Composite Pavements: A Technical and Economic Analysis During the Pavement Type Selection Process

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(Abstract)

In most road infrastructure networks, the two prevalent types of pavements considered during the pavement type selection (PTS) process are flexible and rigid. Thus, these two structures are the most commonly constructed in the road industry. A consideration of a different pavement alternative is proposed in this study. Composite pavements, which are in essence a combination of a rigid base overlaid with a hot-mix asphalt (HMA) surface course, have the potential to meet the technical and economic requirements that are sought in the PTS process. For that reason, technical and economic evaluations were performed to justify the consideration of composite pavement systems in the PTS process.

At the technical level, composite pavement design guidelines from various transportation agencies were obtained and followed to design their respective composite pavement structures. A mechanistic analysis based on the multi-layer linear elastic theory was performed on different composite structures to understand the behavior they present when compared to traditional pavements. In addition, distresses affecting composite pavements such as fatigue (bottom-up and top-down) cracking, rutting, and reflective cracking were modeled and investigated using sensitivity analyses. At the economic level, a deterministic life cycle cost analysis (LCCA) based on Virginia Department of Transportation (VDOT) guidelines was performed. This LCCA compared two proposed composite pavements (one with a cement-treated base [CTB] and the other with a continuously reinforced concrete pavement [CRCP] base) to traditional flexible and rigid pavement structures. Furthermore, sensitivity analyses involving discount rates and traffic volumes were performed to investigate their effect on the present worth (PW) computation of the four pavement alternatives. Results from this study suggest that composite pavements have both the technical and economic potential to be considered during the PTS process.

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Acronyms and Abbreviations

AADT	annual average daily traffic
AAF	aging adjustment factor
AASHTO	American Association of State Highway and Transportation Officials
AC	asphalt concrete
ACI	American Concrete Institute
ADT	average daily traffic
AI	Asphalt Institute
CBM	cement-bound material
CBR	California bearing ratio
CRCP	continuously reinforced concrete pavement
CSM	chemically stabilized mixture
CTA	cement-treated aggregate
CTB	cement-treated base
ERDC	Engineering Research and Development Center
ESAL	equivalent single-axle load
EUAC	equivalent uniform annual cost
FAF	field adjustment factor
HMA	hot-mix asphalt
IDOT	Illinois Department of Transportation
JPCP	jointed plain concrete pavement
LCCA	life cycle cost analysis
LEA	linear elastic analysis
MEPDG	Mechanistic-Empirical Pavement Design Guide
M&R	maintenance and repair
MR	modulus of rupture
MSA	million single axle
NPV	net present value
PCA	Portland Cement Association
PCC	Portland cement concrete

PCCP	Portland cement concrete pavement
PSI	present serviceability index
PTS	pavement type selection
PW	present worth
RCC	roller-compacted concrete
RUC	road user cost(s)
SR	stress ratio
TAF	temperature adjustment factor
VDOT	Virginia Department of Transportation
VOC	vehicle operating cost(s)

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CHAPTER 1 INTRODUCTION

1.1 Background

In the road industry, the two most commonly designed and constructed pavement types are flexible and rigid. For a transportation agency to decide the best pavement alternative for a particular project, a pavement type selection (PTS) process is typically followed. This process helps pavement engineers determine the most cost-effective pavement type capable of supporting anticipated traffic under existing environmental conditions and providing safety and driving comfort to the traveling public (VDOT 2001).

This investigation studied composite pavement systems and the potential benefits they offer to pavement engineers. A composite pavement, which is in essence a combination of flexible and rigid layers, could potentially meet all design considerations and become a feasible alternative if considered during the PTS process. Technical and economic evaluations were performed to justify the consideration of composite pavements in the PTS process. At the technical level, a mechanistic analysis was performed on different composite structures to understand the behavior of composite pavements compared to that of traditional structures. The multi-layer linear elastic theory was used to investigate the behavior and interaction of the flexible and rigid layers of the composite structure. At the economic level, a deterministic life cycle cost analysis (LCCA) was performed to compare traditional pavements (i.e., flexible and rigid) to the composite one. The LCCA guidelines used for this investigation were obtained from the Virginia Department of Transportation (VDOT) LCCA publication (VDOT, 2002).

1.2 Problem Statement

For many years, the two prevalent pavement alternatives for the road and highway infrastructure have been rigid and flexible pavements. However, other pavement options have become available for pavement engineers to consider. Composite pavements, which are a combination of a rigid base layer and a flexible surface course, are increasingly considered a viable alternative on high-volume highway projects worldwide. To assist pavement engineers and transportation agencies in their consideration of this pavement type during the PTS process, a technical and economic study should be performed to understand the advantages, limitations, and feasibility of designing and constructing a composite pavement.

1.3 Research Objectives

The primary objectives of this thesis study are the following:

- Propose the consideration of composite pavements, supported by a technical and economic investigation, as a viable alternative in the PTS process.
- Model the mechanistic behavior of composite pavements using software based on multi-layer linear elastic theory.
- Analyze the technical advantages and disadvantages of composite pavements.
- Investigate the economic aspects related to composite pavements through a deterministic LCCA.

1.4 Research Scope

Chapter 1 summarizes the background information, problem statement, research objectives, and significance of the thesis. Chapter 2 provides a literature review regarding typical composite pavement analysis, design approaches and methodologies, worldwide experience of composite pavements, and potential benefits. Chapter 3 presents the technical evaluation and the economic evaluation based on a deterministic LCCA. Chapter 4 presents the findings, conclusions, contribution of the study, and recommendation for future research regarding composite pavement systems.

1.5 Significance

An understanding of the behavior of new pavement systems is needed due to the continuous advances in pavement technology. This thesis provides the mechanistic modeling of various composite pavement structures, which can be considered a new type of pavement and differ from the traditional flexible and rigid ones. Stresses, strains, and deflections were computed and plots showing their distribution are explained and discussed. The behavior of composite structures in terms of common pavement distresses such as fatigue (bottom-up and top-down) cracking, permanent deformation (rutting), and reflective cracking was investigated using sensitivity analyses and models available from the literature. In addition to the technical investigation, it is important to determine the viability of a new pavement alternative. Therefore, an economic LCCA evaluation was performed to explore the cost-effectiveness of composite pavements. Finally, using the results from both the technical and economic evaluations, a recommendation on whether to consider composite pavements during the PTS process is given.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

The pavement type selection (PTS) process involves a thorough analysis of the pavement alternatives available for a project. The PTS procedure determines the most cost-effective pavement type capable of supporting the predicted traffic under the prevailing environmental conditions while contributing to safety and driver comfort (VDOT 2001). When performing a PTS, three primary areas need to be addressed: pavement design analysis, life cycle cost analysis (LCCA), and engineering analysis (WSDOT 2005). Each of these aspects has significant impact on PTS decision making.

2.2 Pavement Type Selection (PTS) Process

The first step in the PTS flowchart shown in Fig. 2-1 involves the review and analysis of several pavement design factors such as subgrade, traffic, materials, climate/drainage, environment, and construction (WSDOT 2005). In this step, the pavement design is performed following a standard design methodology, either empirically or mechanistically based. Some of the input parameters during the pavement design stage have a higher impact on the final alternatives to be considered. For example, correctly estimating the traffic volume is crucial when selecting an appropriate pavement; good historical records and an accurate prediction of future traffic is of great importance when designing any pavement alternative. The typical methodology used to design pavements is the AASHTO Guide for Design of Pavement Structures (AASHTO 1993). This empirically-based method includes equations and procedures to design new flexible and rigid pavement alternatives as well as their rehabilitation options. Nonetheless, various design methods, equations, procedures, and recommendations for composite pavements are now documented in the United States and worldwide.

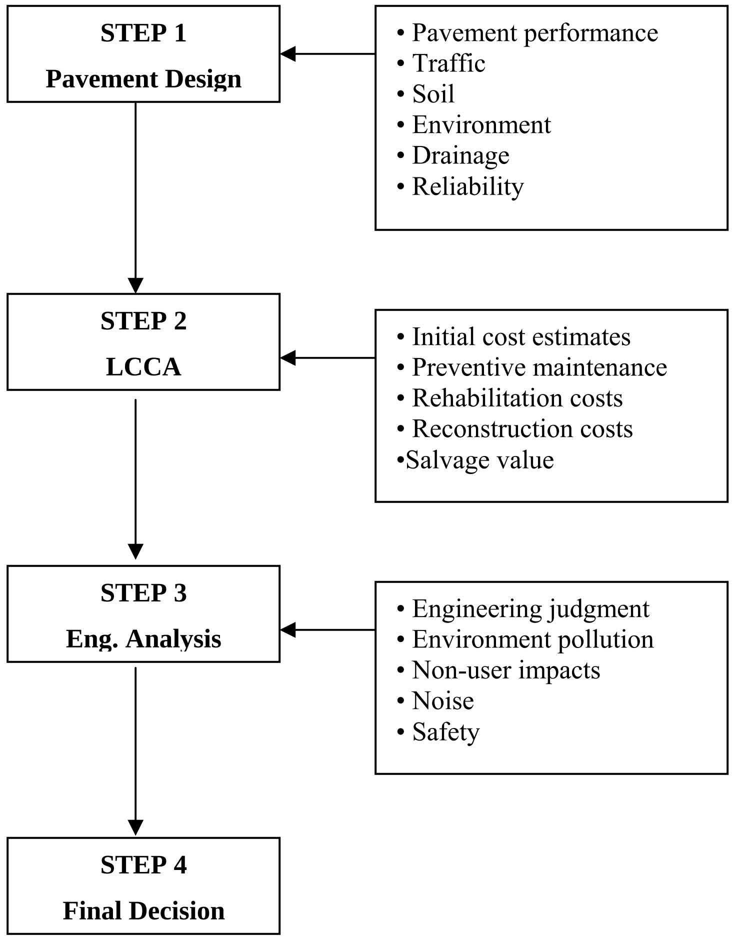

FIGURE 2-1 Typical PTS Flowchart
Source: Adapted from WSDOT 2005

The life cycle cost analysis (LCCA) step provides the pavement engineer with economic models and tools to determine the most cost-effective pavement alternative. Life cycle costs refer to all pavement costs involved with construction, maintenance, rehabilitation, and user-related costs over a given analysis period. They are also defined as the total cost of a pavement alternative until a major reconstruction occurs; at this point, a new life cycle starts (WSDOT 2005). The engineering analysis step involves considerations that are not accounted in the pavement design or LCCA steps such as environmental pollution, non-user impacts such as congestion, tire-pavement noise, and road safety. After the engineering analysis step, a decision (step 4) has to be made considering the technical factors (pavement design, step 1) and the economic factors (LCCA, step 2). This decision should also consider engineering judgment, environmental concerns, non-user impacts, noise, and safety. Even though it is challenging to quantify some of these factors, an effort should be made to minimize negative impacts on environmental and safety factors, among others. An engineering analysis for composite pavements is beyond the scope of this study.

2.2.1 Typical Pavement Structures in the PTS Process

The two most prevalent pavement structures considered as the main options during the PTS process are flexible and rigid pavements. Each of these structures differs from the other in several aspects, including design procedure, service life, deterioration (distress models), construction, and rehabilitation options, among others.

2.2.1.1 Flexible Pavement Structures

Flexible pavements are constructed of bituminous and granular materials (Huang 2004). Their structure is composed of several layers that gradually distribute loads from the hot-mix asphalt (HMA) surface layer to the layers underneath (e.g., granular base, subbase, subgrade). This type of pavement structure ensures that the load transmitted to the successive layers does not exceed each layer's load bearing capacity (Druta 2006). A typical flexible pavement cross-section is shown in Fig. 2-2.

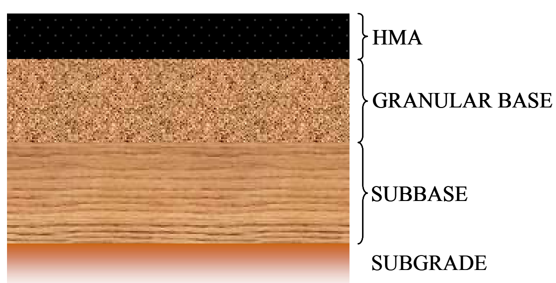

FIGURE 2-2 Typical Flexible Pavement Structure

The design methodology used by the majority of transportation agencies in the United States is based on the AASHTO 1993 Guide for Design of Pavement Structures. This design procedure uses various input parameters to obtain a structural number (SN), which then is used to compute the minimum thicknesses of each of the structural layers that would satisfy the traffic demand of the road. The SN is a method used to quantify the structural capacity of the pavement system.

The surface course material (i.e., HMA) used in composite pavements is the same as that used in purely flexible pavements. As a result, the potential distresses that affect the HMA surface layer are typically investigated using various transfer functions (distress models), which relate structural responses to various types of distresses (Huang 2004). The two most commonly used transfer functions for HMA are fatigue cracking and rutting. For fatigue cracking, Equations 2-1 and 2-2 are generally used.

$$N_f = f_1 \left(\varepsilon_t\right)^{-f_2} \left(E_1\right)^{-f_3} \tag{2-1}$$

$$N_f = f_1 \left(\varepsilon_t\right)^{-f_2} \tag{2-2}$$

where

N_f = number of load repetitions to fatigue cracking

ε_t = tensile strain at the bottom of the HMA layer

E_1 = HMA modulus

f_1 and f_2 = experimentally-determined coefficients

Various transfer functions following the two general models (i.e., Equations 2-1 and 2-2) have been developed by various transportation agencies. The Asphalt Institute fatigue cracking equation for 20 percent of the area cracked is

$$N_f = 0.0796\left(\varepsilon_t\right)^{-3.291} \left(E_1\right)^{-0.854} \tag{2-3}$$

and the Shell equation is

$$N_f = 0.0685\left(\varepsilon_t\right)^{-5.671} \left(E_1\right)^{-2.363} \tag{2-4}$$

Other transportation agencies have proposed different fatigue transfer functions that use Equation 2-2 as the base for their fatigue equations. The Illinois Department of Transportation (IDOT) recommends the following (IDOT 2002):

$$N_f = 5\times10^{-6} \left(\varepsilon_t\right)^{-3.0} \tag{2-5}$$

whereas the Transport Research Laboratory in the United Kingdom presents the following equation:

$$N_f = 1.66 \times 10^{-10} \left(\varepsilon_t\right)^{-4.32} \qquad (2\text{-}6)$$

Two procedures have been used to model rutting or permanent deformation: one limits the vertical compressive strain on top of the subgrade, and the other limits the total accumulated permanent deformations for each individual layer (Huang 2004). The first procedure, which limits the vertical compressive strain on top of the subgrade, has also been defined by several agencies and has the generic form of

$$N_d = f_4 \left(\varepsilon_c\right)^{-f_5} \qquad (2\text{-}7)$$

where

N_d = number of load repetitions to cause permanent deformation on the subgrade

ε_c = vertical compressive strain on top of the subgrade

f_4 and f_5 = experimentally-determined coefficients

The f_4 and f_5 values vary according to the agency criteria used. The Asphalt Institute defines a rut depth of 0.5 in. and models the rutting due to the subgrade permanent deformation according to Equation 2-8:

$$N_d = 1.365 \times 10^{-9} \left(\varepsilon_c\right)^{-4.477} \qquad (2\text{-}8)$$

The Shell transfer function revised in 1985 with an 85 percent reliability uses the following equation:

$$N_d = 1.94 \times 10^{-7} \left(\varepsilon_c\right)^{-4.0} \qquad (2\text{-}9)$$

The Transport Research Laboratory defines 0.4 in. of rutting with an 85 percent reliability in their equation:

$$N_d = 6.18 \times 10^{-8} \left(\varepsilon_c\right)^{-3.95} \qquad (2\text{-}10)$$

The rutting that occurs within the HMA layer is one of the most important distresses to account for in flexible pavements. The equation used in this study is the one proposed by the NCHRP

1-37A Mechanistic-Empirical Pavement Design Guide (MEPDG). This equation is based on statistical analyses of repeated load permanent deformation laboratory tests (NCHRP 2004). The model has the following form:

$$\frac{\varepsilon_p}{\varepsilon_r} = 10^{-3.15552} T^{1.734} N^{0.39937} \tag{2-11}$$

where

ε_p = accumulated plastic strain at N repetitions of load (in./in.)

ε_r = resilient strain of the asphalt material as a function of mix properties, temperature, and time rate of loading (in./in.)

N = number of load repetitions

T = temperature (ºF)

Both HMA distress models (i.e., fatigue and rutting) were considered during the technical analysis of composite pavements.

2.2.1.2 Rigid Pavement Structures

A rigid pavement structure is constructed of a Portland cement concrete (PCC) slab on top of a base, subbase, or directly over compacted subgrade. This type of structure is designed to support loads through flexural action. A typical rigid pavement structure is shown in Fig. 2-3.

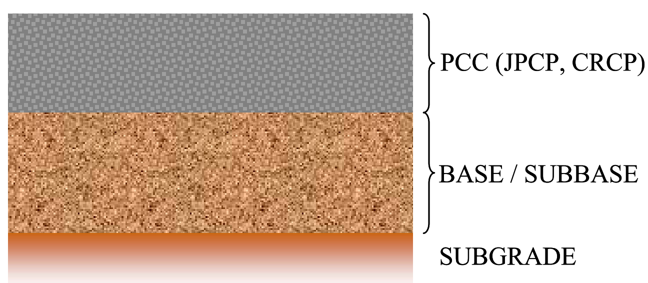

FIGURE 2-3 Typical Rigid Pavement Structure

The design methodology usually used for rigid pavements is the AASHTO 1993 method (VDOT 2003). During the design process, various parameters (e.g., drainage, reliability) and concrete properties, such as elastic modulus and modulus of rupture (MR), are taken into consideration to compute the required slab thickness that would satisfy the traffic demand. Like flexible pavements, the slab fatigue cracking distress for rigid pavements has been modeled by many agencies. The rigid layer fatigue transfer function recommended by the Portland Cement Association (PCA) is shown in Equations 2-12 through 2-14; it has a criterion based on the ratio of equivalent stress to PCC flexural strength (which is the same as MR) to select the appropriate equation.

$$SR \geq 0.55: \qquad \text{Log}\left(N_f\right) = 11.737 - 12.077 \cdot SR \tag{2-12}$$

$$0.45 < SR < 0.55: \qquad N_f = \left(\frac{4.2577}{SR - 0.4325}\right)^{3.268} \tag{2-13}$$

$$SR \leq 0.45: \qquad N_f = \text{unlimited} \tag{2-14}$$

where

SR = ratio of equivalent stress to PCC flexural strength (as defined in Equation 2-15)

N_f = allowable number of repetitions to fatigue cracking

$$SR = \frac{\sigma_{eq}}{MR} \tag{2-15}$$

where

σ_{eq} = equivalent stress = flexural stress in slab

MR = modulus of rupture of concrete = PCC flexural strength

A general relationship used to estimate the MR term is the one shown in Equation 2-16. This relationship uses the compressive strength, which is typically a measured concrete property, to obtain the MR.

$$MR = 8\sqrt{f_c^{'}} \text{ to } 10\sqrt{f_c^{'}} \tag{2-16}$$

where

$f_c^{'}$ = compressive strength in psi

The fatigue model described was used in this study's technical evaluation of composite pavements when a PCC slab or roller-compacted concrete (RCC) base was part of the composite structure.

2.2.2 Life Cycle Cost Analysis (LCCA) in the PTS Process

An LCCA is an economic tool often used during decision-making processes. In road construction, it involves the evaluation of all project costs during the life of the pavement. The initial costs and discounted future costs such as maintenance, user-related costs, rehabilitation, restoring, resurfacing, and salvage value are all taken into consideration in an LCCA to make the most appropriate decision. Both initial construction costs and life cycle costs are important factors to consider (Beg et al. 1998).

During a PTS process, from a life cycle cost perspective, pavement costs can generally be categorized as agency costs and user costs. Agency costs include initial construction cost, rehabilitation, maintenance costs, and salvage value. User costs include indirect costs such as time delay costs at work zones, vehicle operating costs (VOC), accident costs, and discomfort costs (Beg et al. 1998). It is important to determine whether pavement costs are categorized as initial or future costs. The cost of an initial reconstruction or new construction are part of the initial costs, whereas any rehabilitation and maintenance activity performed during the life cycle of the pavement is categorized as a future cost. Future costs entail a high degree of uncertainty, and this could affect the outcome of the LCCA.

There are several economic models that can be used to perform an LCCA, including the benefit/cost ratio method, internal rate of return, equivalent uniform annual costs (EUAC), cost-effectiveness method, and the present worth (PW) method or net present value (NPV) method (Haas et al. 2003). From all of the mentioned models, the PW method and the EUAC method are the two most commonly used economic indicators by many state highway agencies in the United States (NCHRP 2004).

2.2.2.1 Present Worth (PW) Method

The PW method is an economic method that involves the transformation of all present and future expenditures or costs into present-worth dollars (WSDOT 2005; NCHRP 2004). A graphical representation of this method is shown in Fig. 2-4. This method is applied to all pavement alternatives, and the totals of the present value costs are then compared. The alternative with the lowest present value is considered, from an economic standpoint, the most attractive alternative (NCHRP 2004).

