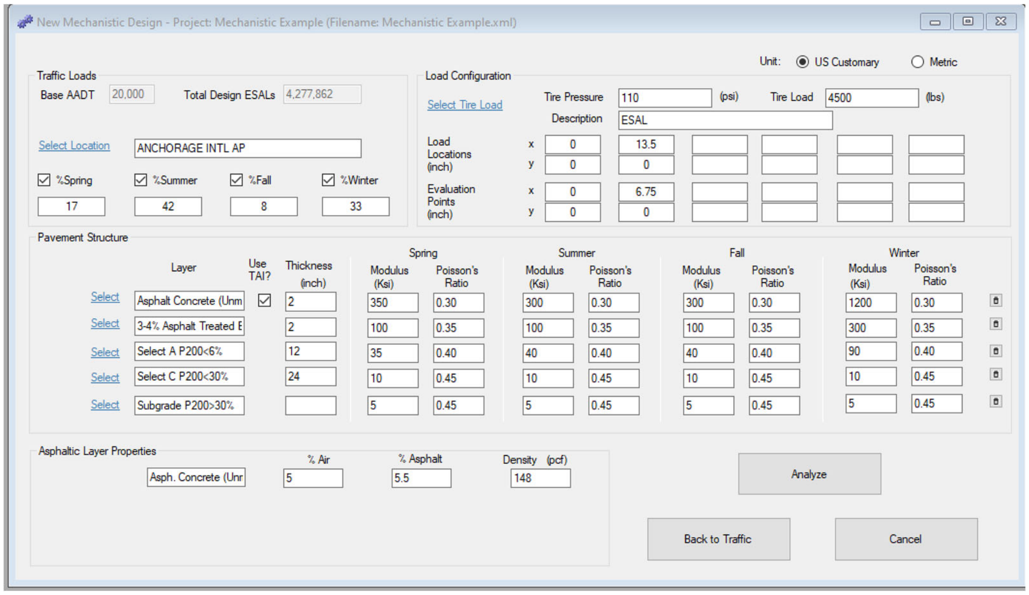
Asph. Concrete (Unr — % Air 5 — % Asphalt 5.5 — Density (pcf) 148

Screen Clip 4-14

The materials properties associated with Asphalt Concrete (Unmodified Asph.) have been inserted. (Screen Clip 4-14) Note that the column labeled "Use TAI?" has been checked. This tells the software that the layer is an asphalt bound material and that The Asphalt Institute fatigue equation should be used to compute the number of cycles to failure. This is defined in the materials database. Also note that the air voids, percent asphalt and density for the asphalt concrete are shown in the "Asphaltic Layer Properties" box. These may be modified based on information from the Materials Section. You may wish to make these changes in the database if these properties will be commonly used.

Now enter the thickness of the Asphalt Concrete. With experience, the designer will learn to estimate the thickness based on the number of loadings (ESALs) and the materials properties. For instructive purposes, this example will assume the asphalt thickness is 2 inches.

Repeat Step 10 for each layer in your pavement structure. Again, refer to Chapter 5 or work with the materials section to determine the appropriate properties.



New Mechanistic Design - Project: Mechanistic Example (Filename: Mechanistic Example.xml)

Unit: ● US Customary ○ Metric

Traffic Loads

Base AADT 20,000 Total Design ESALs 4,277,862

Select Location: ANCHORAGE INTL AP

☑ %Spring 17 ☑ %Summer 42 ☑ %Fall 8 ☑ %Winter 33

Load Configuration

Select Tire Load

Tire Pressure 110 (psi) Tire Load 4500 (lbs)

Description ESAL

Load Locations (inch) x 0, 13.5; y 0, 0

Evaluation Points (inch) x 0, 6.75; y 0, 0

Pavement Structure

			Spring		Summer		Fall		Winter	
Layer	Use TAI?	Thickness (inch)	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio
Asphalt Concrete (Unm	☑	2	350	0.30	300	0.30	300	0.30	1200	0.30
3-4% Asphalt Treated E		2	100	0.35	100	0.35	100	0.35	300	0.35
Select A P200<6%		12	35	0.40	40	0.40	40	0.40	90	0.40
Select C P200<30%		24	10	0.45	10	0.45	10	0.45	10	0.45
Subgrade P200>30%			5	0.45	5	0.45	5	0.45	5	0.45

Asphaltic Layer Properties

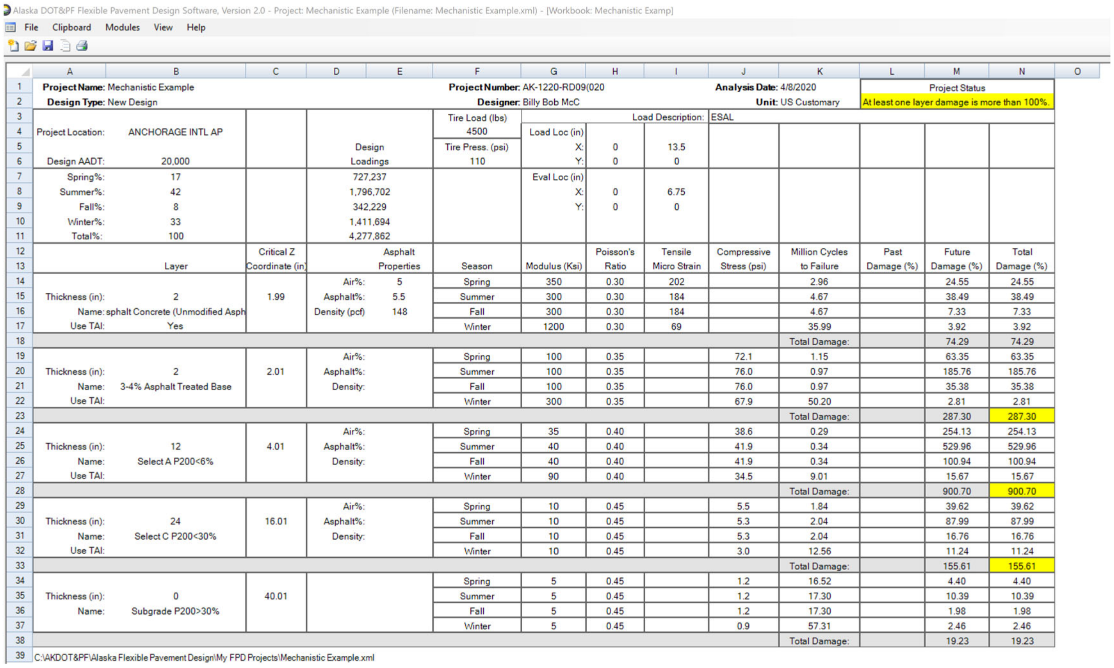
Asph. Concrete (Unr — % Air 5 — % Asphalt 5.5 — Density (pcf) 148

Screen Clip 4-15

The pavement structure will look something like Screen Clip 4-15. Note that the Asphalt Treated Base which has 3-4 % asphalt did not require the use of the TAI. This is because, asphalt treated base with low asphalt cement content is not considered a bound material. Asphalt treated bases above 4% asphalt cement are considered bound. This boundary has been determined through experience and should be used as guidance.

Notice the Subgrade has a thickness of "0." This indicates that the bottom layer is semi-infinite. The last layer will always have a thickness of 0. If the user inserts a value other than 0, the software will change the value to 0.

Step 11. As stated earlier, this procedure does not determine the pavement thickness. Rather, it will indicate whether your design meets Miner's Law and the criteria established by the Department. Consequently, check the design by clicking ***Analyze***.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Project Name:**	Mechanistic Example				**Project Number:**	AK-1220-RD09(020			**Analysis Date:**	4/8/2020	Project Status		
2	**Design Type:**	New Design				**Designer:**	Billy Bob McC			**Unit:**	US Customary	At least one layer damage is more than 100%.		
3						Tire Load (lbs)			Load Description:	ESAL				
4	Project Location:	ANCHORAGE INTL AP				4500	Load Loc (in)							
5				Design		Tire Press. (psi)	X:	0	13.5					
6	Design AADT:	20,000		Loadings		110	Y:	0	0					
7	Spring%:	17		727,237			Eval Loc (in)							
8	Summer%:	42		1,796,702			X:	0	6.75					
9	Fall%:	8		342,229			Y:	0	0					
10	Winter%:	33		1,411,694										
11	Total%:	100		4,277,862										
12			Critical Z		Asphalt			Poisson's	Tensile	Compressive	Million Cycles	Past	Future	Total
13		Layer	Coordinate (in)		Properties	Season	Modulus (Ksi)	Ratio	Micro Strain	Stress (psi)	to Failure	Damage (%)	Damage (%)	Damage (%)
14				Air%:	5	Spring	350	0.30	202		2.96		24.55	24.55
15	Thickness (in):	2	1.99	Asphalt%:	5.5	Summer	300	0.30	184		4.67		38.49	38.49
16	Name:	sphalt Concrete (Unmodified Asph		Density (pcf)	148	Fall	300	0.30	184		4.67		7.33	7.33
17	Use TAI:	Yes				Winter	1200	0.30	69		35.99		3.92	3.92
18											Total Damage:		74.29	74.29
19				Air%:		Spring	100	0.35		72.1	1.15		63.35	63.35
20	Thickness (in):	2	2.01	Asphalt%:		Summer	100	0.35		76.0	0.97		185.76	185.76
21	Name:	3-4% Asphalt Treated Base		Density:		Fall	100	0.35		76.0	0.97		35.38	35.38
22	Use TAI:					Winter	300	0.35		67.9	50.20		2.81	2.81
23											Total Damage:		287.30	287.30
24				Air%:		Spring	35	0.40		38.6	0.29		254.13	254.13
25	Thickness (in):	12	4.01	Asphalt%:		Summer	40	0.40		41.9	0.34		529.96	529.96
26	Name:	Select A P200<6%		Density:		Fall	40	0.40		41.9	0.34		100.94	100.94
27	Use TAI:					Winter	90	0.40		34.5	9.01		15.67	15.67
28											Total Damage:		900.70	900.70
29				Air%:		Spring	10	0.45		5.5	1.84		39.62	39.62
30	Thickness (in):	24	16.01	Asphalt%:		Summer	10	0.45		5.3	2.04		87.99	87.99
31	Name:	Select C P200<30%		Density:		Fall	10	0.45		5.3	2.04		16.76	16.76
32	Use TAI:					Winter	10	0.45		3.0	12.56		11.24	11.24
33											Total Damage:		155.61	155.61
34						Spring	5	0.45		1.2	16.52		4.40	4.40
35	Thickness (in):	0	40.01			Summer	5	0.45		1.2	17.30		10.39	10.39
36	Name:	Subgrade P200>30%				Fall	5	0.45		1.2	17.30		1.98	1.98
37						Winter	5	0.45		0.9	57.31		2.46	2.46
38											Total Damage:		19.23	19.23
39	C:\AKDOT&PF\Alaska Flexible Pavement Design\My FPD Projects\Mechanistic Example.xml													

Screen Clip 4-16

Screen Clip 4-16 shows the output of the analysis.