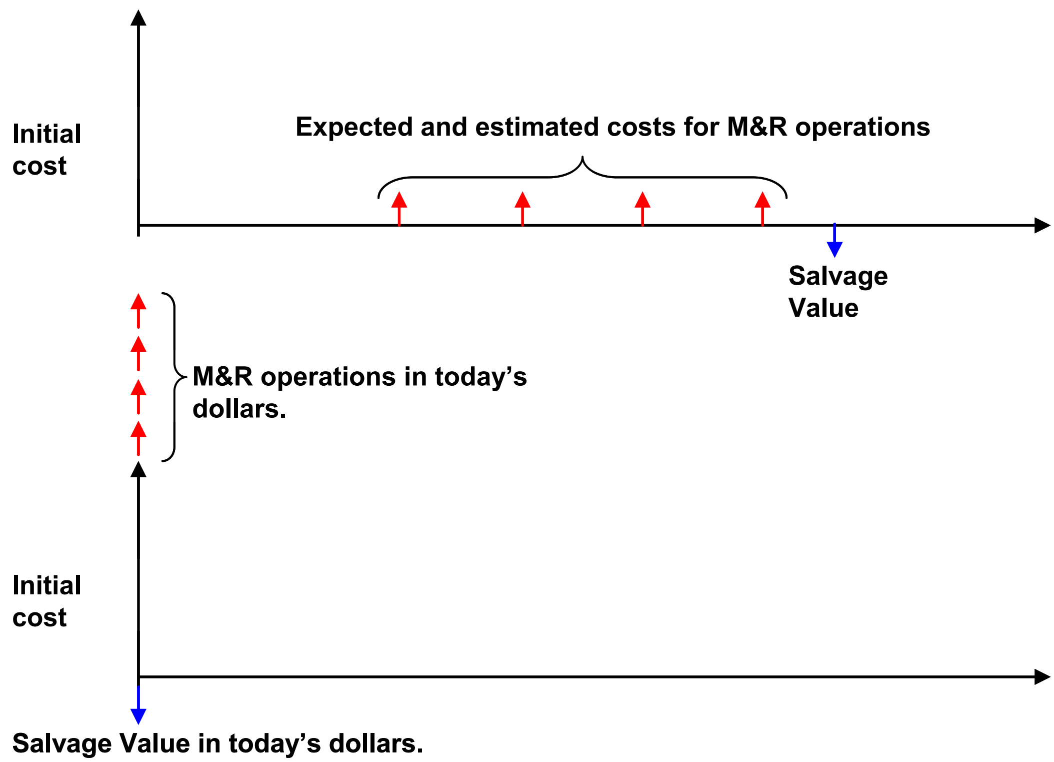

FIGURE 2-4 PW Method Applied to an LCCA
Source: Adapted from NCHRP 2004

The general form of the PW equation is the following:

$$PW = NPV = InitialCost + \sum UpkeepCost_k \bullet \left[\frac{1}{(1+i_{dis})_k^n} \right] \tag{2-17}$$

where

PW = present worth = NPV = net present value

InitialCost = initial construction costs

$UpkeepCost_k$ = costs of maintenance/rehabilitation activity k

k = individual maintenance/rehabilitation activity

n = year of expenditure

i_{dis} = discount rate

Of all the variables in Equation 2-17, the discount rate (i_{dis}) is one of the most important because it may considerably affect the analysis result of a life cycle cost. This variable should be based on historical records and trends over long periods of time. The FHWA recommends using a discount rate between 3 and 5 percent (Walls and Smith 1998). Transportation agencies have frequently used 4 percent over the past years; however, this value may be different depending on the LCCA procedures followed by each agency. There are two types of discount rates: real discount rates and nominal discount rates. Real discount rates reflect the true value of money without accounting for any inflation. Nominal discount rates, on the other hand, include an inflation component and should only be used in combination with inflated future dollar cost estimates of future investments (Walls and Smith 1998). In an LCCA, the use of real discount rates and constant dollars is recommended (Haas et al. 2003).

2.2.2.2 Equivalent Uniform Annual Cost Analysis (EUAC)

In this method, all costs (initial and future costs) are combined into equal annual payments over the analysis period. A benefit of this method is the simplicity and ease of understanding that it offers for public officials. In order to perform the EUAC method, the suggested first step is to determine the NPV and then use Equation 2-18 to convert the present costs into annual uniform costs.

$$EUAC = NPV \bullet \left[\frac{i_{dis} \bullet (1 + i_{dis})^n}{(1 + i_{dis})^n - 1} \right] \tag{2-18}$$

where

n = number of years into the future

i_{dis} = discount rate (typically 0.04 = 4%)

NPV = net present value (calculated using Equation 2-17)

2.2.2.3 User Costs

Road user costs (RUC) are the costs that the highway user must incur over the lifetime of the project. RUC are composed of three other separate cost factors: vehicle operating costs (VOC), user delay costs, and crash-related costs. The AASHTO Red Book (AASHTO 1960) defines VOC as the mileage-dependent cost of using any type of motor vehicle, including vehicle depreciation attributed to mileage increase and the maintenance costs due to vehicle wear such as tire, engine oil, and fuel expenses. Travel time has been found to have the greatest impact on VOC; nevertheless, user travel time is highly dependent on who is traveling and for what purposes, making it extremely variable (Vadakpat et al. 2000). User delay costs can be defined as the cost incurred by the user traveling on the highway and by those who are denied access to the highway by detours due to maintenance, rehabilitation work, or other agency requirements. User costs also have an added level of complexity due to the non-homogeneity of highway users and vehicle types. Non-user costs and accident costs are very difficult to estimate in numerical terms; for this reason they are usually omitted from an LCCA (Vadakpat et al. 2000).

2.3 Composite Pavement Systems

Composite pavements have been studied for many years throughout the world. They are known as semi-rigid pavement structures (NCHRP 2004), premium composite pavements (Von Quintus 1979; Hudson and Roberts 1981), long-life pavements (Nunn et al. 1997), flexible composite pavements (Nunn, 2004), and maintenance-free pavements (Von Quintus 1979). A composite pavement structure is defined as a structure comprising multiple (two or more) layers that combine different characteristics and that act as one composite material (Smith 1963). The two most commonly used materials that compose this composite structure are a flexible layer (e.g., HMA or asphalt concrete [AC]) and a rigid layer (e.g., PCC, cement-treated base or CTB, cement stabilized base or CSB, or lean mix concrete). There is no single definition applicable to composite pavements because an HMA overlay on a CTB can be considered a composite pavement; likewise, a thin PCC overlay on an HMA layer, known as whitetopping, has also been considered a composite pavement. Furthermore, a PCC surface layer applied on top of another PCC layer before the bottom layer has set may be considered a composite “wet on wet” pavement. In this study, the composite pavement system investigated was a rigid base overlaid with a flexible layer as shown in all cross-sections in Fig. 2-5.

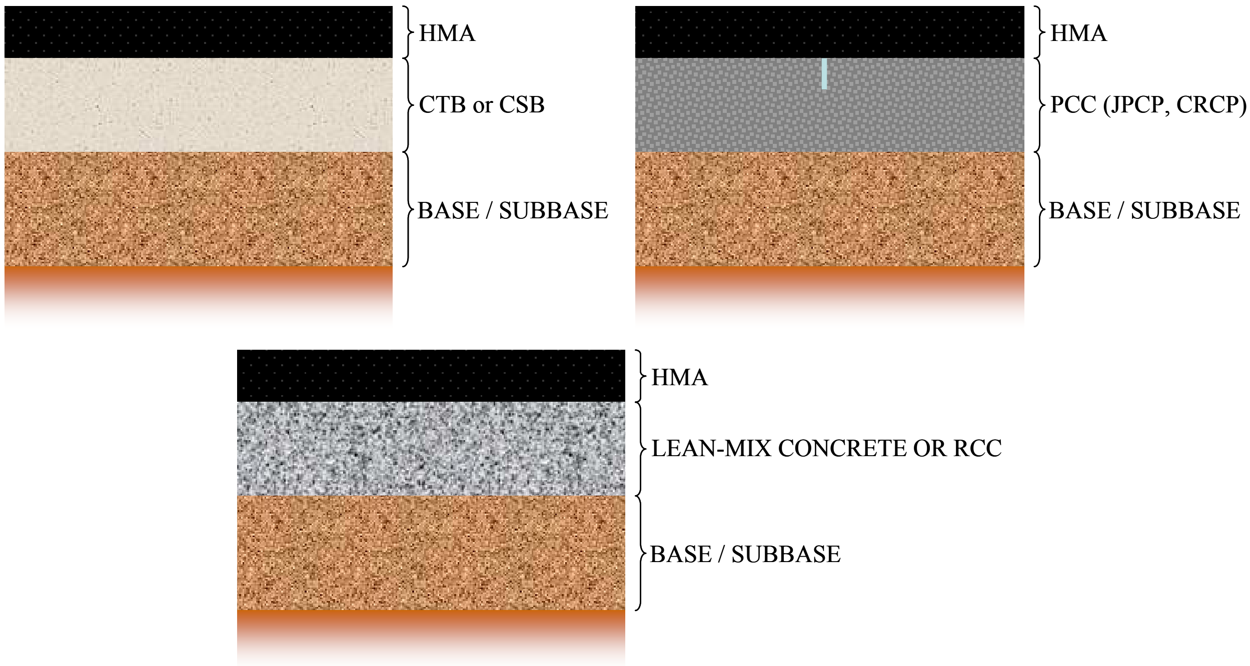

FIGURE 2-5 Typical Cross-sections of Composite Pavements

2.3.1 Benefits of Composite Pavements

Composite pavements, when compared to traditional flexible or rigid pavements, have the potential to provide better levels of performance both structurally and functionally (technical aspects) while being an economically viable alternative (economic aspect). Some of the benefits that composite pavements provide are (Donald 2003; Jofre and Fernandez 2004; Nunn 2004):

- Strong support to the HMA layer provided by the rigid base layer.
- Improvement of the rideability of the pavement and driver comfort by providing a smooth and quiet driving surface.
- Ensuring adequate pavement skid resistance (i.e., friction).
- Preservation of the structural integrity of the rigid base to ensure a long-life pavement system by performing preventive maintenance on the HMA surface course.
- Prevention of the intrusion of deicing salts and surface water to the rigid base due to the impermeable characteristic of the asphalt layer.
- Reduction of the temperature gradient in the rigid layer because of the overlaying asphalt layer.

Donald (2003) discusses how the traditional heavy-duty pavement type is a thick AC or HMA on an unbound aggregate base and granular subbase course. This type of conventional flexible pavement structure relies principally on the HMA for stiffness—the HMA is the layer that provides the majority of the structural capacity. Therefore, tensile strains at the bottom of the HMA layer need to be analyzed when designing a flexible pavement. This means that the risk of fatigue cracking (flexural fatigue) that initiates at the bottom of the HMA layer and propagates upward needs to be considered. Permanent deformation (rutting) is also a distress that affects typical flexible pavements. The compressive strains at the top of the subgrade could potentially cause rutting to show on the flexible layer. Therefore, compressive strain at this location (top of subgrade) needs to be considered a critical strain for rutting just as the tensile strain at the bottom of the HMA is considered for fatigue. In a composite structure, as shown in Fig. 2-6, the critical strain location for flexural fatigue (tensile strain) is shifted to a tensile stress location at the bottom of the rigid layer.

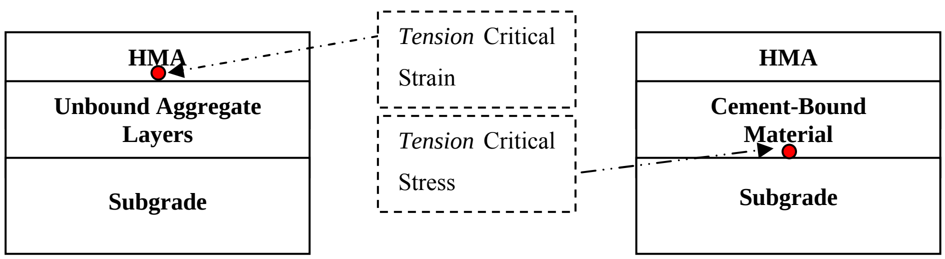

FIGURE 2-6 Shift in Critical Strain Location from a Typical Flexible Pavement (Left) to a Semi-Rigid One (Right)

It is expected that the traffic loading would tend to generate high tensile strains in conventional flexible pavements. A stiff base is needed to reduce these critical strains (Donald 2003). The magnitude of the reduction of strains when comparing a flexible pavement to a composite one is investigated in Chapter 3.

2.3.2 Past Performance of Composite Pavement Systems

Composite pavements have been implemented worldwide in the last decades. In Europe, composite pavements have been used extensively; countries such as Germany, France, and Spain are known for their wide use (30 to 50 percent) of long-life semi-rigid structures in their main road network (Thogersen et al. 2004).

In the U.K., another country that has extensive experience with composite pavement structures, two designs have been used for the past 20 years for their flexible composite pavements. The first design is for a service life of up to 20,000,000 equivalent single-axle loads (ESALs) over 20 years and has a structure comprising a lean concrete base with a maximum thickness of 250 mm surfaced with up to 150 mm of HMA. The second design is for a long but indeterminate life of greater than 20,000,000 ESALs and a structure comprising a 200-mm thick HMA on top of a lean concrete base (Parry 1997). The U.K. had, as of 1999, 649 km of composite pavements in their main road network, which had been constructed between 1959 and 1987 and had carried between 8 and 97 million single-axle (MSA) loads. A composite pavement performance study published by Parry et al. (1999) concluded that there was considerable variability in the performance of these composite structures, particularly in the thickness of the asphalt overlays during maintenance. The study suggested that any preventive or rehabilitating activity such as milling and overlaying to the in-service composite pavement should be done when the residual life of the pavement is short. Currently, the new U.K. Pavement Design Guide includes a new section that deals with flexible composite pavement design—which will be presented in Chapter 3—and that aims to design pavement structures sufficient to carry heavy traffic levels of 100 MSA or more.

A study by Merrill et al. (2006) reviewed the experiences of composite pavements in Europe. The authors commented that composite pavements from the U.K., the Netherlands, and Hungary were performing satisfactorily in terms of rutting, cracking, and deflections. Some of the conclusions mentioned that the expected life of a semi-rigid pavement structure is statistically longer than that of a flexible one, and that semi-rigid structures with relatively thin layers (250 mm total thickness) could achieve a long-life performance even under heavy traffic. Moreover, field observations confirmed that composite structures tend to have longer lives (i.e., they may be classified as long-life pavements). Because of this longevity, these structures may provide highway and transportation authorities with potential economic benefits.

The use of composite pavements in Spain is very wide as documented by Jofre and Fernandez (2004). Composite pavement structures in Spain are called semi-rigid pavements because they do not tend to use a Portland cement concrete pavement (PCCP) as the base. Instead they use different types of rigid bases that mainly differ from one another in the cement content and aggregate type. The typical rigid base characterization presented by Jofre and Fernandez is summarized in Table 2-1.

TABLE 2-1 Typical Properties of Rigid Bases Used in Spain

Rigid Base	7-Day Compressive Strength	E-modulus	Description
Soil-Cement	> 2.5 MPa[a] > 360 psi	6,000 to 10,000 MPa 870 to 1,450 ksi[b]	Granular material + cement content 3 to 7%
Gravel-Cement	> 4.5 MPa > 650 psi	20,000 MPa 2,900 ksi	No fine material and a dense gradation
Gravel-Cement Type II	> 8 MPa > 1,160 psi	25,000 MPa 3,600 ksi	Similar to gravel-cement, except for a higher cement content 5 to 7%
Lean-Mix Compacted Concrete	> 12 MPa > 1,740 psi	25,000 MPa 3,600 ksi	Cement content 5 to 10%. Similar to the RCC in the U.S.
Compacted Concrete	> 18 MPa > 2,600 psi	33,000 MPa 4,790 ksi	Cement content 10 to 14%

[a] Note: 1 MPa = 145.04 psi
[b] Note: 1 ksi = 1,000 psi

As documented by Jofre and Fernandez (2004), some of the technical aspects that should be controlled when constructing semi-rigid structures include the following: reflective cracking control or mitigation and assurance of full bonding (which translates to a full-friction interface) between all layers—especially between the bituminous (HMA) layer and the rigid one. As a concluding remark, the study states that semi-rigid structures have proven to perform satisfactorily with a high level of confidence throughout the years.

In the United States, composite pavements usually have been the result of PCCP rehabilitation, which consists of a bituminous surface being overlaid onto the deteriorated rigid pavement, thus creating a composite structure. This rehabilitation task has been widely accepted and used to restore the functional and structural performance of an existing pavement; it has also been used to increase the structural capacity in order to improve performance and handle additional and heavier traffic. The performance of composite pavements may vary due to different factors such as design of rigid base, selection of adequate HMA type, constructability, and maintainability. A study of composite pavements presented by Hein et al. (2002) concluded that (1) there is a difficulty in predicting the condition of the concrete base based on the surface conditions of the HMA, (2) faulting and spalling were effectively hidden from view, (3) the use of an open-graded HMA interlayer does not mitigate reflection cracking, (4) there is an early (3 to 5 years) deterioration due to reflective cracking on the HMA from the underlying rigid layer's discontinuities, and (5) the pavement condition ratings based only on the HMA surface do not accurately reflect the condition of the overall pavement structure and/or concrete base.

2.3.3 Composite Pavement Design

Although there is no current U.S. standard in designing composite pavement structures, several agencies in the country and worldwide have developed guidelines, manuals, and procedures for composite pavements based on experience and structural analysis. This section summarizes, published literature from different agencies.

2.3.3.1 AASHTO 1993 Guide

The 1993 AASHTO Guide for Design of Pavement Structures could be used to design two different composite pavements: (1) a flexible pavement with a cement-treated (or soil-cement) base and (2) a rehabilitated PCC pavement using a specific section in the guide for the design of AC overlays of PCC (both jointed plain concrete pavement [JPCP] and continuously reinforced concrete pavement [CRCP]).

The first alternative, a flexible pavement with a cement-treated base, includes the design of a conventional flexible pavement with a cement-stabilized soil base. The most important characteristic of this design would be an adequate layer coefficient, a_2, for the stabilized base from the flexible SN design equation:

$$SN = a_1D_1 + m_2a_2D_2 + m_3a_3D_3 \tag{2-19}$$

where

SN = structural number

a_1, a_2, a_3 = layer coefficients

m_2, m_3 = drainage coefficients

D_1, D_2, D_3 = thickness of each layer (layer 1 = HMA, layer 2 = base, layer 3 = subbase)

A study performed by Richardson (1996) provided a general equation that could be used to determine the modulus, E_c, of various cemented materials (e.g., soil cement, cement-treated bases, cement-stabilized soils) and with that, compute the layer coefficient a_2. Once the cemented material coefficient and all other needed parameters are obtained, the composite structure can be designed.

$$E_c = -34.367 + 2006.8\left(q_u\right)^{0.7784} \tag{2-20}$$

$$a_2 = -2.7170 + 0.49711 \times \mathrm{Log}\left(E_c\right) \tag{2-21}$$

where

E_c = chord modulus (MPa)

q_u = unconfined compressive strength (MPa)

The second alternative using the AASHTO 1993 guide is based on the procedure for designing rehabilitation of PCC pavements with an AC overlay. In this case, the first step is to design a conventional PCC pavement, in other words, compute the thickness to satisfy the traffic demand, D_f. Once the slab thickness has been obtained, it could be assumed that placing an AC layer with a thickness slightly greater than 2 in. would allow for the decrease of 1 in. of PCC layer. This is because the guide's "AC Overlay of PCC Pavement" procedure indicates that the required thickness, D_{OL}, of an AC overlay of PCC is calculated using the following equation:

$$D_{OL} = A\left(D_f - D_{eff}\right) \tag{2-22}$$

where

A = factor to convert PCC thickness deficiency to AC overlay thickness

D_f = slab thickness to carry future traffic (in.)

D_{eff} = effective thickness of existing slab (in.)

Therefore, two assumptions are made. First, in a new composite pavement design, D_{eff} is equal to D_f because it is appropriate to assume that a newly constructed PCCP would not have any distresses, thus none of the adjustment factors shown in Equation 2-23 would be applicable.

$$D_{eff} = F_{jc} \bullet F_{dur} \bullet F_{fat} \bullet D \tag{2-23}$$

where

D = original slab thickness (this would be equal to D_f)

F_{jc}, F_{dur}, F_{fat} = adjustment factors for joints and cracks, durability, and fatigue = 1

The second assumption involves the A factor in Equations 2-22 and 2-24. According to the guide, the A factor is computed using the following equation:

$$A = 2.2233 + 0.0099\left(D_f - D_{eff}\right)^2 - 0.1534\left(D_f - D_{eff}\right) \tag{2-24}$$

Because it was established that D_f = D_{eff}, A = 2.2233 would be obtained. This implies that because the A factor is 2.2233, for every 1 in. of PCC thickness, 2.2233 in. of HMA should be used as overlay. Once the overlay thickness is computed, it is rounded up to the nearest 0.5 in.

2.3.3.2 U.S. Army and Air Force Design

The U.S. Department of Defense has developed a Pavement Design Manual for Roads, Streets, and Open Storage Areas that includes a section for flexible pavements with stabilized bases (UFC 2004). Such structures would constitute a semi-rigid pavement when a CTB is used underneath the HMA layer.

The pavement design software PCASE developed by the U.S. Army and Air Force uses the procedure described in their guide, which is based on an asphalt strain criteria that uses Equation 2-25a to determine the limiting tensile strain at the bottom of the asphalt layer (UFC 2004):

$$\text{Allowable Strain} = \varepsilon_{AC} = 10^{-A} \tag{2-25a}$$

$$A = \frac{N + 2.665 \bullet \text{Log}\left(E/14.22\right) + 0.392}{5} \tag{2-25b}$$

where

N = log(coverage)

E = elastic modulus of bituminous concrete (psi)

Once the allowable strain is calculated, the allowable coverage of load repetitions is approximated using the following equations:

$$\text{Allowable Coverage} = 10^{X} \quad (2\text{-}25c)$$

$$X = 5 \times \text{Log}\left(\varepsilon_{AC}\right) + 2.665 \times \text{Log}\left(E/14.22\right) + 0.392 \quad (2\text{-}25d)$$

where

ε_{AC} = allowable (tensile) strain

2.3.3.3 Illinois Department of Transportation (IDOT) Design

The Illinois Department of Transportation (IDOT) includes in its Pavement Design Guide published in 2002 a complete design process and guidelines for new composite pavement design. This agency defines a composite pavement as a structure consisting of an HMA surface course overlaying a PCC slab of relatively high bending resistance that acts as the principal load-distributing component of the pavement system (IDOT 2002).

This comprehensive design methodology includes sections such as potential use of composite pavements, minimum material requirements, design period, structural design, traffic factors, subgrade requirements, performance graded (PG) binder selection, design reliability, minimum design thickness, pre-adjusted slab thickness, slab thickness adjustments, and typical sections. Some of the major sections and inputs of the design include the following:

- Minimum design period of 20 years
- Computation of traffic factors
- Guide requirements for subgrade
- Performance graded binder selection to mitigate distresses such as rutting
- Minimum thickness of HMA according to PCC thickness
- Adjustment of slab thickness as a function of subgrade rating
- Adjustment of slab thickness as a function of traffic factors
- Adjustment of slab thickness as a function of HMA layer thickness

- Determination of a composite pavement structural number (SN_C)
- Computation of the required thickness of the new HMA layer

The equation provided to compute the thickness of the new HMA overlay, D_O, is the following:

$$D_O = \frac{SN_C - 0.33 \bullet D_B}{0.40} \qquad (2\text{-}26)$$

where

D_O = thickness of HMA layer for new composite pavement (in.)

SN_C = composite pavement structural number (obtained from a nomograph in their guide)

D_B = thickness of new PCC base course (in.)

After the composite pavement design has been completed, it should be compared to the minimum thickness and material requirements that are provided in the guide. Table 2-2 shows these requirements.

TABLE 2-2 Minimum Thicknesses and Material Requirements for Composite Pavements

Structural Number (SN_C)			**Minimum Thickness (in.)**	**Minimum Material**
From		**To**	**Surface & Binder**	**Surface & Binder**
	< 2.50		2	SUPERPAVE with Low ESALs
2.51	--	2.99	3	SUPERPAVE with Low ESALs
3.00	--	3.49	3	SUPERPAVE (4% voids)
	> 3.50		4	SUPERPAVE (4% voids)

2.3.3.4 U.K. Pavement Design Guide

Transportation agencies (e.g., Transport Research Laboratory) and designers in the UK have extensive experience with composite pavements' specifications, design, construction, and testing. Composite pavements are commonly referred to as "flexible composite pavements" in the U.K. The design methodology and procedure used in the U.K. Pavement Design Guide is based on the TRL Report 615 prepared by Nunn (2004).

The U.K. design method uses a nomograph to obtain two parameters: (1) the thickness of the hydraulically bound material (HBM) base and (2) the flexible surfacing thickness (mm) on top of a HBM base. First, the foundation stiffness (modulus of resilience) is categorized based on the following ranges:

- Class 1 ≥ 50 MPa (7,252 psi)
- Class 2 ≥ 100 MPa (14,503 psi)
- Class 3 ≥ 200 MPa (29,007 psi)
- Class 4 ≥ 400 MPa (58,015 psi)

Second, the hydraulically bound base thickness (mm) is obtained as a function of the cement-bound material (CBM) category described in Table 2-3.

TABLE 2-3 Design Thicknesses for CBM Base for More than 80,000,000 ESALs

	Foundation Class			
CBM Base	**Class 1 50 MPa (7,250 psi)**	**Class 2 100 MPa (14,500 psi)**	**Class 3 200 MPa (29,000 psi)**	**Class 4 400 MPa (58,000 psi)**
CBM3G	275 mm (10.8 in.)	250 mm (9.8 in.)	225 mm (8.9 in.)	200 mm (7.9 in.)
CBM4G	220 mm (8.7 in.)	200 mm (7.9 in.)	180 mm (7.0 in.)	150 mm (5.9 in.)
CBM5G	200 mm (7.9 in.)	180 mm (7.0 in.)	160 mm (6.3 in.)	150 mm (5.9 in.)
CBM3R	220 mm (8.7 in.)	200 mm (7.9 in.)	180 mm (7.0 in.)	150 mm (5.9 in.)
CBM4R	200 mm (7.9 in.)	180 mm (7.0 in.)	160 mm (6.3 in.)	150 mm (5.9 in.)
CBM5R	165 mm (6.5 in.)	150 mm (5.9 in.)	150 mm (5.9 in.)	150 mm (5.9 in.)

The properties of the base materials are shown in Table 2-4. Once the thickness of the base is obtained, the thickness of the asphalt layer (mm) can be obtained from Equation 2-27.

$$H_{asphalt} = -16.05 \bullet \left(\mathrm{Log}(N)\right)^2 + 101 \bullet \mathrm{Log}(N) + 45.08 \tag{2-27}$$

where

$H_{asphalt}$ = asphalt thickness (mm) (for 50 MSA < N < 80 MSA)

N = cumulative traffic (MSA = million single axles = 1,000,000 ESALs)

TABLE 2-4 Properties of CBM

CBM	Minimum 7-day Compressive Strength, MPa (psi)
CBM1	4.5 (653)
CBM2	7.0 (1,015)
CBM1A	10.0 (1,450)
CBM2A	10.0 (1,450)
CBM3R/G	10.0 (1,450)
CBM4R/G	15.0 (2,175)
CBM5R/G	20.0 (2,900)

2.3.3.5 The Danish Road Institute (Report 138)

In 2004 the Danish Road Institute published a mechanistic design guide for semi-rigid pavements (Thogersen et al. 2004). This mechanistic guide was developed as a result of a survey that showed the superior performance of pavements with CTB, especially on heavily trafficked pavement sections. In order to understand the behavior of such pavements and establish a mechanistic design, a full-scale test on six semi-rigid pavements (three different types, each with two replications) was carried out. A generalized incremental-recursive model based on tensile strain at the bottom of the CTB layer was chosen as the desired approach to verify the deterioration model (Thogersen et al. 2004). The results were then compared to existing semi-rigid pavements that had been in service for more than 20 years. The comparison of these results showed that the deterioration model was accurate.

The study focused on the failure of the semi-rigid structure in terms of fatigue of the rigid layer. The determining factor in the fatigue damage was the longitudinal (tensile) strain at the bottom of the CTB layer. The structure was composed of the following layer thicknesses: AC surface layer = 30 mm, CTB layer = 180 mm, and subbase layer = 200 mm. The investigation concluded that for their semi-rigid pavement structure, at 75 percent confidence, the following deterministic design criterion should be used to prevent fatigue failure of the structure:

$$\varepsilon_{\text{PERMISSIBLE}} = 99\mu\text{str} \times \left(N / 10^6 \right)^{-0.12} \qquad (2\text{-}28)$$

where

$\varepsilon_{\text{PERMISSIBLE}}$ = maximum strain at bottom of CTB layer

μstr = micro-strain (10^{-6} strain)

N = number of load repetitions (passes) to failure

Once the mechanistic behavior of the semi-rigid structure was modeled, the criterion constants were utilized to provide designs for various traffic volumes (Thogersen et al. 2004). In the following design table, Table 2-5, the load is represented as a dual-wheel load with 20 percent dynamic load additions as used in the new Danish design standards.

TABLE 2-5 Semi-rigid Pavement Design for the Danish Road Institute (Thogersen et al. 2004)

Layer		Number of Equivalent 10-ton Axles (million)							
		0.2	**0.5**	**1**	**2**	**5**	**10**	**20**	**50**
Asphalt surface and binder	E = 2,500 MPa (362.6 ksi) Thickness in mm (in.)	60 (2.5)		80 (3.5)					
CTB with $E_{initial}$ = 12,000 MPa	Allowable initial strain, μstr	65	57	51					
	Required thickness, mm (in.)	215 (8.5)	235 (9.3)	245 (9.6)					
CTB with $E_{initial}$ = 16,000 MPa	Allowable initial strain, μstr			75	69	62	57	52	47
	Required thickness, mm (in.)			150 (5.9)	165 (6.5)	180 (7.1)	190 (7.5)	205 (8.0)	225 (8.9)
Gravel base	E = 300 MPa (43.5 ksi)	Thickness 150 mm (5.9 in)							
Subbase	E = 100 MPa (14.5 ksi)	Thickness minimum 200 mm (7.9 in)							
Subgrade	E = 40 MPa (5.8 ksi)	-							

2.3.3.6 Guide for Mechanistic-Empirical Design (NCHRP 1-37A)

In the proposed Mechanistic-Empirical Pavement Design Guide (Chapter 3, Part 3) an equation is provided to predict the fatigue cracking in chemically stabilized mixtures (CSM) (NCHRP 2004). CSM layers include layers that have cementious, lime, fly ash, or slug material in their composition. The fatigue model proposed by the new guide, based on equation 2-12, is the following:

$$\log\left(N_f\right) = \frac{\left(0.972\beta_{c1} - \left(\frac{\sigma_t}{MR}\right)\right)}{0.0825\beta_{c2}} \tag{2-29}$$

where

N_f = number of repetitions to fatigue cracking of the CSM layer

σ_t = maximum traffic-induced tensile stress at the bottom of the CSM layer (psi)

MR = 28-day modulus of rupture (flexural strength) (psi)

β_{c1}, β_{c2} = field calibration factors

Both of the field calibration factors are equal to 1 due to the complexity and requirements of field section design input and performance data. Typical MR values for various CSM materials are presented in Table 2-6.

TABLE 2-6 Typical Flexural Strength (MR) Values for CSM

Chemically Stabilized Material	Typical MR (psi)
Lean concrete	450
Cement stabilized aggregate	200
Open-graded cement stabilized	200
Soil cement	100
Lime-cement-fly ash	150
Lime-stabilized soils	25

The proposed guide mentions the following points that need to be considered regarding fatigue cracking of a CSM layer:

- If there is an HMA surface course (composite pavement scenario), any fatigue cracking in the CSM layer *will* result in a fraction of the cracking reflected through the HMA layer.
- If a crack relief layer (e.g., unbound granular layer) is placed between the HMA and CSM layer, it is possible to minimize or potentially eliminate reflective cracking through the HMA layer.
- As the CSM layer is subjected to high levels of fatigue damage, the equivalent CSM layer modulus may be significantly degraded. This stiffness reduction will reduce the CSM layer modulus, which will cause relatively high tensile strains at the bottom of the HMA layer, thus bottom-up alligator cracking may occur.

2.3.3.7 Fatigue Criteria for Semi-Rigid Pavements

Balbo and Cintra (1994) proposed an analytical, mechanistically-based approach for modeling fatigue of semi-rigid structures. The process included the combination of Linear Elastic Layer Theory and the AASHTO 1986 Pavement Design Guide. The paper suggests that the design of the semi-rigid structure is governed by the structural capacity of the rigid layer. Furthermore, a semi-rigid pavement will have significant changes in its behavior after a determined, yet not well defined, number of repetitions of loads due to the fatigue process in the cement-treated layer; afterward, the material would tend to behave as a very good granular material if it was produced originally with aggregates (Balbo and Cintra 1994).

The fatigue relationship proposed by the study has the following form:

$$SR = a + b \bullet \mathrm{Log}(N) \tag{2-30}$$

where

SR = ratio between applied stress and ultimate strength

a, b = regression constants

N = number of load applications

The fatigue relation used in their publication was the one proposed by Balbo (1993):

$$SR = 0.874 + 0.051 \bullet \mathrm{Log}(N) \tag{2-31}$$

The SR term in Equation 2-31 is related to the stress at the bottom of the cement-treated layer and the ultimate strength, which is equivalent to the flexural strength (or MR). The procedure proposed is based on the computation of N load applications for each type of axle (i.e., single, tandem, and tridem) as shown in Equations 2-32, 2-33, and 2-34, respectively.

Single: $$\sigma_f = 59.463847 \cdot t_r^{-0.323205} \cdot t_b^{-1.178098} \cdot t_s^{-0.007887} \cdot E_s^{-0.214274} \cdot L^{0.970153} \tag{2-32}$$

Tandem: $$\sigma_f = 9.301950 \cdot t_r^{-0.267539} \cdot t_b^{-0.883009} \cdot t_s^{-0.008576} \cdot E_s^{-0.340332} \cdot L^{0.927047} \tag{2-33}$$

Tridem: $$\sigma_f = 2.288453 \cdot t_r^{-0.227463} \cdot t_b^{-0.705838} \cdot t_s^{-0.009278} \cdot E_s^{-0.392020} \cdot L^{0.940948} \tag{2-34}$$

where

σ_f = flexural stress on the base (MPa)

t_r = surface course thickness (mm)

t_b = base thickness (mm)

t_s = subbase thickness (mm)

E_s = subgrade resilient modulus (MPa)

L = total axle load (kN)

Once the flexural stress for each of the axle types is computed, three SR factors would be obtained, one for each of the flexural stresses. Each of the three SR factors is then used to calculate the number of repetitions to fatigue failure. Finally, the sum of all the number of repetitions (i.e., the sum of the three allowable load applications for each SR factor) is the expected number of load applications to fatigue failure of the CTB, thus the failure of the semi-rigid structure.

2.3.4 Composite Pavement Distresses

A composite pavement structure, throughout its service life, may present different type of distresses. The distresses that affect composite pavement, according to Von Quintus (1979), are very similar to those of flexible pavements because of the exposure of the HMA layer in the composite structure. Three types of distresses that have been modeled extensively include: fatigue cracking in the HMA layer (both bottom-up and top-down) and the rigid layer, rutting due to permanent (plastic strain) deformations within the HMA layer and subgrade, and reflective cracking.

2.3.4.1 Fatigue Cracking

The fatigue models proposed by the proposed Mechanistic-Empirical Pavement Design Guide (NCHRP 1-37A) are based on the Asphalt Institute model, which is based on a constant stress criterion and expressed as Equation 2-35.

$$N_f = 0.00432 \times k_1' \times C \left(\frac{1}{\varepsilon_t}\right)^{3.291} \left(\frac{1}{E}\right)^{0.854} \tag{2-35}$$

$$C = 10^M \tag{2-36a}$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right) \tag{2-36b}$$

where

N_f = number of load repetitions to fatigue cracking

k_1' = parameter used for either bottom-up or top-down criteria

ε_t = tensile strain at critical location

E = stiffness of material (HMA)

V_b = effective binder content (%)

V_a = air voids (%)

For bottom-up cracking, the $k_1^{'}$ parameter is:

$$k_1^{'} = \frac{1}{0.000398 + \frac{0.003602}{1 + e^{(11.02 - 3.49 \bullet h_{ac})}}} \tag{2-37}$$

whereas for top-down cracking:

$$k_1^{'} = \frac{1}{0.01 + \frac{12.00}{1 + e^{(15.676 - 2.8186 \bullet h_{ac})}}} \tag{2-38}$$

where

h_{ac} = total thickness of asphalt layer (in.)

Both of these fatigue transfer functions (one for bottom-up, one for top-down cracking) may be used to estimate the repetitions to fatigue failure of the HMA layer in composite pavement systems. In addition, the Asphalt Institute fatigue transfer function, Equation 2-3, may be used to perform fatigue life prediction for the HMA layer as well.

2.3.4.2 Rutting (Permanent Deformation)

Two rutting models may be used to estimate the permanent deformation distress of a composite pavement. The first, Equation 2-39, focuses on the permanent deformation within the HMA layer due to increasing plastic deformations (NCHRP 2004).

$$\frac{\varepsilon_p}{\varepsilon_r} = k_1 \bullet 10^{-3.4488} \bullet T^{1.5606} \bullet N^{0.479244} \tag{2-39}$$

where

ε_p = accumulated plastic strain at N repetitions of load (in./in.)

ε_r = resilient strain of the asphalt material as a function of mix properties, temperature, and time rate of loading (in./in.)

N = number of load repetitions

T = temperature (°F)

k_1 = parameter computed from Equation 2-40a

$$k_1 = \left(C_1 + C_2 \bullet \text{depth}\right) \bullet 0.328196^{\text{depth}} \quad \text{(2-40a)}$$

$$C_1 = -0.1039 \bullet h_{ac}^2 + 2.4868 \bullet h_{ac} - 17.342 \quad \text{(2-40b)}$$

$$C_2 = 0.0172 \bullet h_{ac}^2 - 1.7331 \bullet h_{ac} + 27.428 \quad \text{(2-40c)}$$

where

k_1 = confining pressure correction factor

h_{ac} = total asphalt layers thickness (in.)

depth = depth to computational point (in.)

The second rutting model that could be used, to model rutting in the subgrade, is the one proposed in Equation 2-8 by the Asphalt Institute. However, the subgrade deformations of the second model, Equation 2-8, are expected to be greatly minimized because the presence of a high-stiffness base layer (rigid layer) tends to reduce the state of stress and strain within layers directly beneath (NCHRP 2004).

2.3.4.3 Reflective Cracking

Numerous publications have agreed that reflective cracking (also called reflection cracking) is a major type of distress in composite pavement systems. Reflective cracks are cracks that occur in the asphalt surface course of the composite pavement system and that coincide with cracks of appreciable width or joints in the underlying layers; they are caused by relative horizontal and vertical movements of these cracks or joints caused by temperature cycles and/or traffic loading (Von Quintus 1979; Oowusu-Antwi et al. 1998; Mukhtar and Dempsey 1996). These reflective cracks are undesirable in a composite pavement structure because they tend to widen progressively, permitting the leakage of surface water to the layers beneath and causing serious raveling and disintegration of the asphalt surfacing adjacent to the cracks (Van Breemen 1963).

2.3.4.3.1 Causes and Mechanisms

Reflective cracks are caused by existing discontinuities (e.g., joint, crack, patch, and edge) in the underlying layers that propagate through an HMA overlay (Elseifi and Al-Qadi 2003). As previously mentioned, reflective cracking occurs due to relative movement of cracks or joints of the layer underneath the HMA due to load and thermally induced action (i.e., stresses). At these discontinuities, the stress intensity is such that a reflected crack appears in the surface course as shown in Fig. 2-7. According to Lytton (1989) three types of critical pulses occur when a wheel load passes over a crack in the existing pavement as discussed in the next paragraph. As the crack movement increases, the propagation of the crack to the HMA overlay accelerates. In addition, changes in temperature can also contribute to crack propagation; this translates to induced horizontal stresses in the HMA overlay due to contraction and curling of the rigid pavement—the rigid base layer in the case of composite pavements—caused by temperature variations that result in the opening of existing cracks. In other words, traffic and seasonal temperature variations are the main causes of discontinuities in the (rigid) base layer reflecting through the HMA overlay.

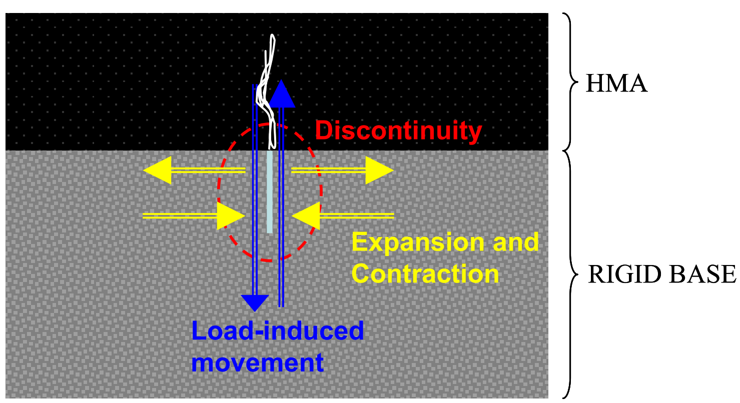

FIGURE 2-7 Reflective Cracking Mechanism

Fracture mechanics theory can be used to describe the crack growth process in the HMA. Generally, a cracked pavement system can be loaded in any one or a combination of three fracture modes (Elseifi and Al-Qadi 2003):

- Mode I (opening mode, K_I) results from loads applied normally to the crack plane. These are due to thermal effects and traffic loads.

- Mode II (sliding mode, K_{II}) results from in-plane shear loading; as a result, crack faces slide against one another to the leading edge of the crack. This is due to traffic loading.
- Mode III (tearing mode, K_{III}) results from out-of-plane loading; as a result, crack faces slide parallel to the crack leading edge. This loading mode is insignificant for pavements.

Two distinct phases can be defined during the cracking process of pavement systems, the crack initiation phase and the crack propagation phase. The crack initiation phase, in which two distinct phases of microcracking and formation of macrocracks occur, is defined as the number of load cycles before a visible damage zone forms at the bottom of the overlay (Elseifi and Al-Qadi 2003; Uzan 1997). The crack initiation for reflective cracking induced by Mode II loading can be determined using Equation 2-41 (BRRC 1998).

$$N = 4.856 \times 10^{-14} \gamma_{zx}^{-4.76} \tag{2-41}$$

where

N = number of cycles before crack initiation

γ_{zx} = shear strains 10 mm above the existing crack

In the crack propagation phase, the crack propagates to the surface through the entire thickness of the HMA overlay. Several studies have shown that Paris' crack growth law, Equation 2-42, may be adequately used to model the relationship between crack propagation in nonlinear viscoelastic materials (e.g., HMA) and their stress intensity factors and other material fatigue properties (Owusu-Antwi 1998).

$$\frac{dc}{dN} = A\left(\Delta K\right)^{n} \tag{2-42}$$

where

c = crack length

N = number of loading cycles

dc/dN = crack growth per load cycle

A, n = fracture parameters of the material

ΔK = stress intensity factor amplitude

2.3.4.3.2 Mechanistic-Empirical Modeling

A mechanistic-empirical overlay design method for reflective cracking was proposed by Sousa et al. (2002). This study focused on the modeling of reflective cracking above cracks in the underlying pavement surface. Both dense-graded HMA and gap-graded asphalt rubber (wet process) mixes were studied in the laboratory and field to derive mechanistic relationships and statistically based equations. The measured versus predicted crack activity, both before and after the overlay was placed, was investigated. The Von Mises strain, necessary for the modeling, was developed as the following:

$$\varepsilon_{VM}\left(1\times10^{-6}\right) = a\bullet\left(\text{Overlay Thickness (m)}\right)^{b} \tag{2-43}$$

where

ε_{VM} = Von Mises strain

a, b = coefficients obtained experimentally

The model was calibrated using iterative processes. Three adjustment factors were developed: aging adjustment factor (AAF), temperature adjustment factor (TAF), and a field adjustment factor (FAF). All of these factors affected the value of ε_{VM}, which was used to determine the number of ESALs that can be sustained by the HMA overlay before the onset of reflective cracking. The final model was the following:

Asphalt rubber mix: $$\text{ESALs} = 4.1245\times10^{19}\bullet\left[\varepsilon_{VM}\left(1\times10^{-6}\right)\right]^{-4.9761} \tag{2-44}$$

Dense-graded mix: $$\text{ESALs} = 4.1245\times10^{20}\bullet\left[\varepsilon_{VM}\left(1\times10^{-6}\right)\right]^{-5.93} \tag{2-45}$$

These ESALs, Equations 2-44 and 2-45, need to be multiplied by the FAF to obtain the final design ESALs required for the overlay to reach a specific percentage of reflective cracking.

CHAPTER 3 RESEARCH APPROACH

The evaluation of composite pavement systems is based on a technical and economic analysis. To perform a technical analysis, the technical benefits of a composite structure were investigated first. In addition, various mechanistic-based analyses were performed on various composite pavements, mainly varying the type of rigid base, to understand the behavior of the structure under various base rigidity scenarios. The three types of distresses previously mentioned in Chapter 2, namely fatigue cracking, rutting, and reflective cracking, were modeled and investigated as well. Typical composite pavements were designed using available applicable guides and their final thicknesses were compared. To perform an economic evaluation, a deterministic approach was chosen. Typical agency values were obtained for material cost, rehabilitation procedures, and discount rates. In this economic evaluation, typical rigid (continuously reinforced concrete pavement or CRCP), flexible, and two composite pavements were considered.

3.1 Technical Analysis of Composite Pavement Systems

To understand the technical advantages of composite pavements, a technical evaluation was performed. This evaluation involved a mechanistic modeling of a typical composite pavement structure that was obtained using one of the various methodologies available for the design of composite systems. In addition, sensitivity analyses were performed on different parameters that influence the behavior and response of the composite structure.