The first column (column B, below row 13) provides the input description of each layer.

The second column (column C) provides the critical Z coordinate (depth) of the analysis. Note that the depth of the analysis of the Asphalt Concrete is 0.01 inches above the bottom of that layer. This is because we are looking for the horizontal strain at the bottom of the asphalt concrete layer. By locating the analysis point just above the bottom of the layer, we ensure the software analyzes the layer at the appropriate point.

All unbound layers are analyzed just below the top of the layer for the same reason except that the vertical compressive stress will be used to estimate the number of cycles to failure. It is always a good idea to check these values to ensure the software is selecting the analysis points correctly.

The third column (columns D-E) shows the Design Loadings for each season based on the seasonal distribution shown in column B. These values are used to estimate the damage in each layer for each season. Below that, the asphalt properties are provided for the asphalt concrete layers.

Columns F, G, H, and I (above row 11) display the loading input and the seasonal properties provided by the user. Check these to ensure the values you input. If not, return to the input screen to make the appropriate modifications.

Columns I and J (below row 13) display the output generated by WESLEA for each layer and season. The horizontal strain for each asphaltic layer and for each season is provided in Column I. Column J provides the vertical stress at the top of each layer and season for every unbound layer.

Column K displays the number of cycles to failure for each layer and for each season. The equations/transfer functions are discussed earlier in the chapter.

Columns L and M provide the damage (i.e. actual traffic divided by the number of cycles to failure shown in column K) that are caused by the traffic both past and future. Since this is a new pavement structure, there is no past traffic. (Column L is empty).

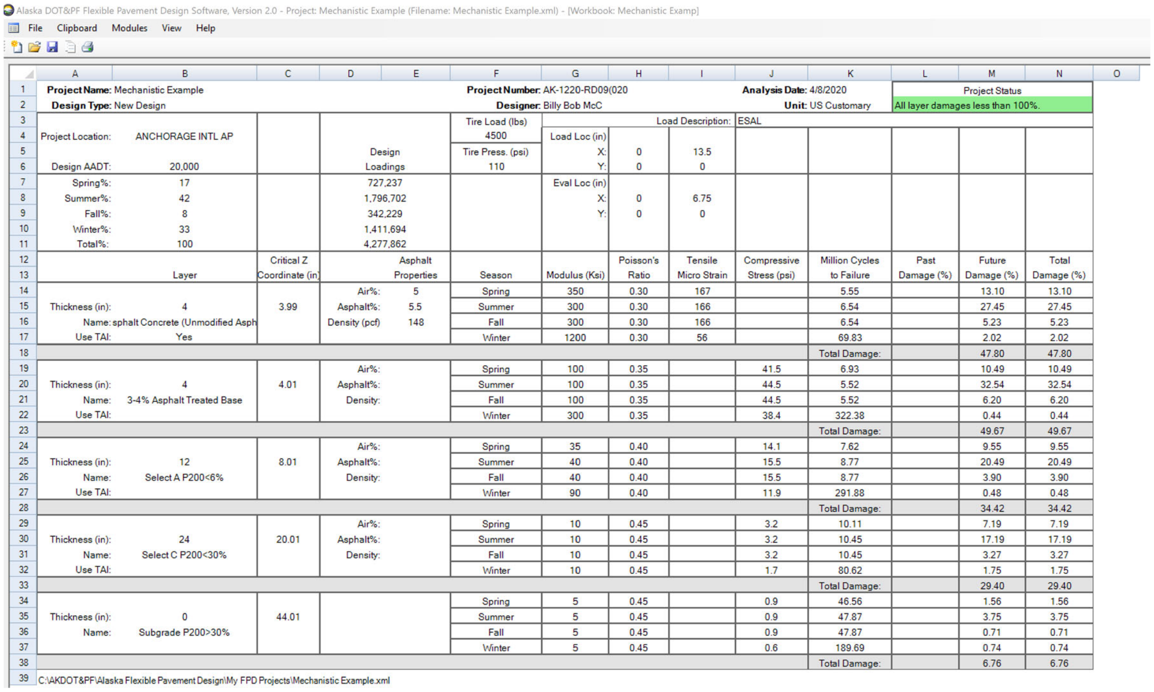
Finally, column N shows the total damage as the sum of the past and future damage. Since there is no past traffic, column M and N should be equal.

All values in column N must be equal to or less than 100 %. If any of the values exceed 100%, the proposed pavement structure is inadequate and therefore rejected. If this is the case, go back to the input screen and modify the pavement structure. As you gain experience, the process will become more efficient.

The software highlights any damage value exceeding 100% in yellow and issues the warning “*At least one-layer damage is more than 100%”* in the upper right corner under Project Status. The warning is highlighted in yellow.

Note that the second layer (3-4% ATB) is the one that failed. Modifying the layers below will have limited effect on reducing the damage in the layer. To reduce the vertical stress at the top of the layer requires increasing the thickness or stiffness of the ATB or/and the asphalt concrete layer.

Step 12. To return to the Mechanistic Input Screen, click on ***Modules*** in the ribbon and click ***Mechanistic Design.*** You will be returned to Screen Clip 4-15. Change the thickness of the Stabilized Base to 4 inches and the Asphalt Concrete thickness to 4 inches. Click ***Analyze***. Screen Clip 4-17 shows the output.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Project Name:**	Mechanistic Example				**Project Number:**	AK-1220-RD09(020			**Analysis Date:**	4/8/2020	Project Status			
2	**Design Type:**	New Design				**Designer:**	Billy Bob McC			**Unit:**	US Customary	All layer damages less than 100%.			
3						Tire Load (lbs)			Load Description:	ESAL					
4	Project Location:	ANCHORAGE INTL AP				4500	Load Loc (in)								
5				Design		Tire Press. (psi)	X:	0	13.5						
6	Design AADT:	20,000		Loadings		110	Y:	0	0						
7	Spring%:	17		727,237			Eval Loc (in)								
8	Summer%:	42		1,796,702			X:	0	6.75						
9	Fall%:	8		342,229			Y:	0	0						
10	Winter%:	33		1,411,694											
11	Total%:	100		4,277,862											
12			Critical Z		Asphalt			Poisson's	Tensile	Compressive	Million Cycles	Past	Future	Total	
13		Layer	Coordinate (in)		Properties	Season	Modulus (Ksi)	Ratio	Micro Strain	Stress (psi)	to Failure	Damage (%)	Damage (%)	Damage (%)	
14				Air%:	5	Spring	350	0.30	167		5.55		13.10	13.10	
15	Thickness (in):	4	3.99	Asphalt%:	5.5	Summer	300	0.30	166		6.54		27.45	27.45	
16	Name:	sphalt Concrete (Unmodified Asph		Density (pcf)	148	Fall	300	0.30	166		6.54		5.23	5.23	
17	Use TAI:	Yes				Winter	1200	0.30	56		69.83		2.02	2.02	
18											Total Damage:		47.80	47.80	
19				Air%:		Spring	100	0.35		41.5	6.93		10.49	10.49	
20	Thickness (in):	4	4.01	Asphalt%:		Summer	100	0.35		44.5	5.52		32.54	32.54	
21	Name:	3-4% Asphalt Treated Base		Density:		Fall	100	0.35		44.5	5.52		6.20	6.20	
22	Use TAI:					Winter	300	0.35		38.4	322.38		0.44	0.44	
23											Total Damage:		49.67	49.67	
24				Air%:		Spring	35	0.40		14.1	7.62		9.55	9.55	
25	Thickness (in):	12	8.01	Asphalt%:		Summer	40	0.40		15.5	8.77		20.49	20.49	
26	Name:	Select A P200<6%		Density:		Fall	40	0.40		15.5	8.77		3.90	3.90	
27	Use TAI:					Winter	90	0.40		11.9	291.88		0.48	0.48	
28											Total Damage:		34.42	34.42	
29				Air%:		Spring	10	0.45		3.2	10.11		7.19	7.19	
30	Thickness (in):	24	20.01	Asphalt%:		Summer	10	0.45		3.2	10.45		17.19	17.19	
31	Name:	Select C P200<30%		Density:		Fall	10	0.45		3.2	10.45		3.27	3.27	
32	Use TAI:					Winter	10	0.45		1.7	80.62		1.75	1.75	
33											Total Damage:		29.40	29.40	
34						Spring	5	0.45		0.9	46.56		1.56	1.56	
35	Thickness (in):	0	44.01			Summer	5	0.45		0.9	47.87		3.75	3.75	
36	Name:	Subgrade P200>30%				Fall	5	0.45		0.9	47.87		0.71	0.71	
37						Winter	5	0.45		0.6	189.69		0.74	0.74	
38											Total Damage:		6.76	6.76	
39	C:\AKDOT&PF\Alaska Flexible Pavement Design\My FPD Projects\Mechanistic Example.xml														

Screen Clip 4-17

Note the Project Status has been changed to "*All layer damages less than 100%*" highlighted in green. The proposed pavement structure is acceptable. However, this may not be the most cost-effective solution. The designer will want to look at alternative designs to find the most cost-effective design. This will be discussed further in Chapter 8.

Step 13: It is suggested that the results be printed as documentation of the design by clicking ***File*** to the left of the ribbon. Then click ***Print*** and follow the instructions.

Step 14. Before creating a new pavement structure, create a copy of the existing structure to modify. Simply go to the ribbon, click ***File*** then ***Copy To*** and enter a new name such as Mechanistic Design A. This will allow the user to document several alternatives without the need to recreate the data input.

Now click "***Modules***" then "Mechanistic Design" from the ribbon. Modify the pavement structure and analyze the structure. Repeat the process until an optimal pavement structure is realized.