3.1.1 Designed Composite Pavement Structures

To compare the output (thicknesses mainly) and layer recommendations from the different design methodologies mentioned previously, it was important to design the composite pavement systems so that some constant criteria were used throughout the analysis. Therefore, the design procedures from various transportation agencies were followed to design composite pavement structures based on the same input parameters (e.g., traffic, design life). Table 3-1 shows the parameters that were used to design these composite structures. Table 3-2 shows the typical values used for the material properties of each layer used for the structures (NCHRP 2004; Huang 2004).

TABLE 3-1 Parameters Used for the Design of Composite Structures

Parameter	Value
Design life	40 years
Traffic	50,000,000 ESALs[a] 58,230 ADT[b]$_o$ 12% trucks
Reliability	95% (AASHTO design) 75% (Danish design)
PSI_o[c]	4.5
PSI_f	3.0

[a] Note: ESAL = equivalent single-axle load
[b] Note: ADT = annual daily traffic
[c] Note: PSI = present serviceability index

TABLE 3-2 Typical Material Properties for the Composite Pavement Layers

Material	Elastic Modulus (psi)	Poisson's Ratio	MR
HMA	500,000[a]	0.35	-
PCC	4,000,000	0.15	650
RCC	3,500,000	0.15	600
Lean concrete	2,000,000	0.15	450
CTB	1,000,000	0.20	200
Soil cement	500,000	0.20	100
Granular base	30,000	0.35	-
Subbase	20,000	0.40	-
Subgrade	7,500	0.40	-

[a] Note: Tested at 68°F and 0.1 cycles/sec (NCHRP, 2004)

Composite pavement structures were designed according to all the design procedures and methods described in Chapter 2. For the two AASHTO alternatives, a simple spreadsheet was created to compute all the values obtained from the AASHTO 1993 guide. The IDOT alternative was computed using all the tables, formulas, and nomographs published in their 2002 Pavement Design Guide (IDOT 2002). The U.S. Air Force and Army alternative was designed using the PCASE military pavement design software available as freeware from their website (PCASE 2007). The Danish design was based on the Danish Road Institute mechanistic design table with a 75 percent reliability because their incremental-recursive criteria ensured that 75 percent of all measured E-moduli were above the prediction lines in the analysis (Thogersen et al. 2004). The U.K. design thicknesses were obtained using Equation 2-27. Fig. 3-1 presents the cross sections of all the designed composite structures.

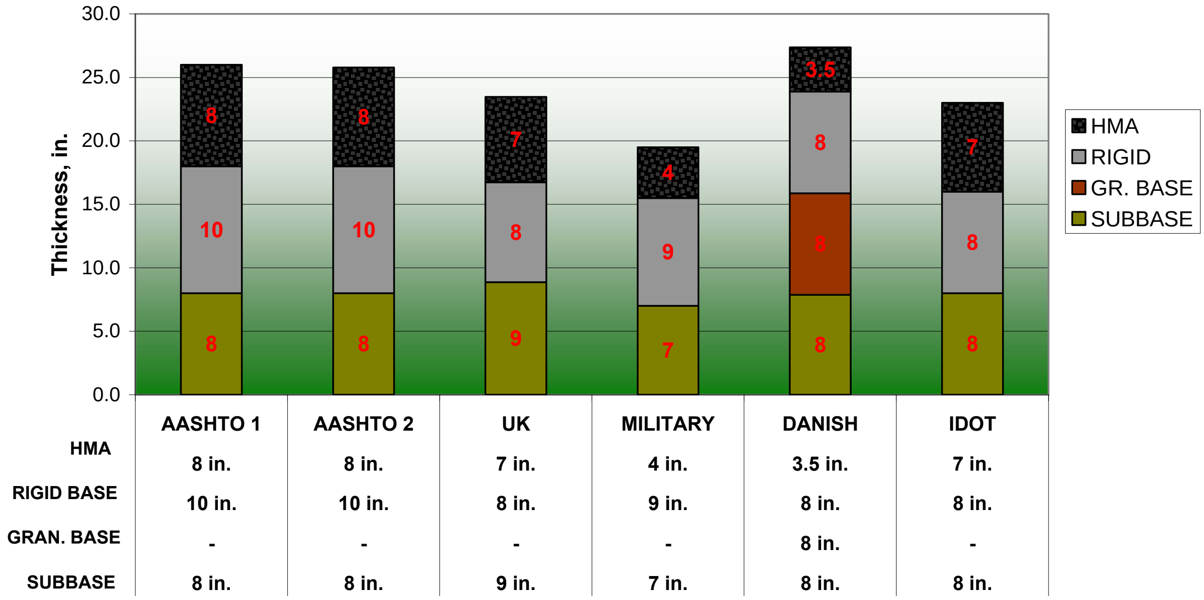

FIGURE 3-1 Comparison of All Designed Composite Pavement Structures

The composite structures shown in Fig. 3-1 ranged from a total thickness of 20 to 28 in. The subgrade is not shown for any structure; however, a 7,500 psi subgrade was assumed, which would be equivalent to a 5 percent California bearing ratio (CBR) for all structures. The computed structures may be grouped into three design groups according to similar thicknesses in the HMA and rigid base layer: Group 1, the two AASHTO alternatives; Group 2, the U.K. and IDOT alternatives; and Group 3, the military and Danish alternatives. In Group 1, an 8-in. HMA surface course and a 10-in. rigid base was the result of the design. In the AASHTO 1 alternative, flexible pavement procedure with a CTB, the structural coefficient of the HMA, a_1 = 0.47, was greater than the CTB, a_2 = 0.27. This suggests that the structural capacity provided by CTB is much lower than that of the HMA; this is contrary to the literature, which states that the load-carrying layer is the rigid base more so than the HMA. In the AASHTO 2 alternative, rigid pavement procedure with HMA rehabilitation, the structural package was the same as the AASHTO 1 alternative. It is important to note, however, that in the AASHTO 2 alternative the HMA overlay provides structural support and acts as a load-carrying layer along with the PCC slab.

Group 2 alternatives are very similar to one another. An HMA of 7 in. and a rigid base of 8 inches were the result of the calculations. The thickness of the HMA would tend to greatly reduce the temperature gradient in the rigid layer, reduce the tensile stress at the bottom of the rigid base, and provide a thicker medium that would help mitigate reflective cracking. The rigid bases in these two designs were a lean-mix concrete (or CTB because the elastic modulus of the rigid base was computed to be less than 2,000,000 psi, which falls within both the lean mix and CTB typical ranges) and a PCC for the U.K. and IDOT procedures, respectively. The layers' designed thicknesses obtained by following the design procedure of these transportation agencies was chosen as the typical composite pavement to be analyzed through the mechanistic modeling. The main reason why this design was selected as the typical composite pavement is because of the vast experience both agencies had from publishing their comprehensive design procedures for new composite pavements. This was especially true in the U.K., which according to the literature is one of the countries that has the most experience investigating, designing, and constructing composite pavement systems in the past couple of decades.

Group 3 alternatives had the lowest thicknesses for the HMA surface layer. Despite this low value, the Washington State Department of Transportation specifies, based on experience, that a 4-in. HMA thickness is thought to be thick enough to retard reflective cracking (WSDOT 2007). It is interesting that the Danish alternative is the only one that proposes the use of a granular base layer underneath the rigid base and above the subbase layer. The presence of this granular base layer could account for the lower modulus of the subbase (14,500 psi) and of the subgrade (5,800 psi) used as fixed values in their design table (Table 2-5). In addition, this alternative had the lowest HMA surface thickness (3.5 in.). According to the two procedures used, the thickness of the HMA is enough to retard reflective cracking.

3.1.2 Mechanistic Analysis

In order to understand and model pavement behavior and responses (e.g., stress, strain, deflections) a mechanistic-based analysis was performed. The MICH-PAVE and WinJULEA software, available as a freeware, were used to model, based on the linear elastic analysis (LEA) theory, the mechanistic responses of the composite structures.

WinJULEA is the Windows-based version of the JULEA software developed by the Engineering Research and Development Center (ERDC) of the U.S. Army and Air Force Departments of Defense. The software has been used in the new MEPDG to compute pavement responses for flexible pavements (NCHRP 2004). Results from the MEPDG suggest that the low computation time and accuracy of the mechanistic responses make WinJULEA a good candidate for the analysis of flexible pavement structures.

MICH-PAVE is a non-linear finite element software for the analysis of flexible pavements based on the multi-layer elastic theory. The program calculates displacements, stresses, and strains within the pavement structure due to a single circular wheel load (Harichandran and Baladi 2000). A user-defined mesh can be visualized using the software, and the nodes that compose the mesh are used to compute pavement responses at specific locations at both vertical and radial distances from the applied load. Both of the software outputs were compared prior to using them in this study; their obtained results were very similar.

Mechanistic analyses were performed on various composite structures to understand their behavior as various rigid bases were used. The material properties (i.e., elastic modulus, Poisson's ratio) for each layer are given in Table 3-2. The composite structure analyzed included the following input parameters:

- Surface course: HMA layer; 4 in. of thickness
- Base course: either granular, soil cement, CTB, lean mix, RCC, or PCC; 8 in. of thickness.
- Subbase: granular subbase; 6 in. of thickness
- Subgrade: compacted subgrade; at least 12 in. (sometimes an infinite thickness was assumed by the software because the subgrade was the last layer in the structure)
- Load: either two 4,500-lb loads with a 12-in. separation and a tire pressure of 120 psi or one 9,000-lb load with a tire pressure of 120 psi
- X, Y, and Z coordinates: changed according to the analysis performed

3.1.2.1 Deflections

Composite pavements have been known to provide greater structural support than traditional flexible pavements in addition to the quiet, smooth, comfortable riding surface. High structural support of a pavement structure has been traditionally associated with low deflections at the surface (i.e., deflection measurements are known to be reduced when the bearing capacity of the road is high). In addition, a reduction of deflection under an applied load to the pavement reduces the traffic-induced stresses and strains within the layers of the structure (Nunn et al. 1997). Therefore, a structure that provides lower deflection measurements would tend to reduce the layers' state of stress and strain, causing the pavement structure to be less affected (damaged) by the loading conditions.

The deflection analysis performed is shown in Fig. 3-2. The deflection data was obtained using the WinJULEA computer software.

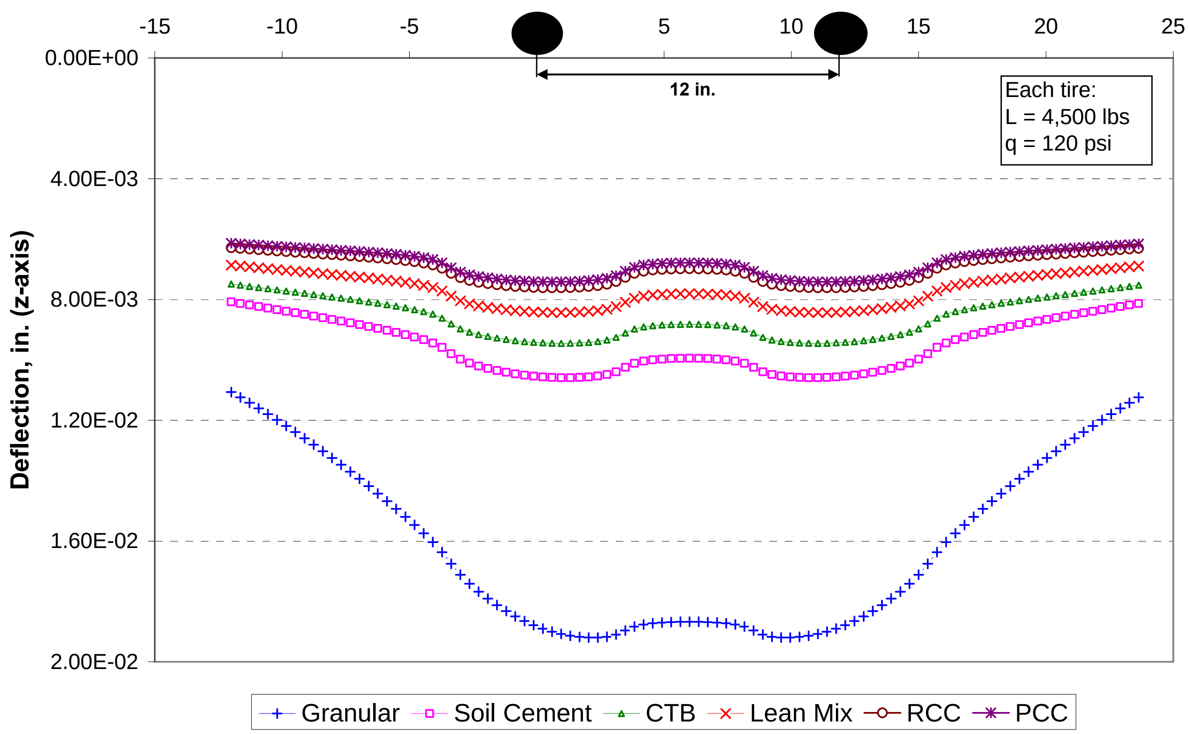

FIGURE 3-2 Surface Pavement Deflections of Various Structures

As confirmed by the mechanistic model, the deflections measured at the pavement surface are greatly reduced as the stiffness of the base increases. In this case, the stiffness or elastic modulus (E) of the base increased from soil cement (E = 500,000 psi) to PCC (E = 4,000,000 psi). The maximum deflection obtained when the granular base was used was 1.92×10^{-2} in.. Table 3-3 shows the percent reduction of deflections, when comparing rigid bases to the granular one, as stiffer base layers were used in the pavement structure.

TABLE 3-3 Maximum Deflection of Pavement Surface with Different Base Layers

Base Layer	Max. Deflection (in.)	Percent Reduction (%)
Granular	1.92×10^{-2}	0
Soil cement	1.04×10^{-2}	45
CTB	9.45×10^{-3}	51
Lean mix	8.43×10^{-3}	56
RCC	7.61×10^{-3}	60
PCC	7.42×10^{-3}	61

Table 3-3 shows that as the rigidity of the base increases, the deflections of the pavement structure decrease. This suggests a reduction of stresses and strains in the various pavement layers, especially in the HMA.

3.1.2.2 Horizontal Stresses and Strains

A pavement structure, when subjected to a load, presents stress and strain responses that are a function of the load force, load location, pressure, and material properties, among other factors. Horizontal stresses have been investigated in the past to understand their effect on failure of HMA and cement-bound materials (e.g., soil cement, CTB, lean mix, RCC, PCC) (Kennedy 1983; Balbo 1993). In addition, horizontal strains have also been investigated to predict HMA and cement-bound material failure (Kennedy 1983; Thogersen et al. 2004; Shook et al. 1982).

The stress analysis performed is shown in Fig. 3-3. The stresses obtained for the plot were computed using the MICH-PAVE computer software.

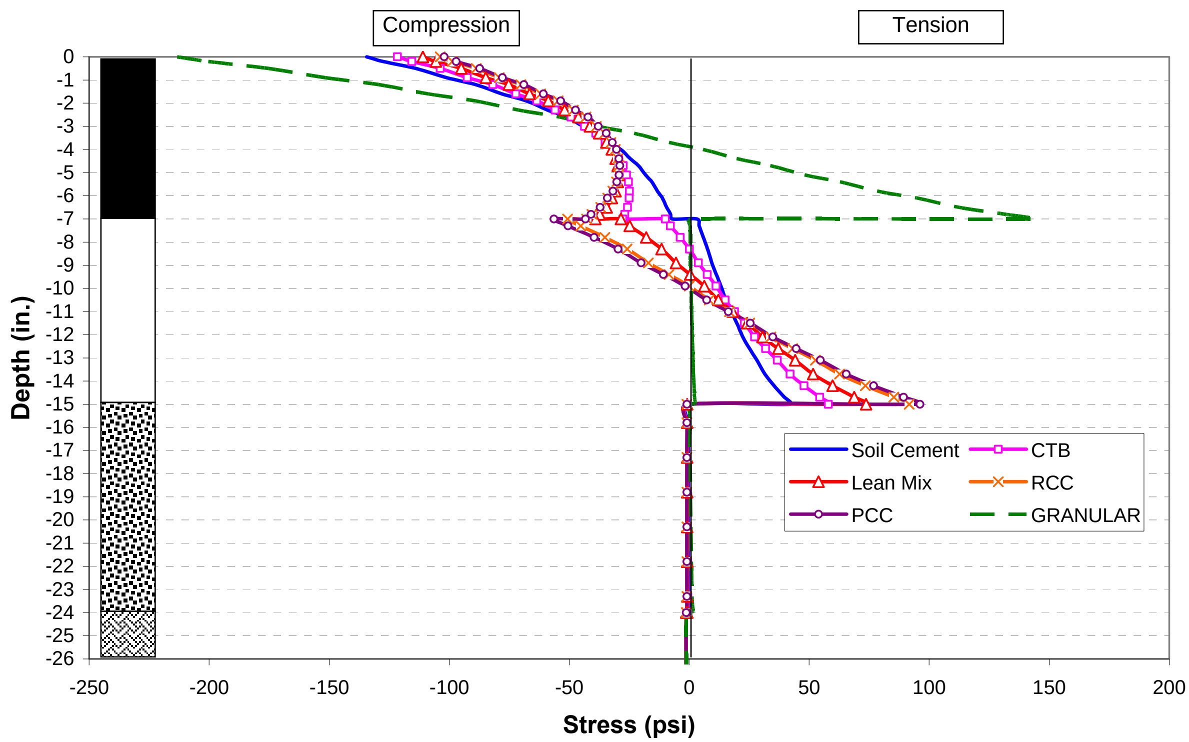

FIGURE 3-3 Horizontal Stresses Analysis Varying Base Stiffness

Two observations from the horizontal stresses output of the mechanistic model can be discussed. First, considerably higher compressive and tensile stresses can be observed in the HMA layer of the typical pavement structure (granular base scenario). In the case of rigid bases, the magnitude of both compressive and tensile stresses is significantly reduced. For a flexible pavement structure, the highest compressive stress is located at the top of the HMA layer, whereas the highest tensile stress is located at the bottom of the HMA layer. For the case of composite pavements, the stresses at the top and bottom of the HMA are in compression due to the rigidity of the base as compared to a granular base.

Second, in the base layer from depths of 7 to 15 in. of the typical flexible pavement structure, the stresses inside the granular base are small because of its low modulus. In the case of composite pavements, the stress distribution goes from compression (top of rigid layer) to tension (bottom of rigid layer). The magnitude of both of these stresses increments as the stiffness of the base increases. According to the literature, the tensile stress at the bottom of the rigid layer criteria is the one used to predict fatigue failure of this layer. The fatigue evaluation of rigid layers will be investigated in the Fatigue Analysis section of this chapter.

The strain analysis performed is shown in Fig. 3-4. The strains obtained for this plot were computed using the MICH-PAVE computer software.

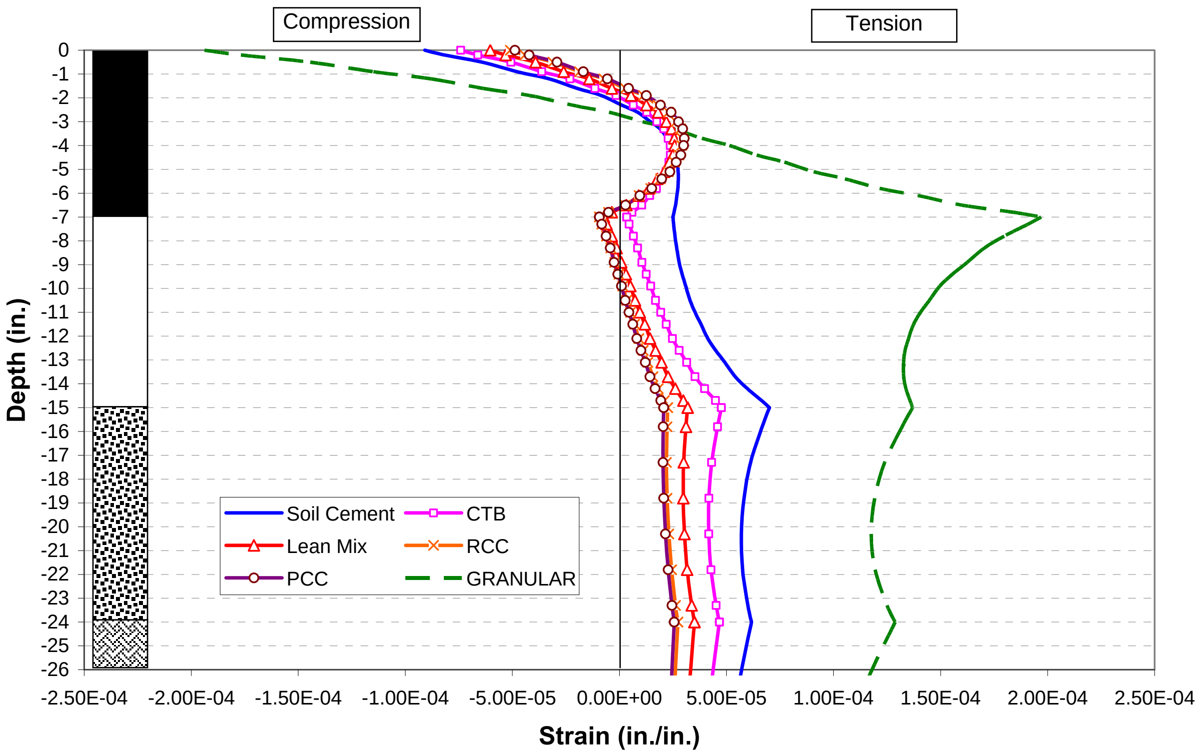

FIGURE 3-4 Horizontal Strain Analysis Varying Base Stiffness

The horizontal strains output obtained from the mechanistic modeling are consistent with the results from the horizontal stresses. In this case, it can be observed that the tensile strain at the bottom of the HMA, which is the most commonly used point of interest when investigating flexural fatigue damage, is significantly larger in the granular base case than in any of the ones obtained when a rigid base was used. This suggests that the chance of having fatigue failure in the HMA when using a granular base is much higher than that with any composite pavement structure. Furthermore, the tensile strain at the bottom of the HMA only occurs for granular, soil cement, and CTB bases; when lean mix, RCC, and PCC are used as bases, the strains become compressive in nature. Thus the likelihood of fatigue cracking is greatly minimized. This phenomenon was also noted in previous publications (NCHRP 2004; Donald 2003).

In the rigid base analysis, due to the rigidity of the base, the highest stresses shown in Fig. 3-3 correspond to the smallest strain responses in Fig. 3-4. In other words, in Fig. 3-3, the rigid layer with the highest stress at the bottom was PCC, whereas in Fig. 3-4, PCC was the layer with the smallest tensile strain magnitude.