4.6 Design Strategy

The underlying premise used in pavement design is to limit the stress or strain on each layer such that the layer will perform as desired. Experience has shown that it is best to work from the bottom up. In general, it is best to reduce the load at the top of each unbound layer either by increasing one or more of the layers above that layer or to stiffen one or more layers above the layer in question. Changing the stiffness below that layer will typically have little impact. The designer must contemplate whether it is less expensive to increase the failing layers stiffness or to reduce the vertical loading by stiffening one or more layers using a more expensive material.

If the bound layers are failing, there is no choice but to alter the material below the bound layer. In most cases, it is more effective to modify the thickness or stiffness immediately below the bound layer that is failing.

It is critical to get the materials properties of the wearing course and the subgrade correct. The properties of the wearing course effectively determine the relationship between the horizontal strain and the number of cycles to fatigue. The subgrade properties are essentially fixed by the local geology. However, these properties affect the response of the pavement structure above. Take a few moments to test this by fixing the pavement structure and modifying the subgrade modulus.

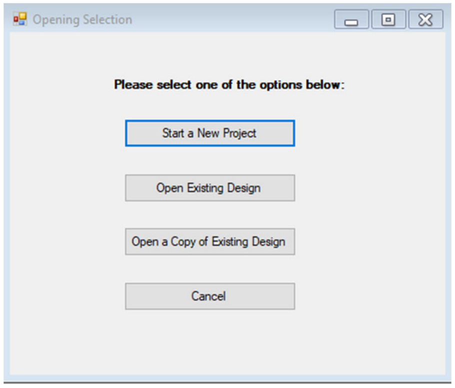
Designers are encouraged to explore the impacts of modifying layer properties on the other layers in the pavement structure.

4.7 Example 2—An Overlay Design

This example makes use of the Mechanistic Overlay Design procedures contained within AKFPD-2 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 structural life expended due to past ESAL applications. Past ESALs are those that were applied to the original pavement structure before the overlay placement.

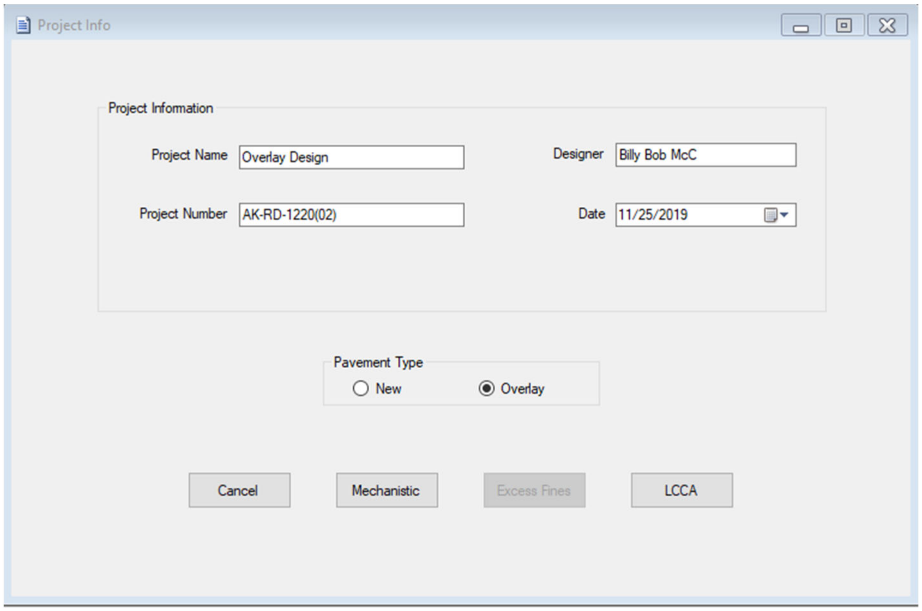
You will gain cumulative experience by going through each design example because each example builds on information and tips contained in the previous one. This example uses many of the program operation techniques presented in Section 4.5.2, example 1. **If you have not thoroughly familiarized yourself with example 1, do so before proceeding with this example.**

Step 1. Begin this example by starting a new project. (Clip 4-18) Click ***Start a New Project.***



Screen Clip 4-18

Step 2. Fill in the project information. Change the Pavement Type from **New** to **Overlay** by clicking ***Overlay***. Now click ***Mechanistic*** to save the project information (Screen Clip 4-19)



Project Name: Overlay Design

Project Number: AK-RD-1220(02)

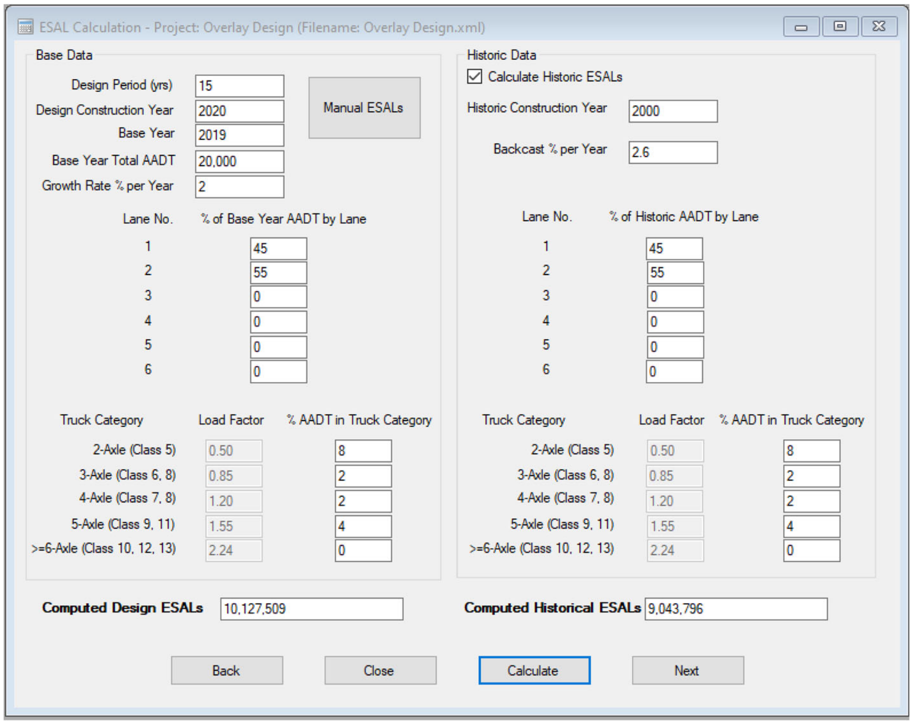
Designer: Billy Bob McC

Date: 11/25/2019

Pavement Type: ○ New ● Overlay

Screen Clip 4-19

Step 3. Note the Historical Data box is now available. (Screen Clip 4-20) The Planning/Traffic Data Section will provide the data for this input screen. As before, you can either fill in the data or select "***Manual ESALs***. If you input the data click ***Calculate***. If the "Computed Design ESALs" and the "Computed Historical ESALs" look reasonable click ***Next***.



ESAL Calculation - Project: Overlay Design (Filename: Overlay Design.xml)

Base Data

Design Period (yrs) 15
Design Construction Year 2020
Base Year 2019
Base Year Total AADT 20,000
Growth Rate % per Year 2

Lane No.	% of Base Year AADT by Lane
1	45
2	55
3	0
4	0
5	0
6	0

Truck Category	Load Factor	% AADT in Truck Category
2-Axle (Class 5)	0.50	8
3-Axle (Class 6, 8)	0.85	2
4-Axle (Class 7, 8)	1.20	2
5-Axle (Class 9, 11)	1.55	4
>=6-Axle (Class 10, 12, 13)	2.24	0

Computed Design ESALs 10,127,509

Historic Data

☑ Calculate Historic ESALs

Historic Construction Year 2000
Backcast % per Year 2.6

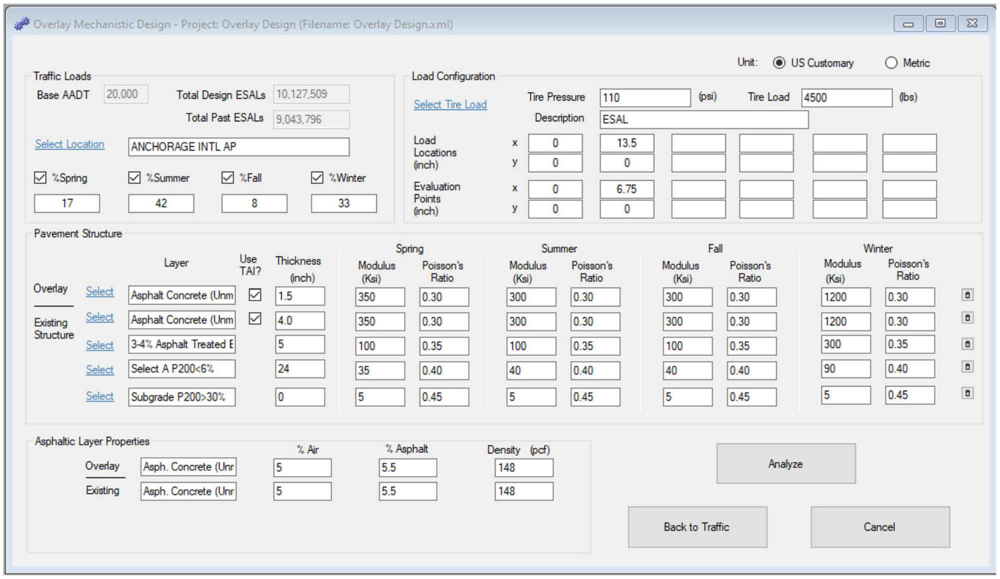
Lane No.	% of Historic AADT by Lane
1	45
2	55
3	0
4	0
5	0
6	0

Truck Category	Load Factor	% AADT in Truck Category
2-Axle (Class 5)	0.50	8
3-Axle (Class 6, 8)	0.85	2
4-Axle (Class 7, 8)	1.20	2
5-Axle (Class 9, 11)	1.55	4
>=6-Axle (Class 10, 12, 13)	2.24	0

Computed Historical ESALs 9,043,796

Screen Clip 4-20

Step 4. Note that both the future and historical ESALs have been brought forward from the traffic data input. (Screen Clip 4-21) As before click Select Location to choose project location. Note that the Pavement Structure has two sections, the ***Overlay*** and the ***Existing Structure***. The Existing Structure represents the in-situ structure. Guess an overlay thickness. It doesn't matter what the guess is since the software will start with 0.5 inches of asphalt concrete with the properties specified and increment by 0.5 inches until an acceptable overlay is obtained. The minimum overlay has been set to 1.5 inches. Once the data has been entered click ***Analyze.***