3.1.2.3 Vertical Strains

Vertical strains have been used in the past to determine how much deformation is likely to occur on top of the subgrade and thus help determine rutting due to subgrade permanent deformation (Huang 2004). In addition, vertical strains are used in the permanent deformation model proposed by the proposed MEPDG; in this model, resilient vertical strain responses are computed to obtain plastic strain accumulations that are then used to compute the rutting within the HMA layer (NCHRP 2004). The vertical strain analysis performed is shown in Fig. 3-5. The strains obtained for the plot were computed using the MICH-PAVE computer software.

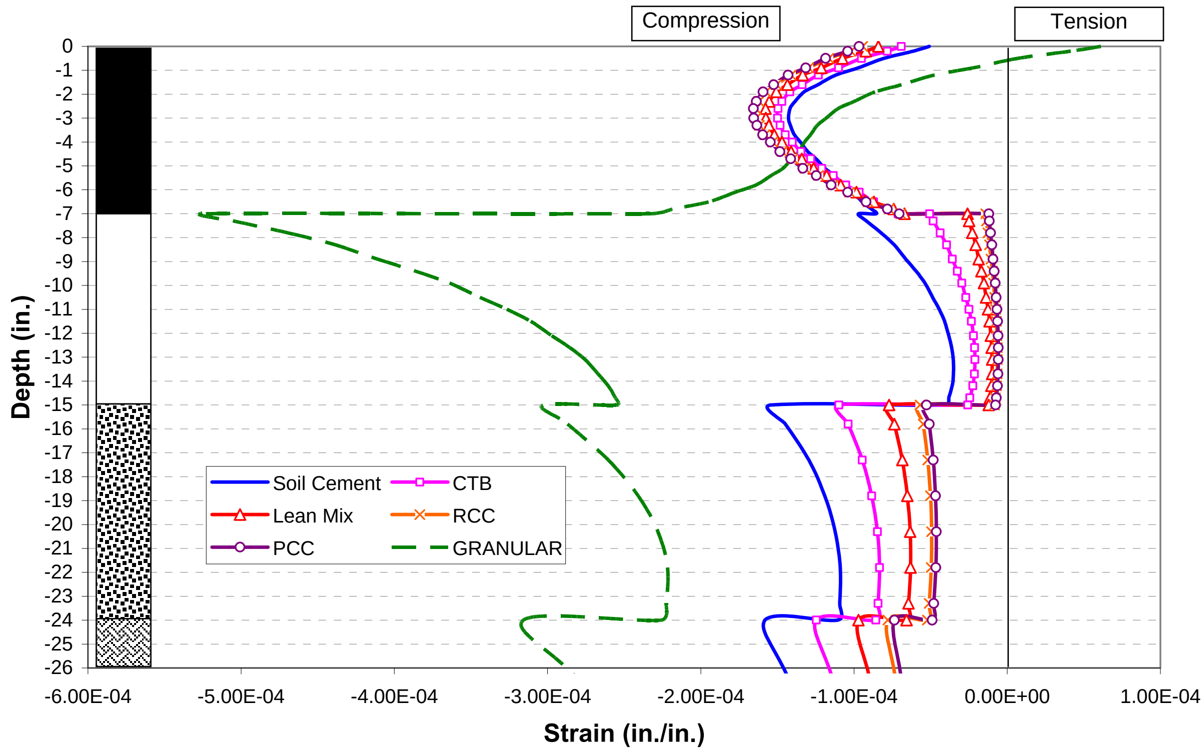

FIGURE 3-5 Vertical Strain Analysis Varying Base Stiffness

The mechanistic model output shows an interesting vertical strain distribution especially in the HMA layer (0 to 7 in.). In the granular case, vertical strains at the top region (0 to 0.5 in.) are tensile in nature. When a lower Poisson's ratio value was used for the HMA (e.g., 0.30), the vertical strains at the top region of the HMA showed compressive responses instead of tensile. Contrarily, when a higher Poisson's ratio value was used for the granular base (e.g., 0.40) the vertical responses gave a greater magnitude of tensile strains than the ones shown in Fig. 3-5. The remainder of the strain distribution (granular case) suggests that the rest of the HMA is in compression with the lower region (4 to 7 in.) presenting a greater magnitude of compressive responses. This lower region, in the case of composite pavements, instead of showing an increasing compressive magnitude as the granular case, shows a reduction of compressive strains. This suggests that higher vertical deformations presented in the HMA are prone to occur in the upper region of the layer (0 to 4 in.).

As the stiffness of the base increases, the compressive strains in the unbound layers (subbase and subgrade) noticeably decrease. The significant reduction of vertical strains at top of the subgrade—at a depth just below 24 inches—suggests that rutting due to permanent deformation of the subgrade is greatly minimized or even unlikely to occur.

3.1.2.4 MICH-PAVE Versus KENSLAB Pavement Responses

According to Huang (2004), to accurately compute the stresses, both compressive and tensile, of each layer in a composite pavement structure, the plate theory should be used. In a composite system, a full bonding between the HMA and the rigid base should be assumed, and an equivalent section can be used with the plate theory to determine the flexural stress in the rigid base (Huang 2004). Consequently, the KENSLAB computer program, developed by Huang and based on the finite-element method, was compared to the results obtained using MICH-PAVE to assess the accuracy of the linear-elastic approach to the plate theory in regards to the computed stresses in the HMA and rigid base.

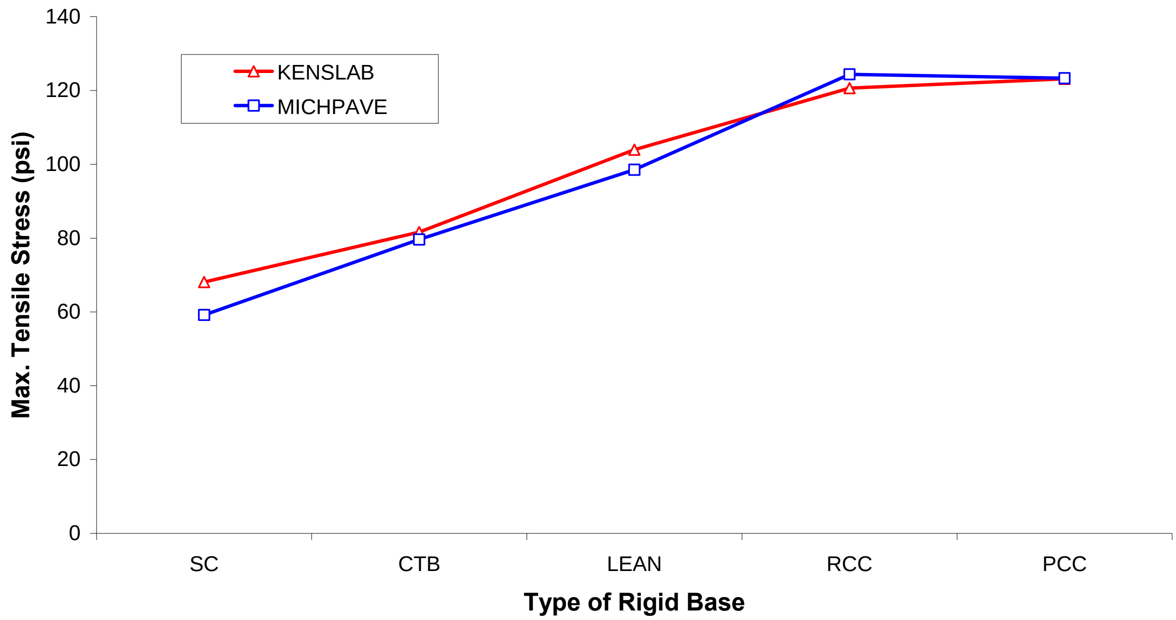

FIGURE 3-6 KENSLAB and MICHPAVE Tensile Stresses Comparison

An evident correlation between the results obtained by MICH-PAVE and KENSLAB can be seen in Fig. 3-6. This suggests that the responses obtained using the linear-elastic-based software (MICH-PAVE) are in agreement with those of the one based on the finite-element method (KENSLAB). It is important to note that the pavement responses computed assume no joints or wide cracks (acting as joints) in the rigid base as is likely to occur when a CRCP base is used for the composite pavement. However, Delatte (2004) published an analysis, using KENSLAB, of a composite pavement that used RCC as the base layer where the presence of any discontinuities in the base were not accounted for. To account for the scenario where discontinuities acting as joints are present, a more sophisticated software package (e.g., ILLISLAB2000) should be used; KENSLAB does not have the capability to analyze two bonded slabs where the bottom slab has joints and the top slab does not. Therefore, in this study all fatigue analyses regarding composite pavements are based on the results obtained by MICH-PAVE considering that the responses obtained from this software are very similar to the ones obtained from KENSLAB.

3.1.3 Distress Modeling and Analysis

Three types of distresses for composite pavements were modeled: fatigue cracking, rutting, and reflective cracking.

3.1.3.1 Fatigue Cracking

The fatigue analyses for composite pavements include the investigation of fatigue failure due to HMA and rigid base fatigue. In the HMA fatigue case, (1) the Asphalt Institute transfer function, Equation 2-35, was used to estimate the number of load repetitions to bottom-up fatigue failure of the layer and (2) the top-down fatigue phenomenon was also modeled using Equations 2-35 and 2-38. In the rigid layer fatigue case, the modeling was based on two criteria: (1) the MEPDG CSM fatigue failure transfer function for soil cement, CTB, and lean mix (Equation 2-29) and (2) the PCA concrete fatigue failure transfer function for RCC and PCC (Equations 2-12 through 2-14).

3.1.3.1.1 HMA and Rigid Base Fatigue

Transfer functions to compute the fatigue failure for the HMA (bottom-up) and rigid bases were used. A summary of the results of the fatigue analysis is shown in Table 3-4 and illustrated in Fig. 3-7. A line indicating 50,000,000 ESALs is provided as a reference.

TABLE 3-4 HMA and Rigid Base Fatigue

Structure	Tensile Strain ($x10^{-6}$) bottom of HMA	Tensile Stress (psi) bottom of RIGID layer	Repetitions to HMA Fatigue (ESALs)[a]	Repetitions to RIGID Fatigue (ESALs)
HMA on granular	197	-	12,808,767	-
HMA on soil cement	25	42.01	44,452,000,000	4,890,000
HMA on CTB	3.44	57.96	*infinite*	186,000,000
HMA on lean mix	-	73.71	*infinite*	6,260,000,000
HMA on RCC	-	96.69	*infinite*	*infinite*
HMA on PCC	-	96.16	*infinite*	*infinite*

[a] Note: The V_b and V_a parameters in Equation 2-36b are assumed to be 7 percent and 4 percent, respectively.

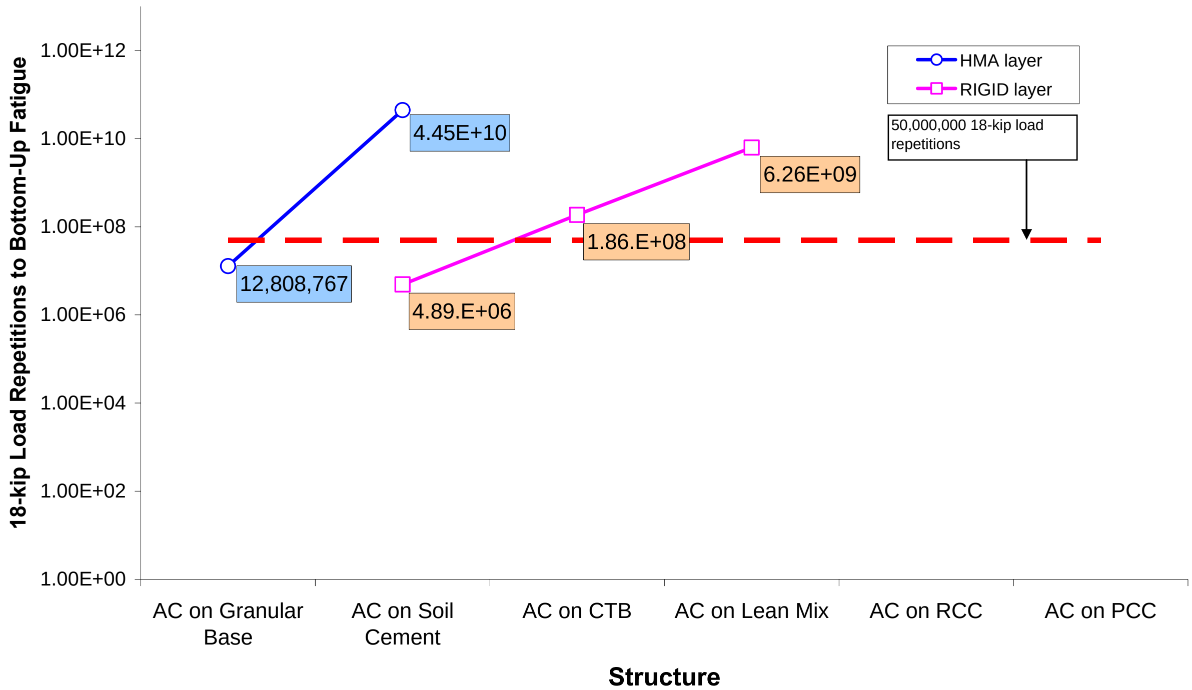

FIGURE 3-7 HMA and Rigid Base Repetitions to Fatigue Failure

According to Fig. 3-7, the number of load repetitions to HMA fatigue is much greater in a pavement with a cement-bound base (e.g., soil cement) than in pavement with a granular base. Table 3-4 shows an infinite number of load repetitions for the HMA on CTB, lean mix, RCC, and PCC base courses; this is because when any of these bases are used, the strain at the bottom of the HMA becomes very small (CTB case) or compressive in nature (lean mix, RCC, and PCC cases) and the flexible layer is highly unlikely to fail due to fatigue cracking.

It can be observed that for composite pavements where the rigid base is a soil cement, CTB, or lean mix, the base is the layer that controls the design, in terms of fatigue, as it would fail earlier than the HMA layer. In the case of RCC and PCC fatigue evaluation, the repetitions were determined to be infinite because the stress ratio (SR) term after a load was applied for RCC and PCC were 0.17 and 0.16, respectively. The fatigue behavior of RCC was assumed to be similar to that of conventional PCC as recommended by the American Concrete Institute (ACI) (Delatte 2004).

In the HMA top-down fatigue modeling, the tensile strain responses at the surface of the pavement structure (z = 0) caused by an 18-kip load were computed. The repetitions to top-down fatigue are plotted in Fig. 3-8. However, it should be noted that this analysis is conducted for illustration purposes only since the available top-down models are only preliminary. These models to not consider the stresses developed close to the surface because of the interaction between the pavement and the vehicle tire among other factors.

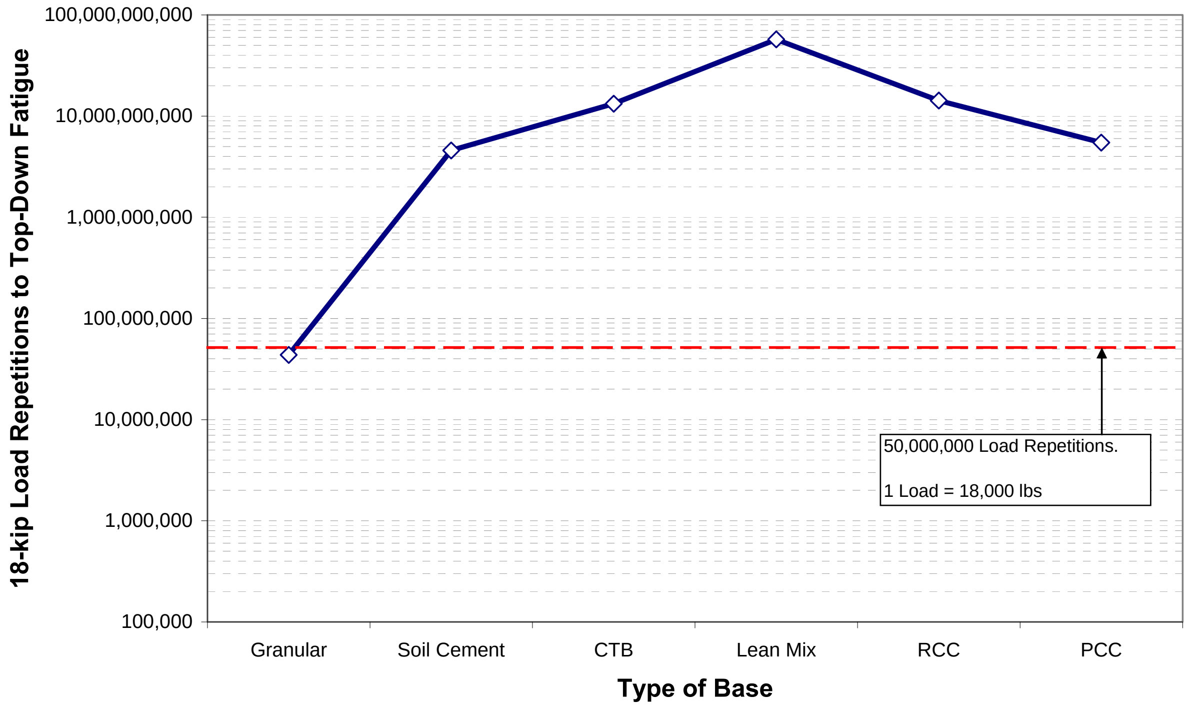

FIGURE 3-8 Top-down Fatigue Analysis

The results from Fig. 3-8 suggest that, generally, as the stiffness of the base layer increases, the top-down fatigue life for the HMA layer is extended. It is important to notice that the number of repetitions is in the order of billions (e.g., for CTB the repetitions calculated were $13\text{x}10^9$). The reason why there is a downward trend in the load repetitions when RCC and PCC are used as the base layer is because of the irregular strain responses obtained at the edge of tire contact with the HMA surface as shown between the –10- and 10-in. x-coordinates in Fig. 3-9.

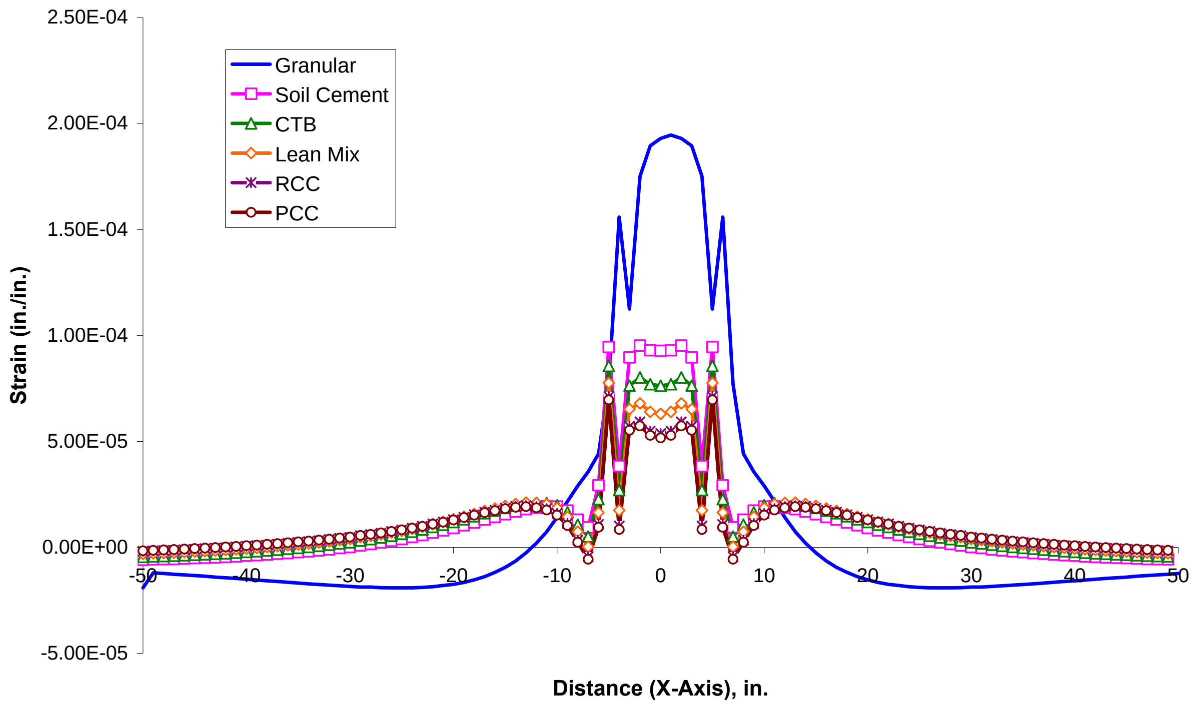

FIGURE 3-9 Horizontal Strains on the HMA Surface Due to Applied Load
Note: negative = tension

Despite the irregular mechanistic responses at the edge of the load, which lead to the sudden drop of load repetitions to top-down fatigue for the RCC and PCC base cases, Fig. 3-8 does confirm that the structures with cement-bound bases can carry many more 18-kip repetitions than the pavement with the granular base.

3.1.3.1.2 Typical Flexible Pavement Versus Composite Pavement Fatigue

A number of typical flexible pavements were compared to various composite pavement structures by varying the thicknesses of both HMA and rigid base layers. All the mechanistic responses were obtained using two 4,500-lb loads with a 120-psi pressure separated by 12 in. Table 3-5 shows a summary of the structures, thickness combinations, and repetitions to failure in this analysis. A plot of the logarithm of all the repetitions to fatigue failure for the various layer combinations is presented as Fig. 3-10.