Overlay Mechanistic Design - Project: Overlay Design (Filename: Overlay Design.xml)

Unit: ● US Customary ○ Metric

Traffic Loads

Base AADT 20,000
Total Design ESALs 10,127,509
Total Past ESALs 9,043,796
Select Location ANCHORAGE INTL AP

☑ %Spring	☑ %Summer	☑ %Fall	☑ %Winter
17	42	8	33

Load Configuration

Tire Pressure 110 (psi)
Tire Load 4500 (lbs)
Description ESAL

Load Locations (inch)	x	0	13.5				
	y	0	0				
Evaluation Points (inch)	x	0	6.75				
	y	0	0				

Pavement Structure

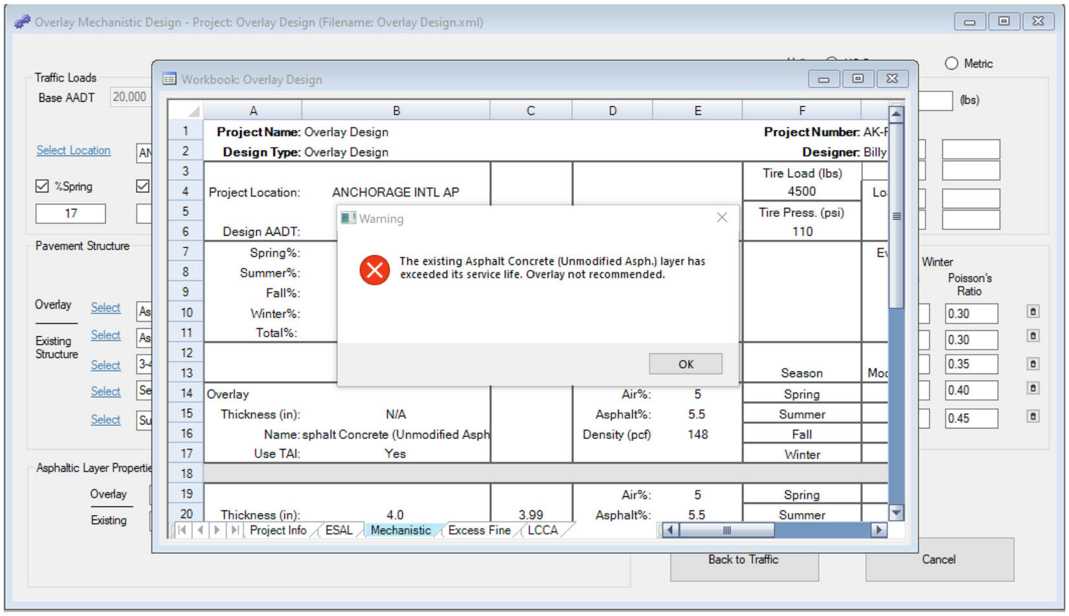
	Layer	Use TAI?	Thickness (inch)	Spring Modulus (Ksi)	Spring Poisson's Ratio	Summer Modulus (Ksi)	Summer Poisson's Ratio	Fall Modulus (Ksi)	Fall Poisson's Ratio	Winter Modulus (Ksi)	Winter Poisson's Ratio
Overlay	Asphalt Concrete (Unm	☑	1.5	350	0.30	300	0.30	300	0.30	1200	0.30
Existing Structure	Asphalt Concrete (Unm	☑	4.0	350	0.30	300	0.30	300	0.30	1200	0.30
	3-4% Asphalt Treated E		5	100	0.35	100	0.35	100	0.35	300	0.35
	Select A P200<6%		24	35	0.40	40	0.40	40	0.40	90	0.40
	Subgrade P200>30%		0	5	0.45	5	0.45	5	0.45	5	0.45

Asphaltic Layer Properties

		% Air	% Asphalt	Density (pcf)
Overlay	Asph. Concrete (Unr	5	5.5	148
Existing	Asph. Concrete (Unr	5	5.5	148

Screen Clip 4-21

Step 5. In this case a warning appears indicating the existing asphalt concrete has already exceeded 80 % of its available life. (Screen Clip 4-22) Consequently, an overlay is not allowed as stated in Section 2.2.3 in Chapter 2. In this case consider removing and replacing the asphalt concrete layer or full depth reclamation.



Overlay Mechanistic Design - Project: Overlay Design (Filename: Overlay Design.xml)

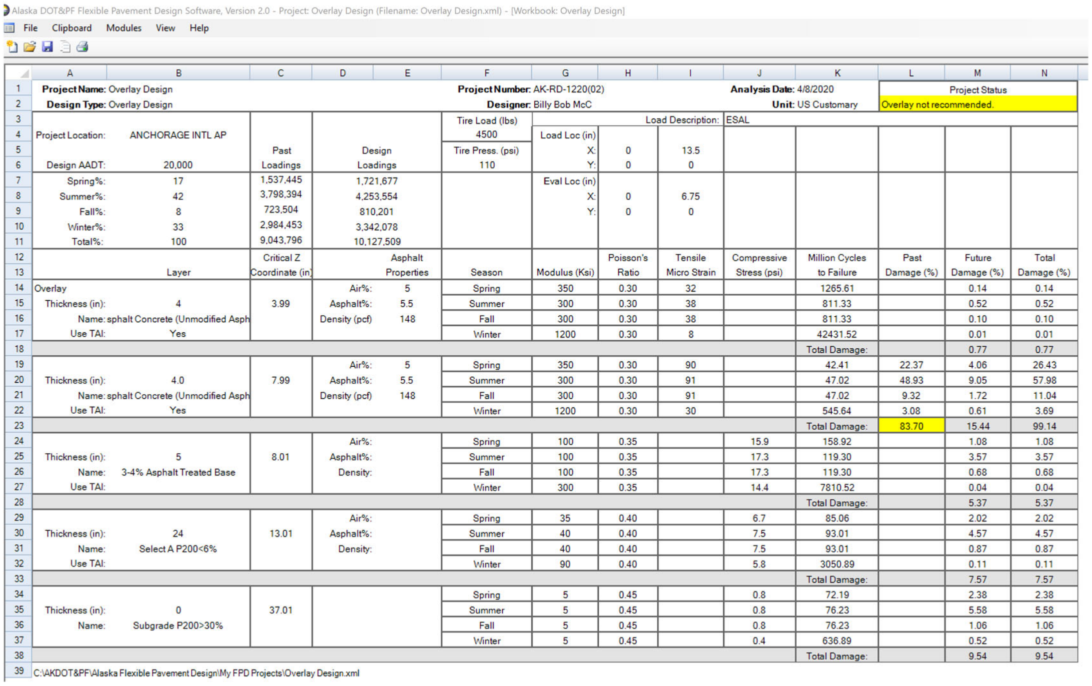
Workbook: Overlay Design

Warning

The existing Asphalt Concrete (Unmodified Asph.) layer has exceeded its service life. Overlay not recommended.

Screen Clip 4-22

Click ***OK***. Look at the column labeled “Past Damage (%)” in Clip 4-23. Note that the existing asphalt layer has already experienced about 82 % damage (i.e. exhausted 82% of its available life). The existing pavement has therefore already exceeded the allowable fatigue life allowed by the policy outline in Section 2.2.3 **For Designing Overlays of Existing Highway Pavements.** Click ***Modules*** in the ribbon then ***Mechanistic Design*** to return to the mechanistic input screen.

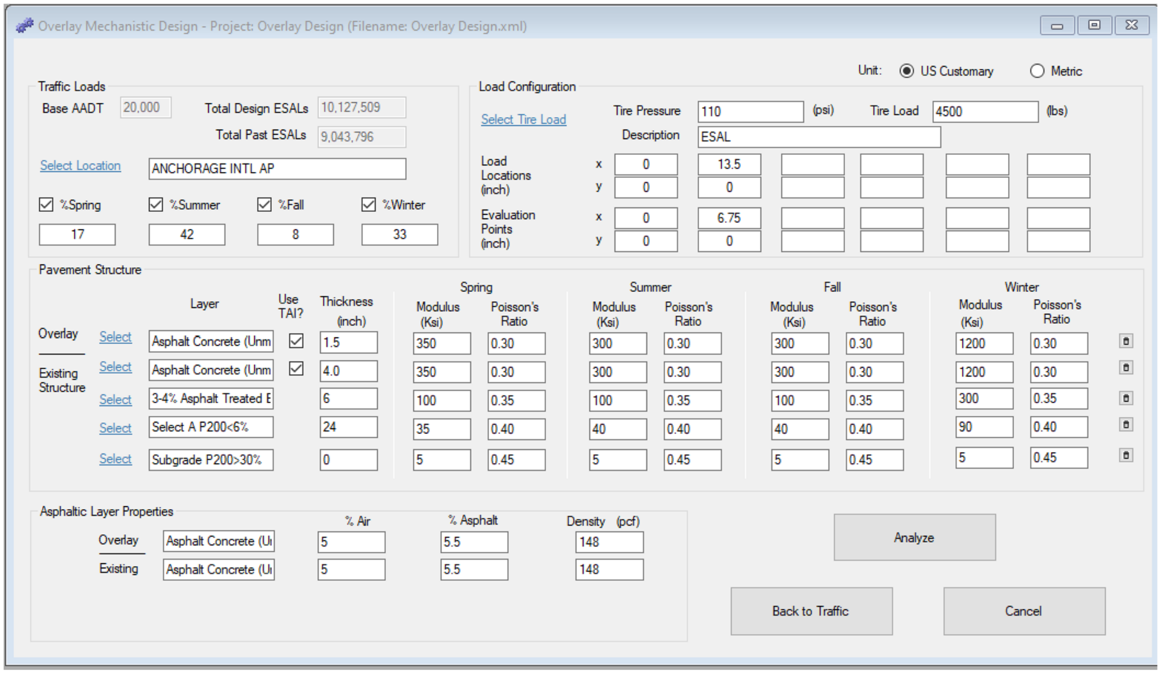


Alaska DOT&PF Flexible Pavement Design Software, Version 2.0 - Project: Overlay Design (Filename: Overlay Design.xml) - [Workbook: Overlay Design]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Project Name:** Overlay Design					**Project Number:** AK-RD-1220(02)				**Analysis Date:** 4/8/2020			Project Status	
2	**Design Type:** Overlay Design					**Designer:** Billy Bob McC				**Unit:** US Customary		Overlay not recommended.		
3						Tire Load (lbs)			Load Description:	ESAL				
4	Project Location:	ANCHORAGE INTL AP				4500	Load Loc (in)							
5			Past	Design		Tire Press. (psi)	X:	0	13.5					
6	Design AADT:	20,000	Loadings	Loadings		110	Y:	0	0					
7	Spring%:	17	1,537,445	1,721,677			Eval Loc (in)							
8	Summer%:	42	3,798,394	4,253,554			X:	0	6.75					
9	Fall%:	8	723,504	810,201			Y:	0	0					
10	Winter%:	33	2,984,453	3,342,078										
11	Total%:	100	9,043,796	10,127,509										
12			Critical Z		Asphalt			Poisson's	Tensile	Compressive	Million Cycles	Past	Future	Total
13		Layer	Coordinate (in)		Properties	Season	Modulus (Ksi)	Ratio	Micro Strain	Stress (psi)	to Failure	Damage (%)	Damage (%)	Damage (%)
14	Overlay			Air%:	5	Spring	350	0.30	32		1265.61		0.14	0.14
15	Thickness (in):	4	3.99	Asphalt%:	5.5	Summer	300	0.30	38		811.33		0.52	0.52
16	Name:	sphalt Concrete (Unmodified Asph		Density (pcf)	148	Fall	300	0.30	38		811.33		0.10	0.10
17	Use TAI:	Yes				Winter	1200	0.30	8		42431.52		0.01	0.01
18											Total Damage:		0.77	0.77
19				Air%:	5	Spring	350	0.30	90		42.41	22.37	4.06	26.43
20	Thickness (in):	4.0	7.99	Asphalt%:	5.5	Summer	300	0.30	91		47.02	48.93	9.05	57.98
21	Name:	sphalt Concrete (Unmodified Asph		Density (pcf)	148	Fall	300	0.30	91		47.02	9.32	1.72	11.04
22	Use TAI:	Yes				Winter	1200	0.30	30		545.64	3.08	0.61	3.69
23											Total Damage:	83.70	15.44	99.14
24				Air%:		Spring	100	0.35		15.9	158.92		1.08	1.08
25	Thickness (in):	5	8.01	Asphalt%:		Summer	100	0.35		17.3	119.30		3.57	3.57
26	Name:	3-4% Asphalt Treated Base		Density:		Fall	100	0.35		17.3	119.30		0.68	0.68
27	Use TAI:					Winter	300	0.35		14.4	7810.52		0.04	0.04
28											Total Damage:		5.37	5.37
29				Air%:		Spring	35	0.40		6.7	85.06		2.02	2.02
30	Thickness (in):	24	13.01	Asphalt%:		Summer	40	0.40		7.5	93.01		4.57	4.57
31	Name:	Select A P200<6%		Density:		Fall	40	0.40		7.5	93.01		0.87	0.87
32	Use TAI:					Winter	90	0.40		5.8	3050.89		0.11	0.11
33											Total Damage:		7.57	7.57
34						Spring	5	0.45		0.8	72.19		2.38	2.38
35	Thickness (in):	0	37.01			Summer	5	0.45		0.8	76.23		5.58	5.58
36	Name:	Subgrade P200>30%				Fall	5	0.45		0.8	76.23		1.06	1.06
37						Winter	5	0.45		0.4	636.89		0.52	0.52
38											Total Damage:		9.54	9.54
39	C:\AKDOT&PF\Alaska Flexible Pavement Design\My FPD Projects\Overlay Design.xml													

Screen Clip 4-23

Step 6. For the purposes of this example, change the ATB -Stabilized Base Course thickness from 5.0 to 6.0 inches in the Existing Structure (Clip 4-24), then click ***Analyze.***


Overlay Mechanistic Design - Project: Overlay Design (Filename: Overlay Design.xml)

Unit: ● US Customary ○ Metric

Traffic Loads

Base AADT: 20,000

Total Design ESALs: 10,127,509

Total Past ESALs: 9,043,796

Select Location: ANCHORAGE INTL AP

☑ %Spring	☑ %Summer	☑ %Fall	☑ %Winter
17	42	8	33

Load Configuration

Tire Pressure: 110 (psi)

Tire Load: 4500 (lbs)

Description: ESAL

Load Locations (inch)	x	0	13.5				
	y	0	0				
Evaluation Points (inch)	x	0	6.75				
	y	0	0				

Pavement Structure

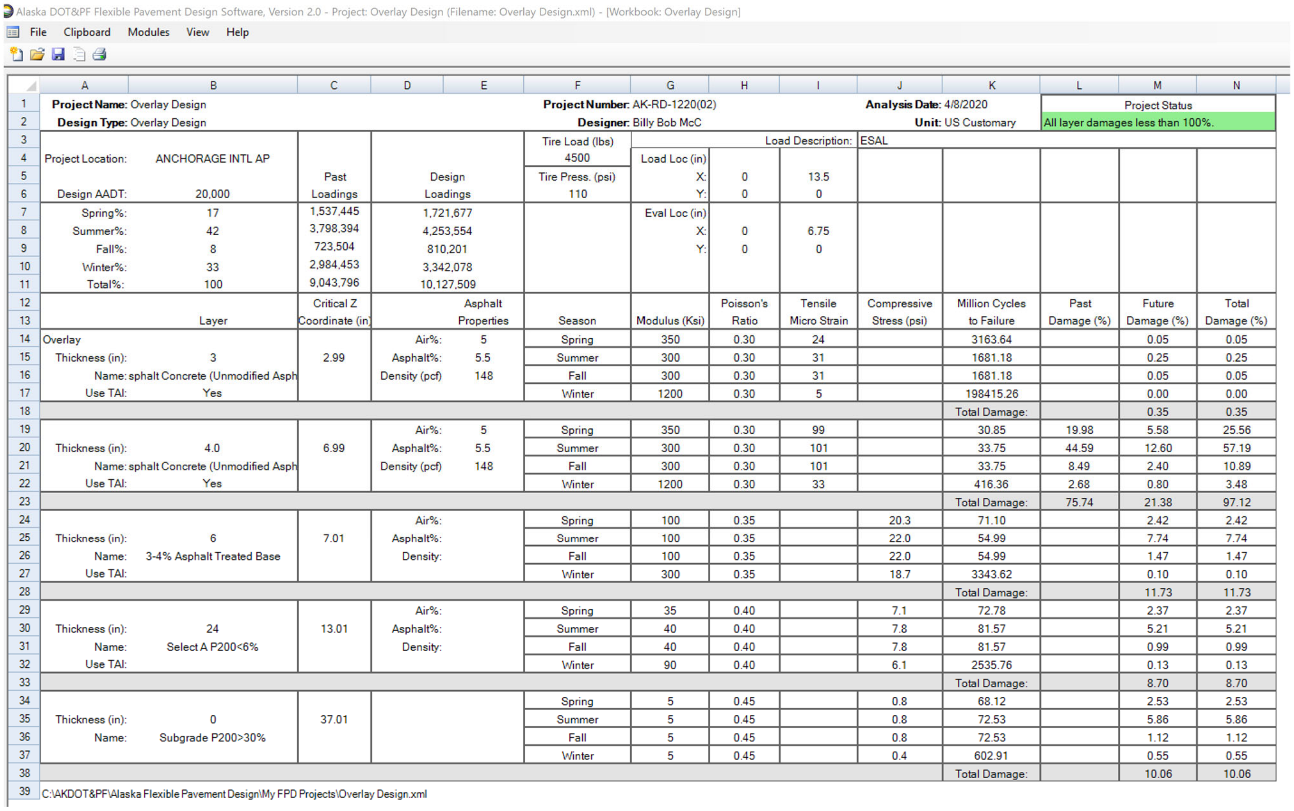
	Layer	Use TAI?	Thickness (inch)	Spring		Summer		Fall		Winter	
				Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio	Modulus (Ksi)	Poisson's Ratio
Overlay	Asphalt Concrete (Unm	☑	1.5	350	0.30	300	0.30	300	0.30	1200	0.30
Existing Structure	Asphalt Concrete (Unm	☑	4.0	350	0.30	300	0.30	300	0.30	1200	0.30
	3-4% Asphalt Treated E		6	100	0.35	100	0.35	100	0.35	300	0.35
	Select A P200<6%		24	35	0.40	40	0.40	40	0.40	90	0.40
	Subgrade P200>30%		0	5	0.45	5	0.45	5	0.45	5	0.45

Asphaltic Layer Properties

		% Air	% Asphalt	Density (pcf)
Overlay	Asphalt Concrete (Ui	5	5.5	148
Existing	Asphalt Concrete (Ui	5	5.5	148

Screen Clip 4-24

Step 7. Interpret the results (Clip 4-25). The total damage in the "Total Damage (%)" column is less than 100%. Note the damage in the overlay is almost zero. This is because this layer is subjected to small tensile strains. The purpose of the overlay is to reduce the tensile strain in the existing layer such that the number of cycles remaining is increased enough to extend the life by the design amount. Thus, the total damage in the existing asphalt layer will be almost 100% at the end of the overlay design period. As a result, future overlays will not be allowed. This will become important to consider in the Life Cycle Costing Module.