TABLE 3-5 Typical Flexible and Composite Pavements Fatigue Analysis

		HMA (in.)	Base (in.)	Subbase (in.)	Reps. to Fatigue
Typical Flexible	**Combination 1**	4	8	6	3.34E+06
	Combination 2	6	8	6	1.76E+07
	Combination 3	8	8	6	7.38E+07
	Combination 4	4	10	6	3.61E+06
	Combination 5	6	10	6	1.91E+07
	Combination 6	8	10	6	7.99E+07
Typical Composite (w/ Soil Cement)	**Combination 1**	4	8	6	8.26E+05
	Combination 2	6	8	6	1.40E+07
	Combination 3	8	8	6	1.05E+08
	Combination 4	4	10	6	1.59E+07
	Combination 5	6	10	6	1.17E+08
	Combination 6	8	10	6	3.77E+09
Typical Composite (w/ CTB)	**Combination 1**	4	8	6	6.26E+07
	Combination 2	6	8	6	3.96E+08
	Combination 3	8	8	6	1.50E+09
	Combination 4	4	10	6	5.17E+08
	Combination 5	6	10	6	1.83E+09
	Combination 6	8	10	6	2.19E+10
Typical Composite (w/ Lean Mix)	**Combination 1**	4	8	6	3.42E+09
	Combination 2	6	8	6	9.02E+09
	Combination 3	8	8	6	1.87E+10
	Combination 4	4	10	6	1.22E+10
	Combination 5	6	10	6	2.29E+10
	Combination 6	8	10	6	3.79E+10
Typical Composite (w/ RCC)	**Combination 1**	4	8	6	inf.
	Combination 2	6	8	6	inf.
	Combination 3	8	8	6	inf.
	Combination 4	4	10	6	inf.
	Combination 5	6	10	6	inf.
	Combination 6	8	10	6	inf.
Typical Composite (w/ PCC)	**Combination 1**	4	8	6	inf.
	Combination 2	6	8	6	inf.
	Combination 3	8	8	6	inf.
	Combination 4	4	10	6	inf.
	Combination 5	6	10	6	inf.
	Combination 6	8	10	6	inf.

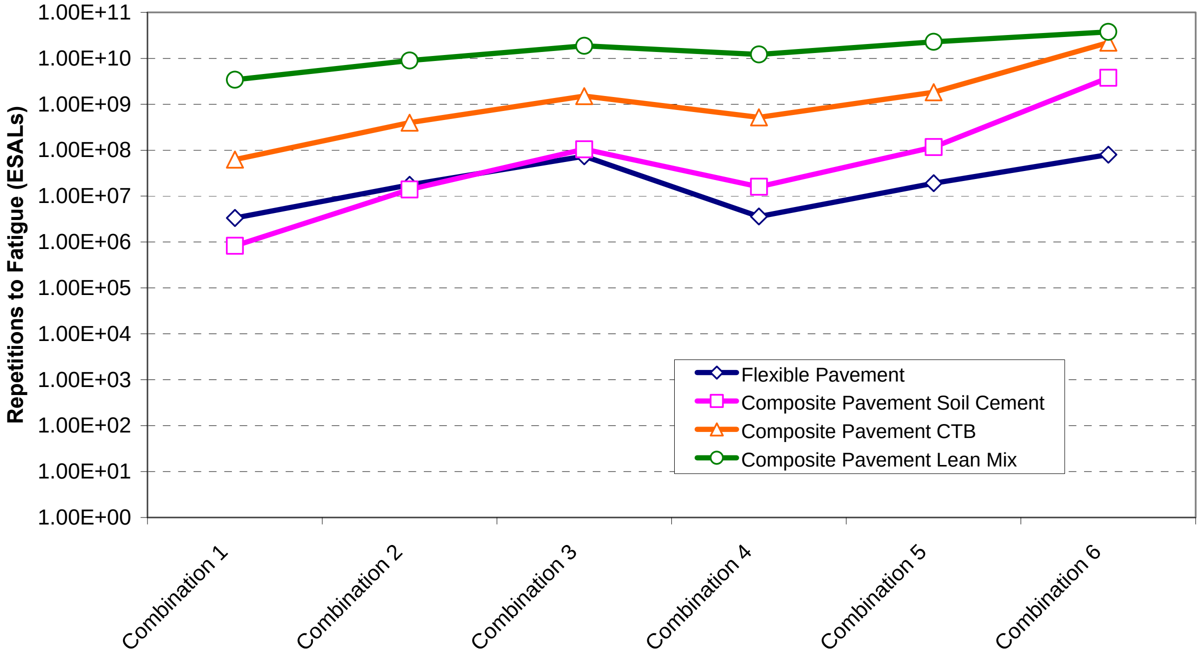

FIGURE 3-10 Typical Flexible and Composite Pavements' Repetitions to Fatigue

The fatigue transfer function used to evaluate the HMA layer fatigue in all combinations for the typical flexible pavement case was Equation 2-35, whereas all composite pavements combinations were evaluated in terms of the rigid layer repetitions to fatigue using Equation 2-29. It can be observed that for any of the combinations shown in Table 3-5, except for some instances of the composite pavements with a soil cement base, all the composite structures performed significantly better in terms of fatigue failure than the typical flexible pavement structure. When a soil cement was used as the base, combinations 1, 2, and 3 showed a similar fatigue performance of the HMA layer and the base layer. Composite pavements with an RCC or PCC base were not considered because the fatigue life of the rigid layer was computed to be infinite in the previous analysis.

3.1.3.2 Rutting

The rutting modeling and analysis includes the investigation of permanent deformations in both the HMA layer and the subgrade that contribute to the rutting distress of pavement structures with an HMA surface course.

3.1.3.2.1 Rutting in the HMA Layer

The modeling of rutting in the HMA layer uses the relationship from the MEPDG (NCHRP 2004), Equation 2-39, to obtain the accumulated plastic strain. This strain results from the sum of various plastic strain deformations inside the bituminous layer, which can be used to determine the rut depth after a specific number of load repetitions. To compute the rut depth, the HMA layer is divided into sub-layers according to the criterion described in the MEDPG, and plastic strains are computed at various points located at different depths from the surface.

Fig. 3-12 shows the results obtained for the rutting in the HMA layer in terms of rut depth (in.) versus the type of base used. The results suggest that as the stiffness of the base increases, the rut depth in the HMA layer increases as well. This was an expected outcome because the high rigidity of the base does not allow any significant vertical deformation to occur, thus the HMA layer absorbs all the vertical strains and deforms itself as illustrated (exaggerated for illustration purposes) in Fig. 3-11.

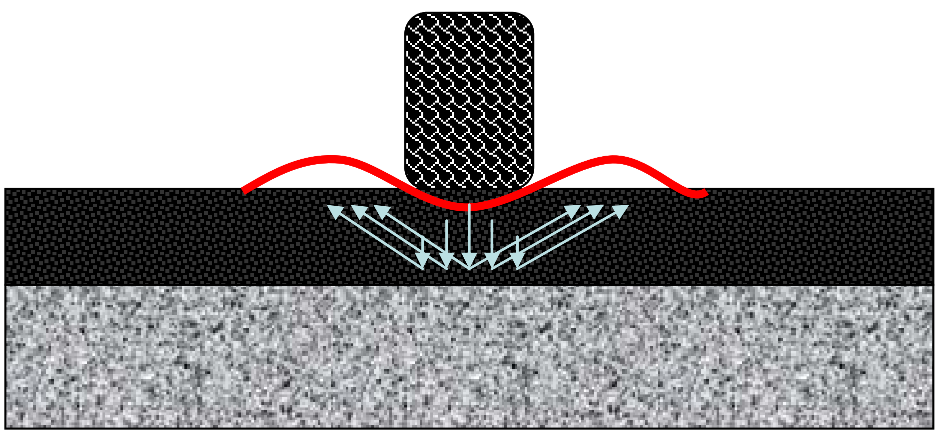

FIGURE 3-11 Permanent Deformation (Rutting) in HMA Layer Due to the Rigidity of the Composite Pavement Cementious Base

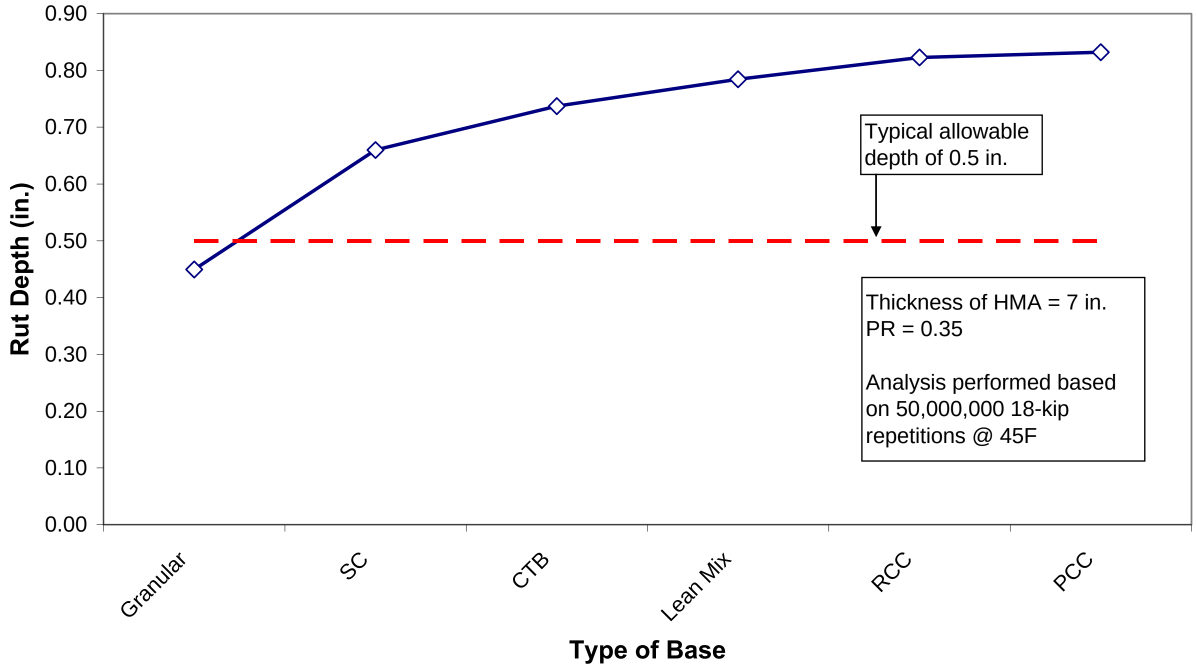

FIGURE 3-12 HMA Rut Depth Versus Base Type

The rut depth line at 0.5 in. shown in Fig. 3-12 represents the value typically allowed by various transportation agencies including the Asphalt Institute (Huang 2004). The HMA rutting results show that for 50,000,000 18-kip load repetitions, the typical flexible pavement was the only structure that met the 0.5-in. rut depth AI criterion. All the composite pavement structures presented greater (up to 0.83-in.) degrees of permanent deformation due to the high number of load repetitions. It is noted, however, that the computed rut depth for all the structures (both flexible and composite) assumed no rehabilitation operations at any time during the 50,000,000 load applications. Therefore, if a functional rehabilitation is applied at any time during the service life of the pavement, part of the permanently deformed HMA would be replaced. Since the upper region of this layer is the one that contributes the most to the rutting (i.e., it is the region that has the highest accumulated plastic strains as a result of the vertical strain responses discussed in Fig. 3-5) the structure may never reach the rut limit of 0.5 in. could potentially be prevented.

3.1.3.2.2 Rutting on Top of the Subgrade

The rutting distress due to subgrade permanent deformation affects flexible pavements mainly because the vertical plastic strains in this unbound (subgrade) layer could potentially influence the total plastic downward deformation in the pavement. However, in the case of composite pavements, because there is a high-stiffness base layer between the unbound layers (subbase and subgrade) and the bituminous one, the rutting due to permanent deformations of the unbound layers is minimized because the vertical stresses that reach the subgrade are very low. Fig. 3-5 shows the vertical strain distributions for various pavement structures and confirms that as the stiffness of the base increased the compressive vertical strains in the unbound layers, including the subgrade, decreased noticeably.

3.1.3.3 Reflective Cracking

The modeling of reflective cracking was based on the study published by Sousa et al. (2002), which proposed a mechanistic-empirical HMA overlay design that predicts the number of 18-kip load repetitions for a predetermined percentage of reflective cracking.

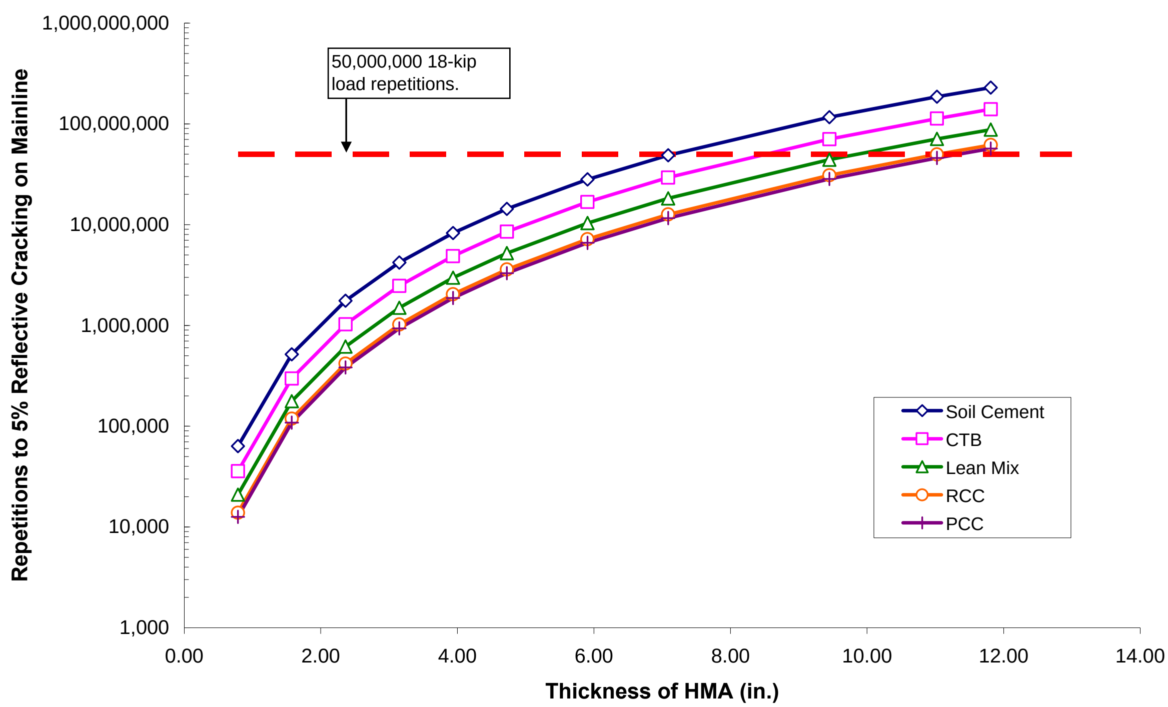

FIGURE 3-13 Reflective Cracking Modeling for Various Rigid Bases and HMA Thicknesses

As the thickness of the HMA layer increases, the number of repetitions to achieve a 5 percent reflective cracking also increases as shown in the semi-log plot (Fig. 3-13). This mechanistic-empirical model was originally proposed to predict the reflected cracks on an HMA overlay placed on top of a cracked HMA. This model was chosen to investigate reflective cracking in composite pavements because of its practical application to predicting this type of distress on HMA overlays. In addition, very few methodologies or procedures have been published to predict reflective cracking on composite pavement systems (i.e., HMA on PCC or rigid bases), mainly because of the difficulty of modeling the behavior and interface interaction of these two very different materials. However, the findings and proposed procedure by Sousa et al. (2002), which involves the computation of vertical crack activities before and after the overlay is placed, were assumed to be reasonably applicable to a composite pavement system when the typical values of a composite structure are input.

For 50,000,000 18-kip load repetitions, as the rigidity of the base increased, the number of repetitions to achieve a 5 percent reflective cracking on the HMA overlay decreased. This suggests that using a stiffer base would tend to generate more reflective cracking on the surface. The thickness of the HMA layer has some effect on the retardation of reflective cracking to reach the surface; this is particularly noticeable for thicknesses between 1 and 4 in. In addition, the asseveration of publications regarding the minimum HMA thickness of 4 in. to control reflective cracking is supported by the results in Fig. 3-13, in which the load repetitions to reflective cracking for any HMA thicknesses less than 4 in. are significantly reduced.

3.1.4 Sensitivity Analysis

The sensitivity analyses included variation of different parameters that were plotted against the results obtained for the various composite pavement systems. A sensitivity analysis was performed on fatigue behavior, rutting in the HMA layer, reflective cracking, and temperature gradient reduction of a PCC slab with an HMA overlay.

3.1.4.1 Fatigue

As mentioned previously, the fatigue behavior of a composite pavement relies on the fatigue of the rigid layer. In addition, the rigid layer fatigue depends mainly on the applied stress at the bottom of the layer and the MR.

The first sensitivity plot, Fig. 3-14, includes the load repetitions (18-kip) to fatigue failure of the various rigid bases when different thicknesses were used. The layer thicknesses varied from 4 to 10 in.; this covers a wide range of possible alternatives in rigid base thicknesses and also complies with ranges of rigid layer thicknesses computed in the designed composite structures previously discussed. As the rigid base thickness increases, the repetitions to fatigue failure increase as expected. The reduction in stresses at the bottom of the rigid layer is apparent as shown in Fig. 3-15. This suggests that in the case of soil cement, CTB, and lean-mix concrete, the use of a thicker layer thickness would significantly increase the fatigue life of the base. Fig. 3-14 does not include the fatigue analysis of RCC and PCC because for both of these layers all the SR values calculated (Equation 2-15) were below 0.45, which suggests that the fatigue life of these two layers is infinite.

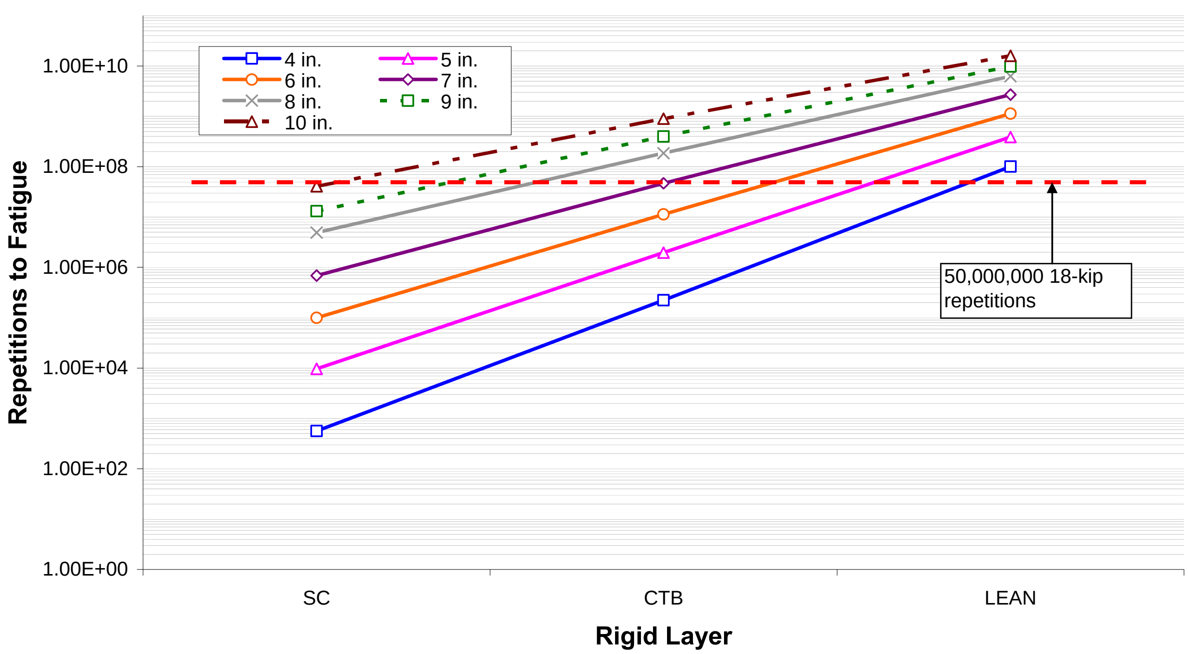

FIGURE 3-14 Repetitions to Rigid Base Fatigue for Various Base Thicknesses

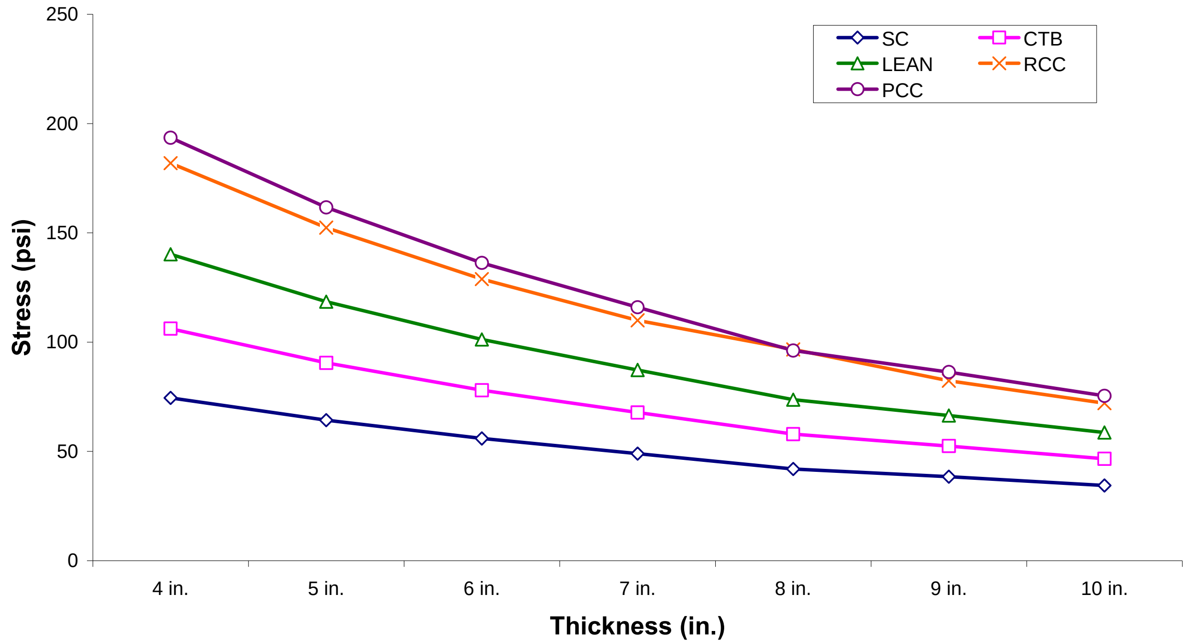

FIGURE 3-15 Tensile Stresses at Bottom of Various Rigid Layer Thicknesses

As previously stated, the fatigue analysis for the rigid layers was based on the new MEPDG model (Equation 2-29) for soil cement, CTB, and lean-mix concrete and the PCA fatigue model (Equations 2-12 through 2-14) for RCC and PCC, as they have a similar behavior. A stress-ratio plot, Fig. 3-16, was created to show how the stress ratio would change as the thickness of the rigid base layer increases. The results show that the behaviors of lean-mix concrete, RCC, and PCC in terms of stress ratio are very similar.