Alaska DOT&PF Flexible Pavement Design Software, Version 2.0 - Project: Overlay Design (Filename: Overlay Design.xml) - [Workbook: Overlay Design]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Project Name:** Overlay Design					**Project Number:** AK-RD-1220(02)				**Analysis Date:** 4/8/2020		Project Status		
2	**Design Type:** Overlay Design					**Designer:** Billy Bob McC				**Unit:** US Customary		All layer damages less than 100%.		
3						Tire Load (lbs)			Load Description:	ESAL				
4	Project Location:	ANCHORAGE INTL AP				4500	Load Loc (in)							
5			Past	Design		Tire Press. (psi)	X:	0	13.5					
6	Design AADT:	20,000	Loadings	Loadings		110	Y:	0	0					
7	Spring%:	17	1,537,445	1,721,677			Eval Loc (in)							
8	Summer%:	42	3,798,394	4,253,554			X:	0	6.75					
9	Fall%:	8	723,504	810,201			Y:	0	0					
10	Winter%:	33	2,984,453	3,342,078										
11	Total%:	100	9,043,796	10,127,509										
12			Critical Z		Asphalt			Poisson's	Tensile	Compressive	Million Cycles	Past	Future	Total
13		Layer	Coordinate (in)		Properties	Season	Modulus (Ksi)	Ratio	Micro Strain	Stress (psi)	to Failure	Damage (%)	Damage (%)	Damage (%)
14	Overlay			Air%:	5	Spring	350	0.30	24		3163.64		0.05	0.05
15	Thickness (in):	3	2.99	Asphalt%:	5.5	Summer	300	0.30	31		1681.18		0.25	0.25
16	Name:	sphalt Concrete (Unmodified Asph		Density (pcf)	148	Fall	300	0.30	31		1681.18		0.05	0.05
17	Use TAI:	Yes				Winter	1200	0.30	5		198415.26		0.00	0.00
18											Total Damage:		0.35	0.35
19				Air%:	5	Spring	350	0.30	99		30.85	19.98	5.58	25.56
20	Thickness (in):	4.0	6.99	Asphalt%:	5.5	Summer	300	0.30	101		33.75	44.59	12.60	57.19
21	Name:	sphalt Concrete (Unmodified Asph		Density (pcf)	148	Fall	300	0.30	101		33.75	8.49	2.40	10.89
22	Use TAI:	Yes				Winter	1200	0.30	33		416.36	2.68	0.80	3.48
23											Total Damage:	75.74	21.38	97.12
24				Air%:		Spring	100	0.35		20.3	71.10		2.42	2.42
25	Thickness (in):	6	7.01	Asphalt%:		Summer	100	0.35		22.0	54.99		7.74	7.74
26	Name:	3-4% Asphalt Treated Base		Density:		Fall	100	0.35		22.0	54.99		1.47	1.47
27	Use TAI:					Winter	300	0.35		18.7	3343.62		0.10	0.10
28											Total Damage:		11.73	11.73
29				Air%:		Spring	35	0.40		7.1	72.78		2.37	2.37
30	Thickness (in):	24	13.01	Asphalt%:		Summer	40	0.40		7.8	81.57		5.21	5.21
31	Name:	Select A P200<6%		Density:		Fall	40	0.40		7.8	81.57		0.99	0.99
32	Use TAI:					Winter	90	0.40		6.1	2535.76		0.13	0.13
33											Total Damage:		8.70	8.70
34						Spring	5	0.45		0.8	68.12		2.53	2.53
35	Thickness (in):	0	37.01			Summer	5	0.45		0.8	72.53		5.86	5.86
36	Name:	Subgrade P200>30%				Fall	5	0.45		0.8	72.53		1.12	1.12
37						Winter	5	0.45		0.4	602.91		0.55	0.55
38											Total Damage:		10.06	10.06
39	C:\AKDOT&PF\Alaska Flexible Pavement Design\My FPD Projects\Overlay Design.xml													

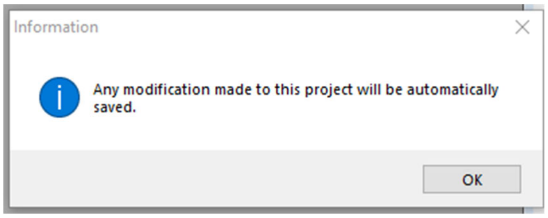
Screen Clip 4-25

4.8 Saving, Recalling, and Modifying Files

AKFPD software is designed to ensure no work is lost. The software uses a series of project specific spreadsheets compiled into an XML document used to save data. These spreadsheets are not available to the user except through AKFPD. Each time the user moves to a new screen or analyzes the data, the data are saved to the appropriate spreadsheet. When the user leaves the software, a warning appears requesting the user confirm the data have been saved.

At any time, a copy of the current file can be created and made current by clicking on ***File*** then ***Copy To*** on the ribbon at the top and entering a new name making sure the name is unique.

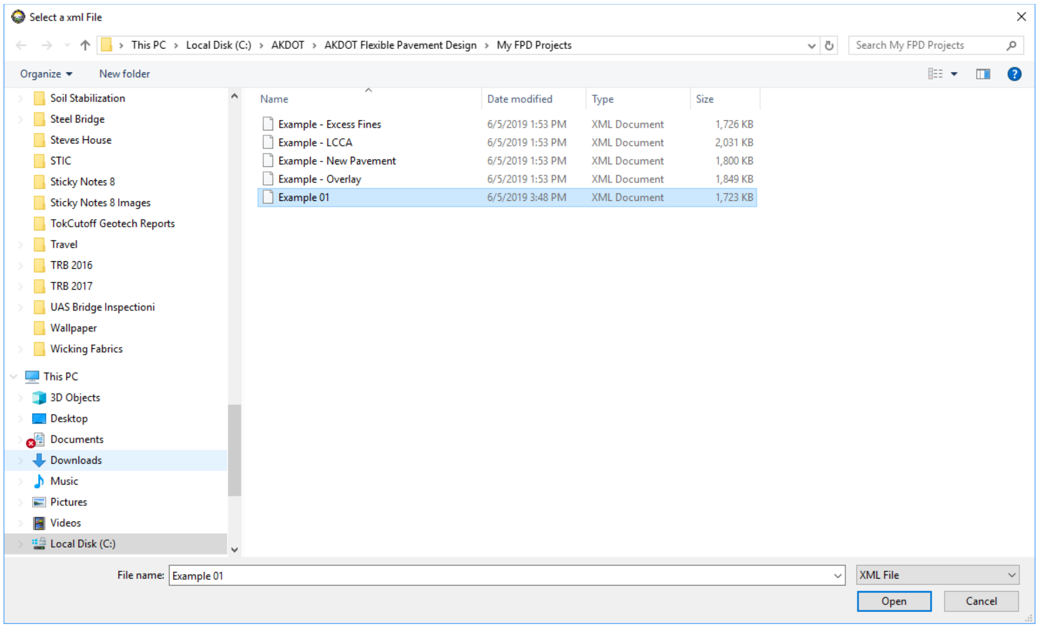
There are two ways of recalling an existing file. By clicking the ***Open Existing Design*** button on the landing page shown in Screen Clip 4-1, Screen Clip 4-26 will appear warning the user that modifications will be saved. Saved data will overwrite the existing data. The warning screen will be replaced with a list of available files (Screen Clip 4-27).



Information

Any modification made to this project will be automatically saved.

Screen Clip 4-26



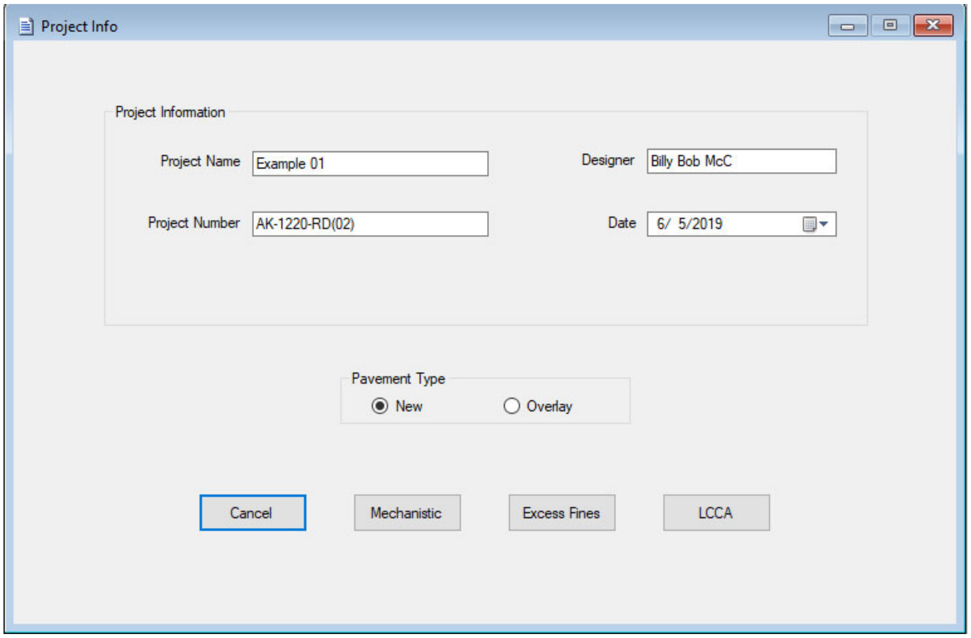
Name	Date modified	Type	Size
Example - Excess Fines	6/5/2019 1:53 PM	XML Document	1,726 KB
Example - LCCA	6/5/2019 1:53 PM	XML Document	2,031 KB
Example - New Pavement	6/5/2019 1:53 PM	XML Document	1,800 KB
Example - Overlay	6/5/2019 1:53 PM	XML Document	1,849 KB
Example 01	6/5/2019 3:48 PM	XML Document	1,723 KB

File name: Example 01

XML File

Screen Clip 4-27

Type in or select “Example01” and then click ***Open***. The Project Info page will open. (Screen Clip 4-28)



Project Name: Example 01

Designer: Billy Bob McC

Project Number: AK-1220-RD(02)

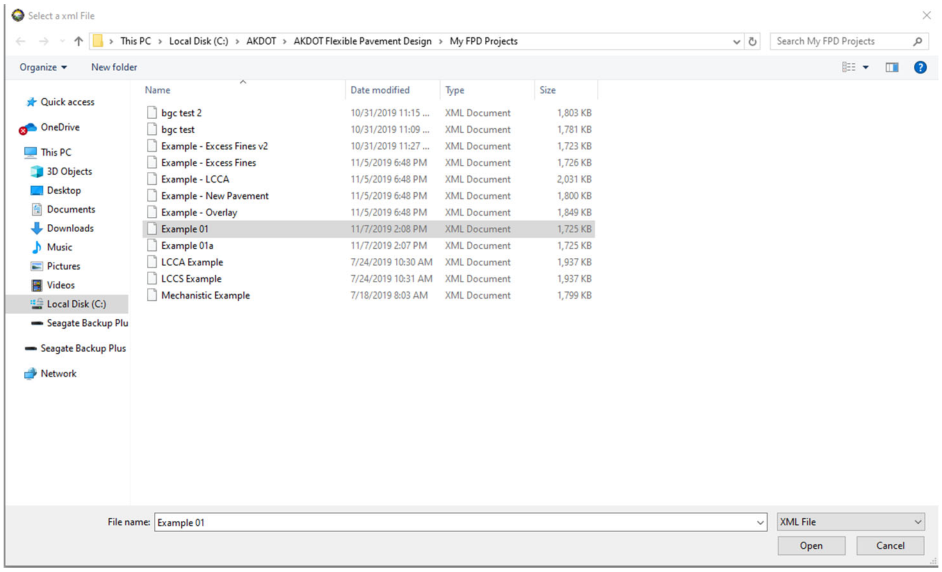
Date: 6/ 5/2019

● New ○ Overlay

Screen Clip 4-28

At this point, any changes to the data will overwrite the data in that file causing the loss of previously stored data.