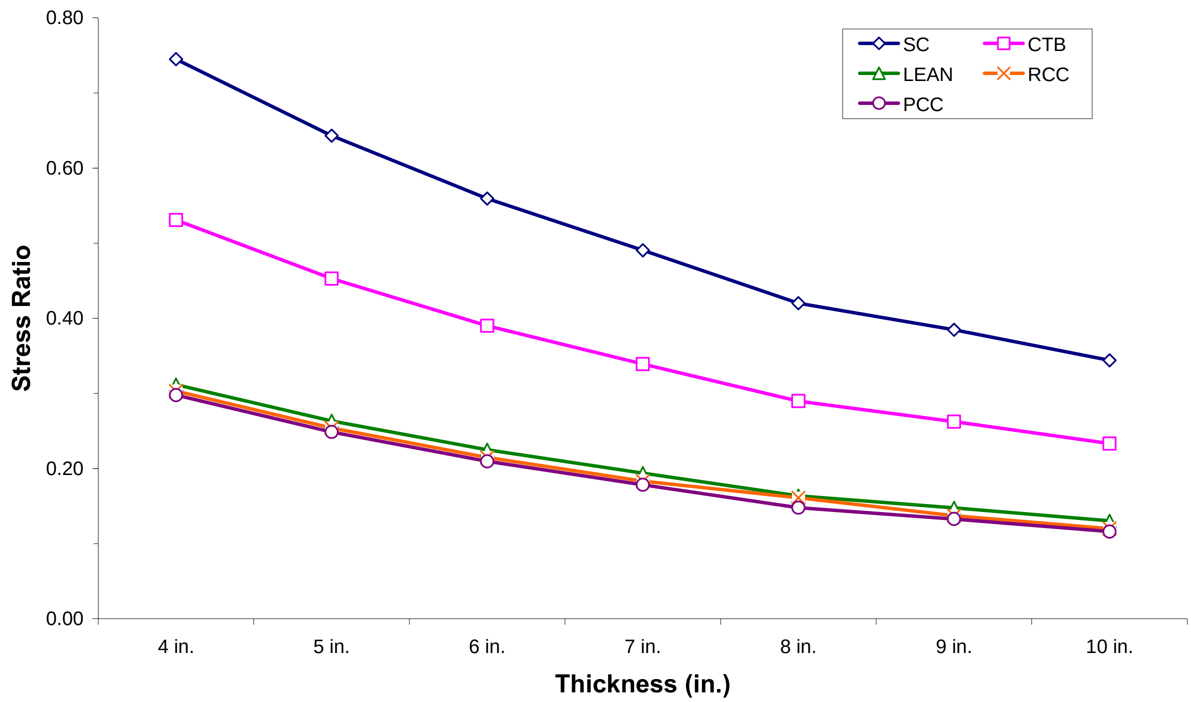

FIGURE 3-16 Stress Ratio of the Rigid Base Layer at Various Thicknesses

The modulus of the HMA layer also has an important influence on the stresses at the bottom of the rigid base, which in turn influence the load repetitions to fatigue failure. Fig. 3-17 shows the result of a sensitivity analysis that focused on the change in stresses and repetitions to fatigue in the rigid layer because the modulus of the HMA tends to fluctuate due to seasonal variations. The HMA modulus variation ranged from 100,000 to 1,000,000 psi. The stress reduction analysis shows that the stresses at the bottom of the lean-mix concrete base decrease at a fairly rapid rate when the modulus goes from 100,000 to 400,000 psi; after this stage, the reduction rate of the tensile stresses moderately diminishes. This suggests that when the HMA modulus goes from a low (100,000 psi) to typical stiffness (450,000 psi), the stresses at the bottom of the rigid base layer tend to reduce more rapidly than when the HMA layer modulus goes from a typical stiffness of 450,000 psi to 1,000,000 psi.

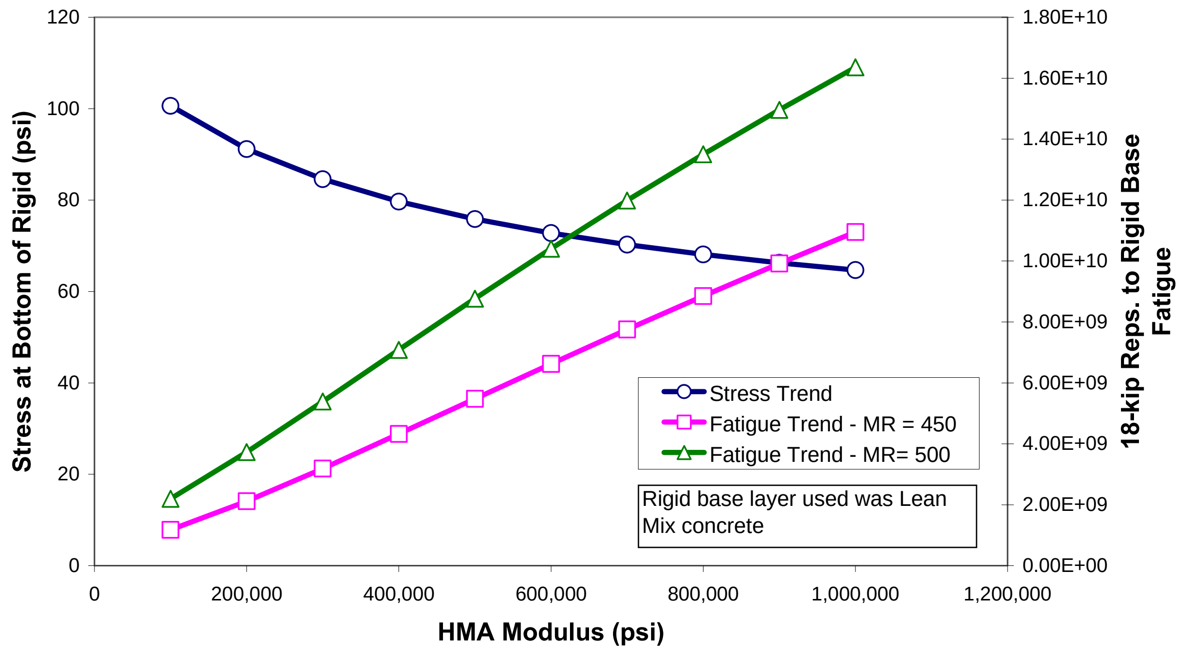

FIGURE 3-17 MR and HMA Modulus Variation Effect on Stresses at Bottom of Rigid Layer Versus ESALs (18-kip Loads) to Fatigue Failure

The MR of the cementious mixtures investigated in this study is a critical factor to consider when evaluating the fatigue resistance of the rigid base. In addition to the HMA modulus variation analysis previously discussed, Fig. 3-17 also includes a secondary y-axis that shows the 18-kip load repetitions to fatigue failure of the lean-mix concrete base layer. Two fatigue trends are shown in this plot: one used the tensile stress values at the bottom of the lean-mix base (which were affected by the HMA modulus) with an MR of 450 psi, whereas the other used the same tensile stress values at the bottom of the lean-mix base but with an MR of 500 psi. As a result, it is evident that the MR value has a higher degree of influence in the number of repetitions to fatigue failure of the rigid base than the tensile stresses at the bottom of the layer.

3.1.4.2 Rutting

Rutting in the HMA layer may be affected by several factors; among these factors are the applied load repetitions and temperature variation. The rutting modeled in Fig. 3-11 included an average annual air temperature of 45 °F, which was the temperature value also considered in the modeling of rutting models by the Asphalt Institute (Huang 2004). In this sensitivity analysis, the number of 18-kip load repetitions ranged from 100,000 to 70,000,000 (Fig. 3-18) and the temperature varied from 25 to 85 °F (Fig. 3-19).

As the number of load repetitions increased, greater rut depths were computed in the HMA layer. This was an expected outcome because the vertical strain distributions in Fig. 3-5 showed a greater magnitude in compressive strains in the HMA layer as the stiffness of the rigid base increased. In addition, as the air temperature increased, the predicted rut depths increased as well.

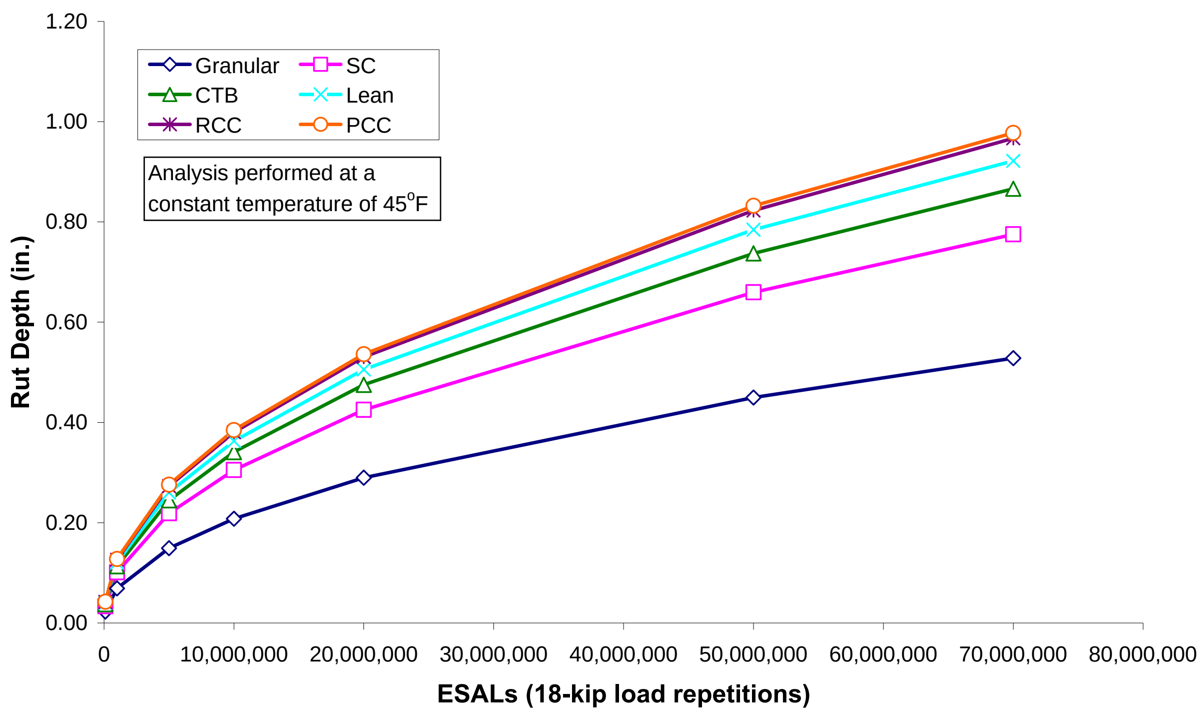

FIGURE 3-18 Rut Depth in HMA Layer Using Various Bases at Different Load Repetitions

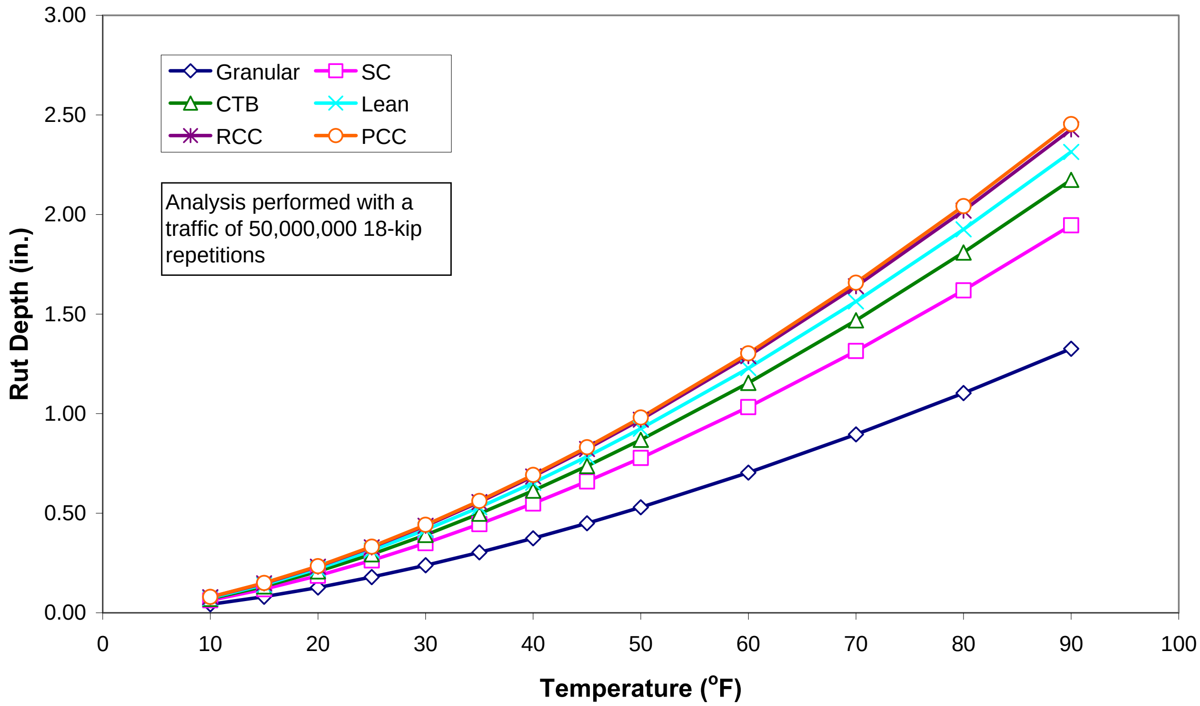

FIGURE 3-19 Rut Depth in HMA Using Various Bases at Different Air Temperatures

3.1.4.3 Temperature Gradient in Concrete Slab

The temperature gradient in a concrete slab can be used to estimate the curling stresses of the slab as follows:

$$\sigma_t = C \bullet \alpha \bullet E \bullet \phi \bullet h_c \tag{3-1}$$

where

σ_t = curling stress

C = constant

α = thermal expansion coefficient of concrete

E = elastic modulus of concrete

ϕ = temperature gradient in concrete slab

h_c = thickness of concrete slab

According to Nishizawa et al. (2000) the reduction effect of temperature gradient in a concrete slab due to the presence of an asphalt surface course can be obtained as follows:

$$\phi_c = \lambda \bullet \phi \tag{3-2}$$

where

ϕ_c = temperature gradient in a concrete slab with an asphalt surface course

λ = reduction factor

The two equations obtained in the Nishizawa et al. (2000) study were derived as a function of the thickness of the asphalt layer for both a dense asphalt concrete surface and a porous asphalt concrete surface.

dense HMA: $$\lambda = 1.43 - 0.114 \bullet h_{as} + 0.00316 \bullet h_{as}^2 \tag{3-3}$$

porous HMA: $$\lambda = 1.41 - 0.118 \bullet h_{as} + 0.00339 \bullet h_{as}^2 \tag{3-4}$$

where

h_{as} = thickness of asphalt surface course (cm)

The range of Equations 3-3 and 3-4, which was the range of the study's sections, is limited from 5 to 10 cm. However, an extrapolation shown in some plots of the publication suggested that an extrapolation might be applicable to the present study. Fig. 3-20 shows a sensitivity analysis involving the increment of thickness of the HMA layer and the reduction factor magnitude for the temperature gradient of a concrete slab.

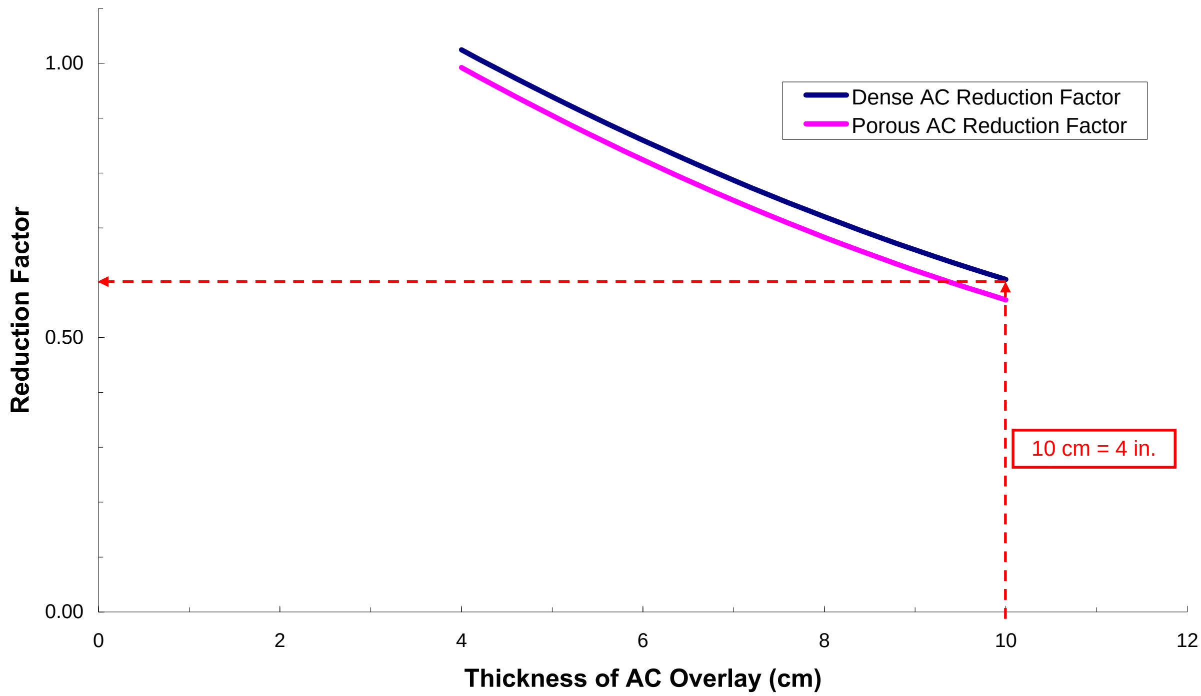

FIGURE 3-20 Reduction Factor of Temperature Gradient Using Various Overlay Thicknesses

As the thickness of the HMA layer increases, the reduction factor decreases, suggesting that the temperature gradient in the concrete slab will decrease noticeably. The publication investigated the use of up to a 10-cm (4-in.) overlay; therefore, the HMA thickness of 7 in. computed for composite pavements may not be directly applicable. However, if a 4-in. overlay had a reduction factor of 0.57, which translates to a temperature gradient reduction of 43 percent in a concrete slab, then a thicker overlay may tend to have a higher temperature gradient reduction.

A low temperature gradient in the concrete slab influences the curling stresses that could accelerate the growth rate of reflective cracks due to thermally induced movements of the slab of a composite pavement system.

3.2 Economic Study of Composite Pavement Systems

The economic study of composite pavement systems was based on a deterministic LCCA of the agency costs following VDOT LCCA guidelines (VDOT 2002). These guidelines include predefined work schedules for various pavement structures. Table 3-6 shows the work schedule used in the LCCA for this study. Although no published documentation regarding rehabilitation and maintenance activity work schedules was found for composite pavements with a CRCP base, the VDOT guidelines for the flexible, rigid (CRCP), and semi-rigid (composite with CTB) pavement structures were used. A continuous 10-year functional mill and overlay maintenance activity was assumed for the composite with CRCP base pavement based on the literature (NCHRP 2004; MDOT 2002; Smith et al. 2001). The geometric characteristics of the designed road section were as follows:

- Total travel lanes width = 24 ft
- Inside shoulder width = 10 ft
- Outside shoulder width = 12 ft
- Length of road section for analysis = 5,280 ft = 1 mile
- Mainline area = 126,720 sq. ft
- Inside shoulder area = 52,800 sq. ft
- Outside shoulder area = 63,360 sq. ft

TABLE 3-6 Layer Thicknesses (in.) of the Pavement Structures used for the LCCA

Layer	Type of Pavement			
	Flexible	**Rigid (CRCP)**	**Composite w/ CTB**	**Composite w/ CRCP Base**
HMA	11.5	-	9	7
CRCP	-	14	-	-
CTA[a]	-	6	8	-
Granular base	8	-	-	-
CRCP base	-	-	-	8
Subbase	9	-	9	9

[a] Note: CTA = cement-treated aggregate

As shown in Table 3-6, four types of pavements were analyzed. In order to obtain accurate agency costs for each of the pavements, thicknesses had to be computed. The cross-sections of all the pavements used are shown in Fig. 3-21. Following the recommendations from VDOT, the thicknesses for the typical flexible, rigid (CRCP), and semi-rigid (Composite with CTB) pavements were obtained using the AASHTO 1993 method, whereas the thickness for the “true” composite pavement with CRCP base was based on the mechanistic modeling and analysis in this study. The design was based on a typical section of Interstate 81 with an annual average daily traffic (AADT) of 50,000 and 30 percent trucks yielding around 67,000,000 ESALs over a 30-year pavement design period. The three AASHTO-based pavements were designed, and the composite pavement with CRCP base was checked to make sure all the structures were able to support the aforementioned traffic volume. The structural package of each of the structures was comprised of the layers and thicknesses shown in Table 3-6.

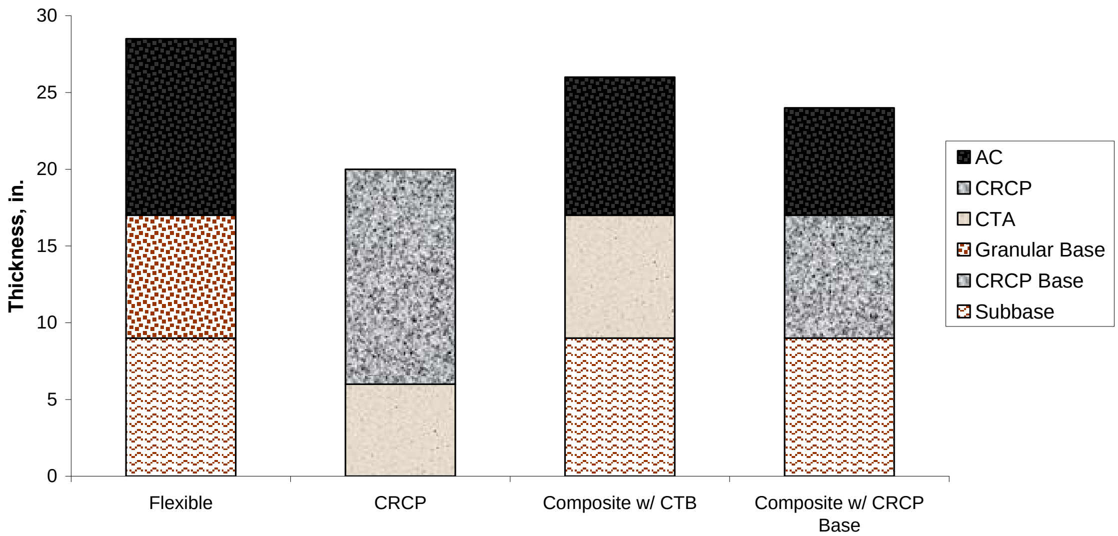

FIGURE 3-21 Pavement Cross-Sections Used for LCCA.