If the user wishes to save the existing data, select ***Open a Copy of Existing Design*** from the opening screen (Clip 4-1). Available files will be displayed (Screen Clip 4-29).

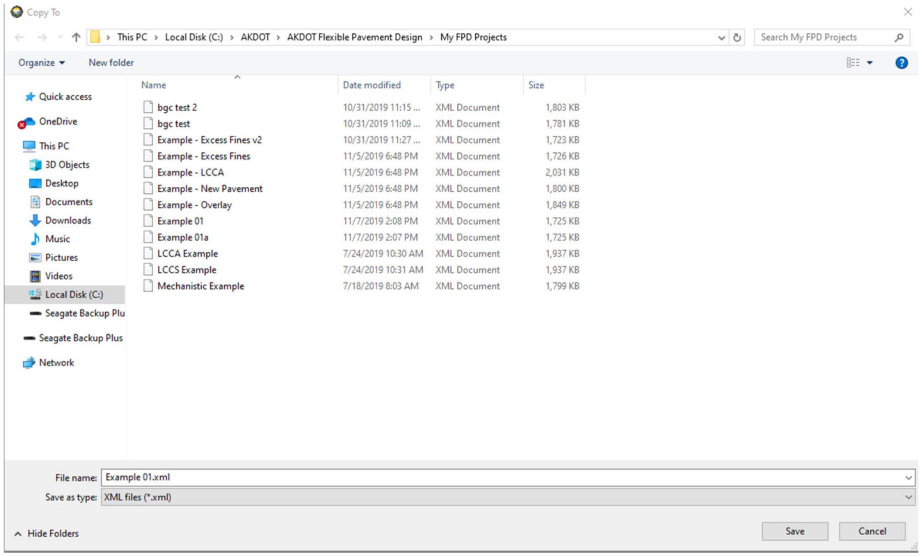


Name	Date modified	Type	Size
bgc test 2	10/31/2019 11:15 ...	XML Document	1,803 KB
bgc test	10/31/2019 11:09 ...	XML Document	1,781 KB
Example - Excess Fines v2	10/31/2019 11:27 ...	XML Document	1,723 KB
Example - Excess Fines	11/5/2019 6:48 PM	XML Document	1,726 KB
Example - LCCA	11/5/2019 6:48 PM	XML Document	2,031 KB
Example - New Pavement	11/5/2019 6:48 PM	XML Document	1,800 KB
Example - Overlay	11/5/2019 6:48 PM	XML Document	1,849 KB
Example 01	11/7/2019 2:08 PM	XML Document	1,725 KB
Example 01a	11/7/2019 2:07 PM	XML Document	1,725 KB
LCCA Example	7/24/2019 10:30 AM	XML Document	1,937 KB
LCCS Example	7/24/2019 10:31 AM	XML Document	1,937 KB
Mechanistic Example	7/18/2019 8:03 AM	XML Document	1,799 KB

File name: Example 01

Screen Clip 4-29

Select the desired file and click ***Open***, in this case Example 01. The screen shown in Screen Clip 4-30 will appear.

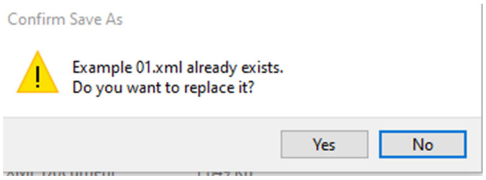


Name	Date modified	Type	Size
bgc test 2	10/31/2019 11:15 ...	XML Document	1,803 KB
bgc test	10/31/2019 11:09 ...	XML Document	1,781 KB
Example - Excess Fines v2	10/31/2019 11:27 ...	XML Document	1,723 KB
Example - Excess Fines	11/5/2019 6:48 PM	XML Document	1,726 KB
Example - LCCA	11/5/2019 6:48 PM	XML Document	2,031 KB
Example - New Pavement	11/5/2019 6:48 PM	XML Document	1,800 KB
Example - Overlay	11/5/2019 6:48 PM	XML Document	1,849 KB
Example 01	11/7/2019 2:08 PM	XML Document	1,725 KB
Example 01a	11/7/2019 2:07 PM	XML Document	1,725 KB
LCCA Example	7/24/2019 10:30 AM	XML Document	1,937 KB
LCCS Example	7/24/2019 10:31 AM	XML Document	1,937 KB
Mechanistic Example	7/18/2019 8:03 AM	XML Document	1,799 KB

File name: Example 01.xml
Save as type: XML files (*.xml)

Screen Clip 4-30

Note that this screen looks much like the previous screen except the button in the lower right has been changed from "Open" to "Save". Give the filename a unique name such as "Example 01a" indicating this is a variation of Example 01. If a unique name is not selected or the user forgets to change the name a message will appear as shown in Screen Clip 4-31.



Example 01.xml already exists.
Do you want to replace it?

Screen Clip 4-31

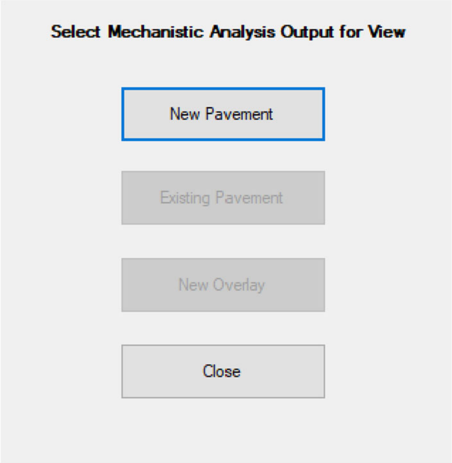
Select ***No*** to go back to the file list to revise the name. Select ***Yes*** to accept the name and the data in that file will be replaced with the new data. From this point forward any changes to the file will overwrite existing data. If the user does not wish to make changes to the file either click ***File,*** then ***Exit*** and restart the program or click ***File*** then ***Close All.***

4.9 Advanced Users

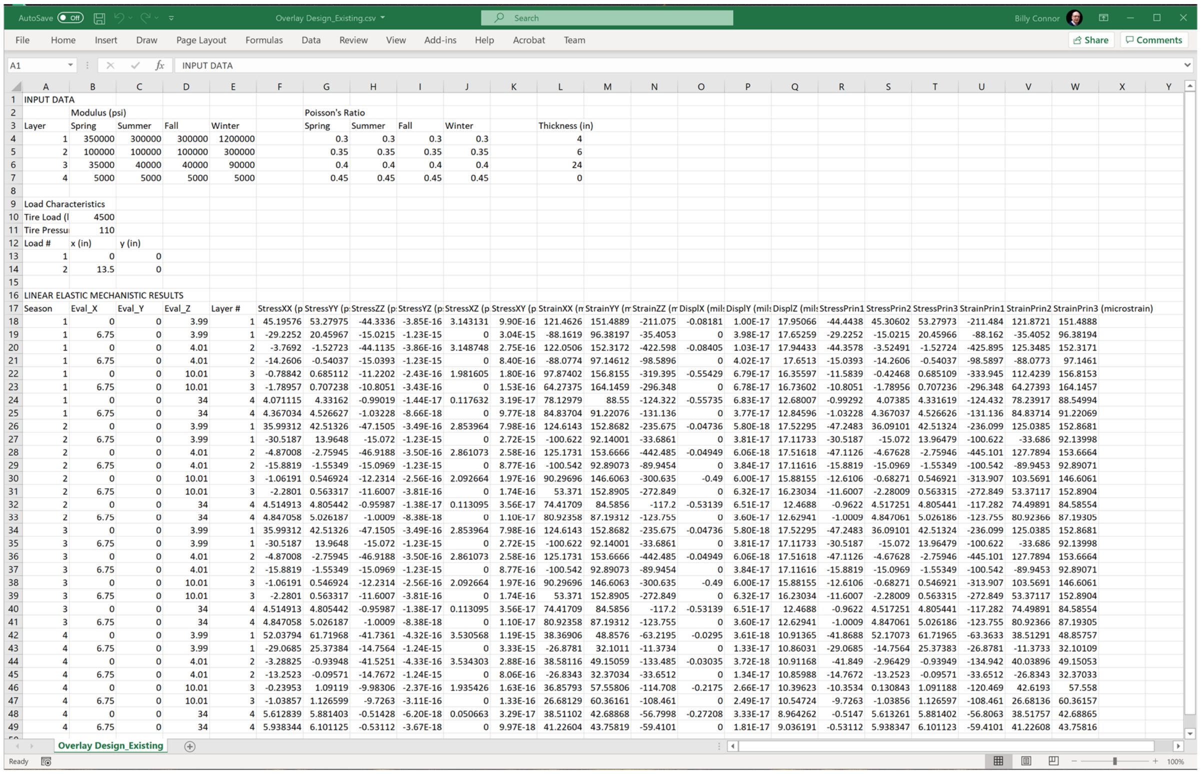
The AKFPD mechanistic module provides the advanced user with a summary of all stresses and strains in the pavement structure at the desired location. These points are defined as the top of unbound layers and at the bottom of bound layers. Consequently, the stresses and strains reported can be controlled by the definition of layers. The steps to produce the report are the same as for a mechanistic-empirical design with one exception. From the report shown in Screen Clip 4-17 click *Modules* followed by *Mechanistic Responses (WESLEA Output).* Select the desired report as shown in Screen Clip 4-32. Note that only *New Pavement* option is available if there is no overlay.

A .csv spreadsheet with the same name as the current analysis will be created in the "C:\AKDOT&PF\Alaska Flexible Pavement Design\My FPD Projects" subdirectory. Note, this file may be opened directly into Excel at any time. The spreadsheet contains the stresses and strains at the specified locations as shown in Screen Clip 4-33. The results shown in Screen Clip 4-33 are the partial results in the interest of saving space. The user may wish to save the file.

A full discussion of the results is not provided here since it is assumed that anyone wishing to use these results has a well-founded understanding of soil mechanics as they apply to mechanistic pavement design.



Screen Clip 4-32



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1	INPUT DATA																								
2		Modulus (psi)					Poisson's Ratio																		
3	Layer	Spring	Summer	Fall	Winter		Spring	Summer	Fall	Winter		Thickness (in)													
4	1	350000	300000	300000	1200000		0.3	0.3	0.3	0.3		4													
5	2	100000	100000	100000	300000		0.35	0.35	0.35	0.35		6													
6	3	35000	40000	40000	90000		0.4	0.4	0.4	0.4		24													
7	4	5000	5000	5000	5000		0.45	0.45	0.45	0.45		0													
8																									
9	Load Characteristics																								
10	Tire Load (l	4500																							
11	Tire Pressu	110																							
12	Load #	x (in)	y (in)																						
13	1	0	0																						
14	2	13.5	0																						
15																									
16	LINEAR ELASTIC MECHANISTIC RESULTS																								
17	Season	Eval_X	Eval_Y	Eval_Z	Layer #	StressXX (p	StressYY (p	StressZZ (p	StressYZ (p	StressXZ (p	StressXY (p	StrainXX (m	StrainYY (m	StrainZZ (m	DisplX (mils	DisplY (mils	DisplZ (mils	StressPrin1	StressPrin2	StressPrin3	StrainPrin1	StrainPrin2	StrainPrin3	(microstrain)	
18	1	0	0	3.99	1	45.19576	53.27975	-44.3336	-3.85E-16	3.143131	9.90E-16	121.4626	151.4889	-211.075	-0.08181	1.00E-17	17.95066	-44.4438	45.30602	53.27973	-211.484	121.8721	151.4888		
19	1	6.75	0	3.99	1	-29.2252	20.45967	-15.0215	-1.23E-15	0	3.04E-15	-88.1619	96.38197	-35.4053	0	3.98E-17	17.65259	-29.2252	-15.0215	20.45966	-88.162	-35.4052	96.38194		
20	1	0	0	4.01	2	-3.7692	-1.52723	-44.1135	-3.86E-16	3.148748	2.75E-16	122.0506	152.3172	-422.598	-0.08405	1.03E-17	17.94433	-44.3578	-3.52491	-1.52724	-425.895	125.3485	152.3171		
21	1	6.75	0	4.01	2	-14.2606	-0.54037	-15.0393	-1.23E-15	0	8.40E-16	-88.0774	97.14612	-98.5896	0	4.02E-17	17.6513	-15.0393	-14.2606	-0.54037	-98.5897	-88.0773	97.1461		
22	1	0	0	10.01	3	-0.78842	0.685112	-11.2202	-2.43E-16	1.981605	1.80E-16	97.87402	156.8155	-319.395	-0.55429	6.79E-17	16.35597	-11.5839	-0.42468	0.685109	-333.945	112.4239	156.8153		
23	1	6.75	0	10.01	3	-1.78957	0.707238	-10.8051	-3.43E-16	0	1.53E-16	64.27375	164.1459	-296.348	0	6.78E-17	16.73602	-10.8051	-1.78956	0.707236	-296.348	64.27393	164.1457		
24	1	0	0	34	4	4.071115	4.33162	-0.99019	-1.44E-17	0.117632	3.19E-17	78.12979	88.55	-124.322	-0.55735	6.83E-17	12.68007	-0.99292	4.07385	4.331619	-124.432	78.23917	88.54994		
25	1	6.75	0	34	4	4.367034	4.526627	-1.03228	-8.66E-18	0	9.77E-18	84.83704	91.22076	-131.136	0	3.77E-17	12.84596	-1.03228	4.367037	4.526626	-131.136	84.83714	91.22069		
26	2	0	0	3.99	1	35.99312	42.51326	-47.1505	-3.49E-16	2.853964	7.98E-16	124.6143	152.8682	-235.675	-0.04736	5.80E-18	17.52295	-47.2483	36.09101	42.51324	-236.099	125.0385	152.8681		
27	2	6.75	0	3.99	1	-30.5187	13.9648	-15.072	-1.23E-15	0	2.72E-15	-100.622	92.14001	-33.6861	0	3.81E-17	17.11733	-30.5187	-15.072	13.96479	-100.622	-33.686	92.13998		
28	2	0	0	4.01	2	-4.87008	-2.75945	-46.9188	-3.50E-16	2.861073	2.58E-16	125.1731	153.6666	-442.485	-0.04949	6.06E-18	17.51618	-47.1126	-4.67628	-2.75946	-445.101	127.7894	153.6664		
29	2	6.75	0	4.01	2	-15.8819	-1.55349	-15.0969	-1.23E-15	0	8.77E-16	-100.542	92.89073	-89.9454	0	3.84E-17	17.11616	-15.8819	-15.0969	-1.55349	-100.542	-89.9453	92.89071		
30	2	0	0	10.01	3	-1.06191	0.546924	-12.2314	-2.56E-16	2.092664	1.97E-16	90.29696	146.6063	-300.635	-0.49	6.00E-17	15.88155	-12.6106	-0.68271	0.546921	-313.907	103.5691	146.6061		
31	2	6.75	0	10.01	3	-2.2801	0.563317	-11.6007	-3.81E-16	0	1.74E-16	53.371	152.8905	-272.849	0	6.32E-17	16.23034	-11.6007	-2.28009	0.563315	-272.849	53.37117	152.8904		
32	2	0	0	34	4	4.514913	4.805442	-0.95987	-1.38E-17	0.113095	3.56E-17	74.41709	84.5856	-117.2	-0.53139	6.51E-17	12.4688	-0.9622	4.517251	4.805441	-117.282	74.49891	84.58554		
33	2	6.75	0	34	4	4.847058	5.026187	-1.0009	-8.38E-18	0	1.10E-17	80.92358	87.19312	-123.755	0	3.60E-17	12.62941	-1.0009	4.847061	5.026186	-123.755	80.92366	87.19305		
34	3	0	0	3.99	1	35.99312	42.51326	-47.1505	-3.49E-16	2.853964	7.98E-16	124.6143	152.8682	-235.675	-0.04736	5.80E-18	17.52295	-47.2483	36.09101	42.51324	-236.099	125.0385	152.8681		
35	3	6.75	0	3.99	1	-30.5187	13.9648	-15.072	-1.23E-15	0	2.72E-15	-100.622	92.14001	-33.6861	0	3.81E-17	17.11733	-30.5187	-15.072	13.96479	-100.622	-33.686	92.13998		
36	3	0	0	4.01	2	-4.87008	-2.75945	-46.9188	-3.50E-16	2.861073	2.58E-16	125.1731	153.6666	-442.485	-0.04949	6.06E-18	17.51618	-47.1126	-4.67628	-2.75946	-445.101	127.7894	153.6664		
37	3	6.75	0	4.01	2	-15.8819	-1.55349	-15.0969	-1.23E-15	0	8.77E-16	-100.542	92.89073	-89.9454	0	3.84E-17	17.11616	-15.8819	-15.0969	-1.55349	-100.542	-89.9453	92.89071		
38	3	0	0	10.01	3	-1.06191	0.546924	-12.2314	-2.56E-16	2.092664	1.97E-16	90.29696	146.6063	-300.635	-0.49	6.00E-17	15.88155	-12.6106	-0.68271	0.546921	-313.907	103.5691	146.6061		
39	3	6.75	0	10.01	3	-2.2801	0.563317	-11.6007	-3.81E-16	0	1.74E-16	53.371	152.8905	-272.849	0	6.32E-17	16.23034	-11.6007	-2.28009	0.563315	-272.849	53.37117	152.8904		
40	3	0	0	34	4	4.514913	4.805442	-0.95987	-1.38E-17	0.113095	3.56E-17	74.41709	84.5856	-117.2	-0.53139	6.51E-17	12.4688	-0.9622	4.517251	4.805441	-117.282	74.49891	84.58554		
41	3	6.75	0	34	4	4.847058	5.026187	-1.0009	-8.38E-18	0	1.10E-17	80.92358	87.19312	-123.755	0	3.60E-17	12.62941	-1.0009	4.847061	5.026186	-123.755	80.92366	87.19305		
42	4	0	0	3.99	1	52.03794	61.71968	-41.7361	-4.32E-16	3.530568	1.19E-15	38.36906	48.8576	-63.2195	-0.0295	3.61E-18	10.91365	-41.8688	52.17073	61.71965	-63.3633	38.51291	48.85757		
43	4	6.75	0	3.99	1	-29.0685	25.37384	-14.7564	-1.24E-15	0	3.33E-15	-26.8781	32.1011	-11.3734	0	1.33E-17	10.86031	-29.0685	-14.7564	25.37383	-26.8781	-11.3733	32.10109		
44	4	0	0	4.01	2	-3.28825	-0.93948	-41.5251	-4.33E-16	3.534303	2.88E-16	38.58116	49.15059	-133.485	-0.03035	3.72E-18	10.91168	-41.849	-2.96429	-0.93949	-134.942	40.03896	49.15053		
45	4	6.75	0	4.01	2	-13.2523	-0.09571	-14.7672	-1.24E-15	0	8.06E-16	-26.8343	32.37034	-33.6512	0	1.34E-17	10.85988	-14.7672	-13.2523	-0.09571	-33.6512	-26.8343	32.37033		
46	4	0	0	10.01	3	-0.23953	1.09119	-9.98306	-2.37E-16	1.935426	1.63E-16	36.85793	57.55806	-114.708	-0.2175	2.66E-17	10.39623	-10.3534	0.130843	1.091188	-120.469	42.6193	57.558		
47	4	6.75	0	10.01	3	-1.03857	1.126599	-9.7263	-3.11E-16	0	1.33E-16	26.68129	60.36161	-108.461	0	2.49E-17	10.54724	-9.7263	-1.03856	1.126597	-108.461	26.68136	60.36157		
48	4	0	0	34	4	5.612839	5.881403	-0.51428	-6.20E-18	0.050663	3.29E-17	38.51102	42.68868	-56.7998	-0.27208	3.33E-17	8.964262	-0.5147	5.613261	5.881402	-56.8063	38.51757	42.68865		
49	4	6.75	0	34	4	5.938344	6.101125	-0.53112	-3.67E-18	0	9.97E-18	41.22604	43.75819	-59.4101	0	1.81E-17	9.036191	-0.53112	5.938347	6.101123	-59.4101	41.22608	43.75816		

Screen Clip 4-33