All the activity items pertaining to each of the activities in the work schedule for the pavements, in addition to the agency costs computed, were obtained following the VDOT LCCA procedure. A 50-year analysis period was used as recommended by VDOT's publication. The unit prices of various items were obtained using the average state bid tabulations published by VDOT's website (VDOT, 2007). The unit weight values for AC, aggregates, and drainage layer remained unchanged for the volumetric computations. All costs computed were based on a 1-mile road section. In addition, the PW method was selected to compare all the different pavement alternatives. A discount rate of 4 percent, as recommended by VDOT and the FHWA, was used.

TABLE 3-7 Work Schedule for Pavement Alternatives Activities

Year	Type of Pavement			
	Flexible	**Rigid (CRCP)**	**Composite w/ CTB**	**Composite w/ CRCP Base**
0	New construction	New construction	New construction	New construction
2				
4				
6				
8				
10		Pavement maintenance		Functional mill and replace
12	Functional mill and replace		Functional mill and replace	
14				
16				
18				
20		Pavement restoration and HMA overlay		Functional mill and replace
22	Structural mill and replace		Structural mill and replace	
24				
26				
28				
30		Functional mill and replace		Functional mill and replace
32	Major rehabilitation		Major rehabilitation	
34				
36				
38				
40		Pavement restoration and HMA overlay		Functional mill and replace
42				
44	Functional mill and replace		Functional mill and replace	
46				
48				
50	Salvage value	Salvage value	Salvage value	Salvage value

To assess the applicability of the work schedule shown in Table 3-7 for the composite pavement with CRCP base alternative, the distress allowable repetitions curves obtained during the technical analysis (i.e., Figs. 3-7, 3-8, 3-13, and 3-18) were used to estimate the number of years required for a maintenance operation to be triggered. The dotted blue line in Fig. 3-22 (a) and (b) shows the graphical method used to determine the years in Table 3-8. Fig. 3-23 was used to determine the year number to which a specific number of ESALs corresponds and the results are shown in Table 3-8.

TABLE 3-8 Years for Composite Pavement with CRCP Base to Reach Distress Trigger Levels

	Fatigue (Bottom-Up)	**Fatigue (Top-Down)**	**Rutting**	**Reflective Cracking**	**Table 3-7 Proposed Year for Maintenance Activity**
Composite w/CRCP Base	50+	50+	~11	~8	10

Table 3-8 shows that the proposed year for maintenance activity is within the range of the rutting and reflective cracking distress. It is important to mention that reflective cracking is highly unlikely due to the absence of longitudinal or transversal joints. Any cracking in the surface of the concrete base will probably propagate through the HMA surface as thin reflective cracks that would not negatively affect the roughness or structural adequacy of the pavement structure. Rutting in the HMA would be the other type of distress considered during the 50-year service life analysis of the composite pavement with CRCP base. As previously mentioned in the rutting technical analysis section, milling and replacing part of the HMA course will correct the developed rutting. The bottom-up and top-down fatigue distresses were determined to have a life of more than 50 years. Therefore, for the composite pavement with CRCP base the 10-year functional maintenance frequency recommended by the literature is appropriate. The result of the LCCA are summarized in Fig. 3-24.

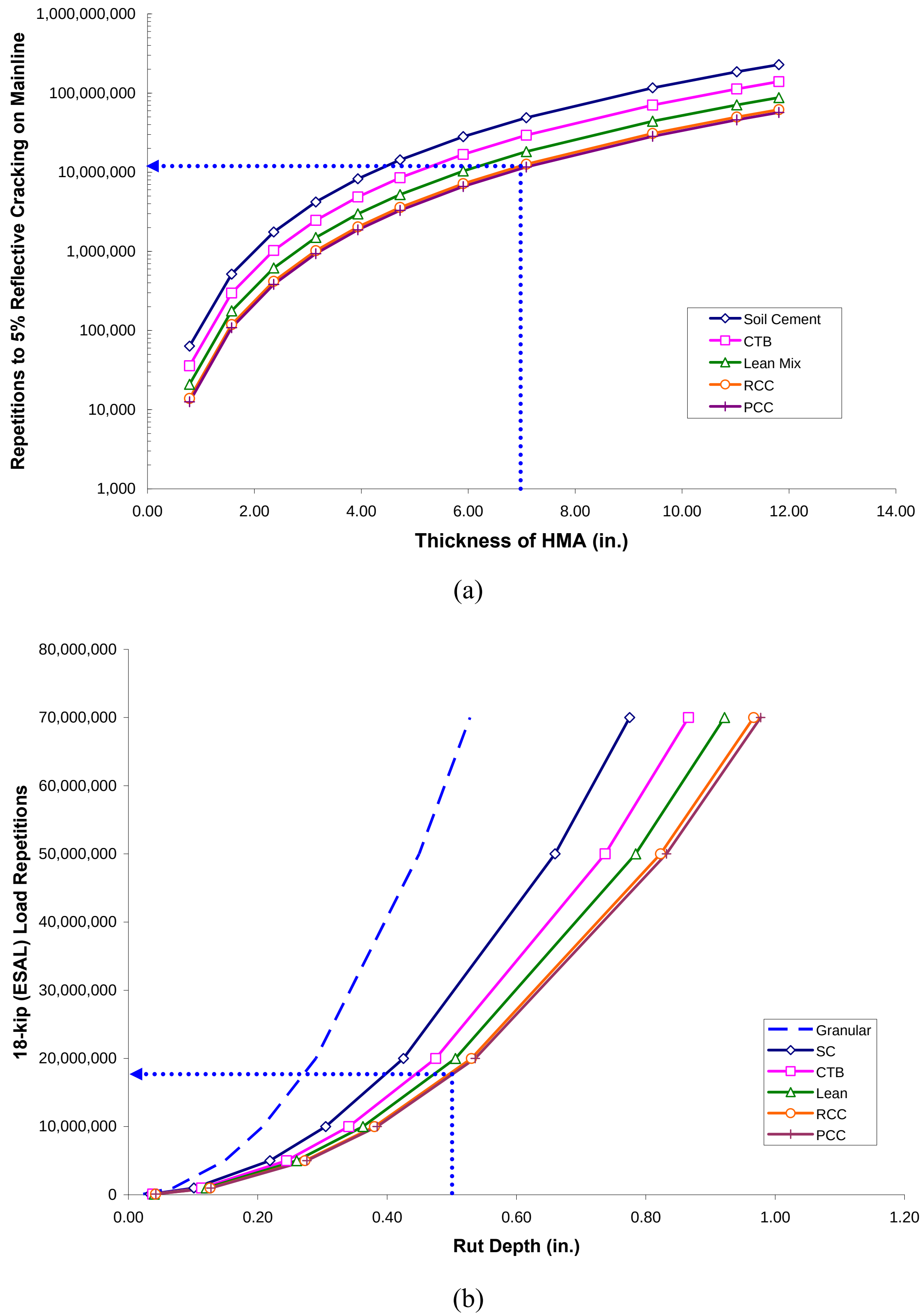

FIGURE 3-22 Load Repetition (ESALs) Triggers for (a) Reflective Cracking, and (b) Rutting

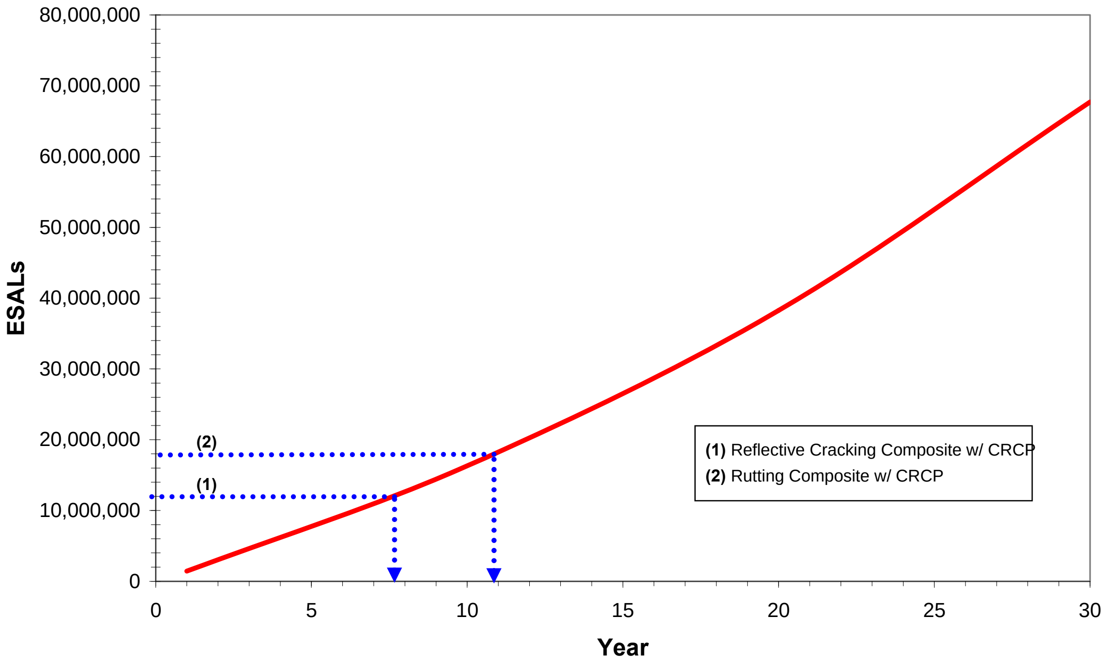

FIGURE 3-23 30-year Cumulative ESALs and Distress Trigger Years for Composite Structures

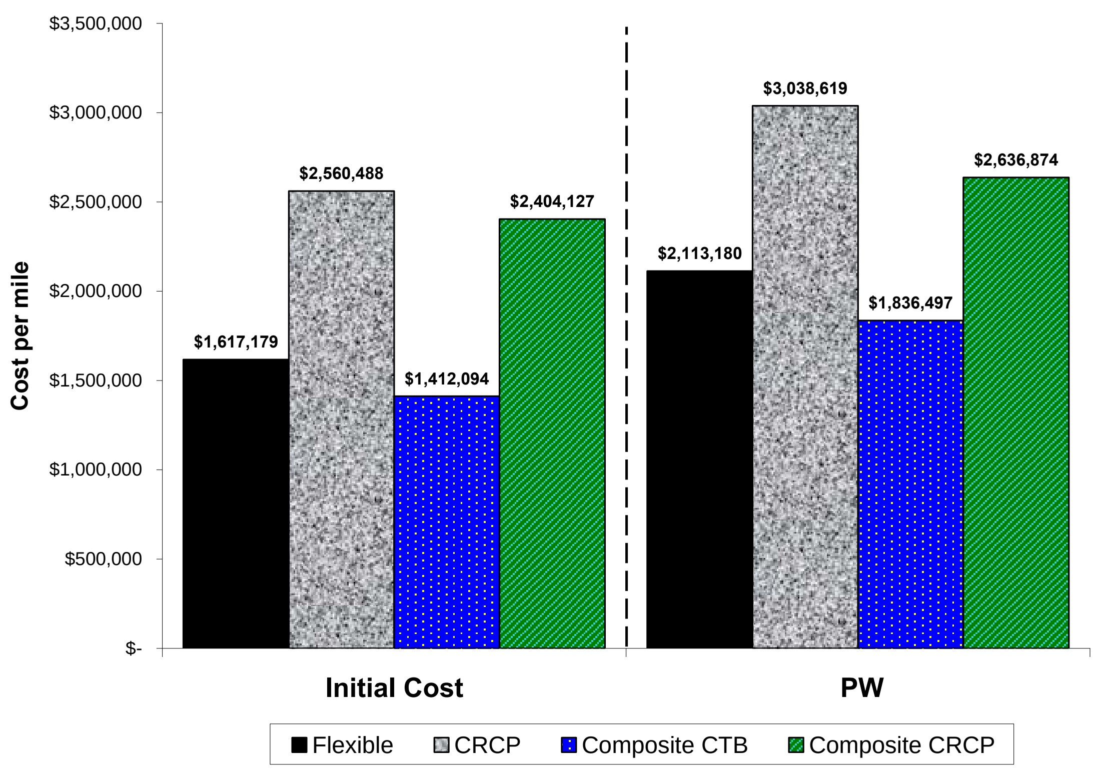

FIGURE 3-24 Initial Construction and PW Costs for all Alternatives

A comparison between all the computed costs, including initial and total life-cycle cost increment due to maintenance and rehabilitation is shown in Table 3-9.

TABLE 3-9 Computed Costs Analysis for the Different Pavement Types

Pavement	Initial Cost	Total LCC
Flexible	$ 1,617,179	$ 2,113,180
CRCP	$ 2,560,488	$ 3,038,619
Composite w/CTB	$ 1,412,094	$ 1,836,497
Composite w/CRCP	$ 2,404,127	$ 2,636,874

An interesting distribution of the agency costs can be observed in Table 3-9 and Fig. 3-24. The least expensive pavement alternative was the composite pavement with a CTB layer. The next least expensive alternative was the flexible pavement, with a cost difference of 13 percent. The composite pavement with a CRCP base layer was the third least expensive alternative, with a cost difference of 30 percent. Finally, the rigid CRCP had the greatest cost of all the pavement alternatives. Several factors contribute to making the composite with CTB the least expensive alternative. The unit price of the cement-treated aggregate (CTA), used to construct the CTB, is \$21.00 per ton with a typical unit weight of 150 lbs/ft^3, whereas the unit price of a granular base (aggregate 21-B) is \$18.00 per ton with a typical unit weight of 152 lbs/ft^3. This suggests that the cost of the base layer (either CTB or granular base) is similar for both the typical and composite pavements with CTB. Because of this, the main cost is attributed to the AC (HMA) layer, which has an average unit price of \$68.00 per ton (\$76.00 for AC surface mix, \$65.00 for AC intermediate mix, and \$62.00 for AC base mix) with a typical unit weight of 146 lbs/ft^3 for the AC surface mix and AC intermediate mix and 153 lbs/ft^3 for the AC base mix. Therefore since the typical AC thickness is 11.5 in. for flexible pavement and 9 in. for the composite with CTB, the cost of this layer makes a difference of \$239,996, which is fairly close to the final difference of \$276,683 between the alternatives. Note that according to the California Asphalt Price Index (California Department of Transportation 2007) and the Asphalt Contractors Association of Florida (2007), the price index of asphalt has experienced a fluctuating but greatly increasing trend over the past couple of years, suggesting that the cost of constructing flexible pavements using thick AC layers and accurately estimating their future expenses is difficult to predict.

In the case of the composite pavement with a CRCP base, the cost of the 8-in. concrete base ($66.00 per sq. yd) is relatively high. With the computed thickness of the rigid slab using the AASHTO 1993 method for the CRCP pavement alternative, the price per square yard was $85.00, which accounts for the majority of the price difference between the composite pavement with CRCP base and the rigid pavement alternative.

Despite the noticeable difference in the PW costs obtained, there is an important consideration regarding composite pavements. According to the VDOT LCCA publication, a composite pavement with a CTB would be due for a reconstruction when year 50 is reached. However, Balbo and Cintra (1994) conclude that because CTB is originally produced with aggregates (i.e., it contains CTA) the material will behave like a very good granular material. This suggests that a reconstruction may not be required; milling and replacement of the AC layer would be sufficient. In the case of the composite pavement with CRCP base, a similar assumption can be made because only functional maintenance operations are performed on the asphalt course throughout its service life. In addition, the longevity of such pavement, due to the bituminous surface layer preserving the structure integrity of the base, suggests that reconstruction is not necessary. In brief, typical flexible and rigid pavements reach the end of their service lives after 50 years, at which time a reconstruction is likely to occur; however, composite pavements can last more than 50 years as long as maintenance and light rehabilitation operations are performed.

Regarding user costs, road user costs (RUC) are very complex and difficult to quantify. The most popular methods for evaluating construction-related RUC are analytical. Some of these methods include deterministic queuing, shock wave analysis, and time-dependent coordinate transformation (Vadakpat et al. 2000). Unfortunately, these analytical methods do not take into consideration driver behavior, which further complicates the RUC analysis. In LCCAs performed by most state agencies, RUC are not included because of their inherent complexity and also because they are not considered part of the state's budget. Vadakpat et al. (2000) state that a 1993 AASHTO *Life Cycle Cost Analysis Survey* "regarding the methods of calculating RUC in all the state highway agencies showed that a significant number of states do not calculate RUC or do not generally use accepted guidelines" (Vadakpat et al. 2000, p. 1). For this reason, a numerical evaluation of RUC is considered to be outside the scope of this study and thus excluded from the LCCA. From a qualitative point of view, however, RUC would tend to be smaller when the "true" composite pavement (HMA over CRCP) is in place, as compared to the traditional flexible and rigid pavements, due to the type of maintenance operations required. For instance, a 2-in. milling and replacing job would take a shorter construction time as compared to crack/punchout repairs in a rigid CRCP pavement or replace of the AC surface mix, intermediate mix, and base mix of a typical flexible pavement as specified in VDOT's LCCA calculations.

3.2.1 Economic Sensitivity Analysis

A sensitivity analysis examining the effect of changing the discount rate on the PW costs is shown in Fig. 3-25. The discount rates affect the composite with CRCP base alternative the least (i.e., the PW cost values are fairly constant as the discount rate increases); this was an expected outcome because the relatively low maintenance operations during its service life. The discount rates tend to similarly affect the PW cost of the rest of the alternatives; but, as anticipated, it does not change their relative order.

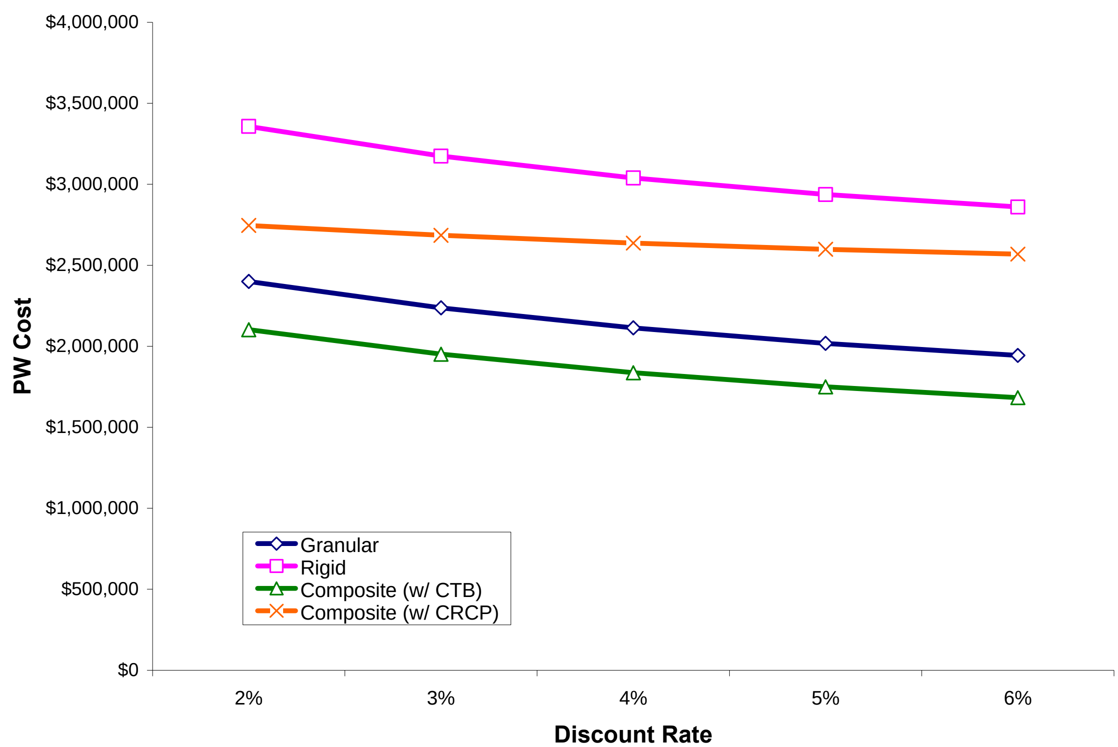

FIGURE 3-25 Sensitivity Analysis Involving Discount Rate and PW Costs

A sensitivity analysis regarding traffic was also performed. This evaluation involved the computation of total agency costs at different traffic volumes. The ESALs for a hypothetical highway were obtained for various AADT volumes, as shown in Table 3-10.

TABLE 3-10 Computed ESALs at Different AADT Volumes

AADT	ESALs
25,000	~33,000,000
50,000	~67,000,000
100,000	~135,000,000

With the ESALs computed in Table 3-10, traffic growth curves were created for the 50-year LCCA analysis period for each AADT case. Then, the years at which rehabilitation needed to take place on the typical traffic growth curve (i.e., ~67,000,000 ESALs) were shifted according to the ESALs required for the same pavement structures to reach a maintenance or rehabilitation trigger. A reconstruction was scheduled for the highest traffic alternative in year 33, except for the composite with CRCP base pavement.

TABLE 3-11 Years to Work Schedule Activity for Different ESALs

Flexible and Composite with CTB			
ESALs	~33M	~67M	~135M
Functional Mill and Replace	21	12	7
Structural Mill and Replace	35	22	13
Major Rehabilitation	47	32	19
Functional Mill and Replace	-	44	29
Salvage Value (Reconstruction)	-	50	(33)
Functional Mill and Replace	-	-	40
Structural Mill and Replace	-	-	46
Rigid (CRCP)			
Concrete Pavement Maintenance	18	10	5
Concrete Pavement Restoration and AC Overlay	33	20	12
Functional Mill and Replace	45	30	18
Concrete Pavement Restoration and AC Overlay	-	40	25
Salvage Value (Reconstruction)	-	50	(33)
Concrete Pavement Maintenance	-	-	38
Concrete Pavement Restoration and AC Overlay	-	-	45
Composite with CRCP Base (“True” Composite)			
Functional Mill and Replace	10	10	10
Functional Mill and Replace	20	20	20
Functional Mill and Replace	30	30	30
Functional Mill and Replace	40	40	40
Salvage Value	50	50	50

The PW computations for all the alternatives using a discount rate of 4 percent are shown in Fig. 3-26. It should be noticed that the maintenance schedule for the composite with CRCP base pavement was not changed based on the experiences reviewed in the literature. However, this assumption would need to be verified experimentally before strong conclusions can be drawn.

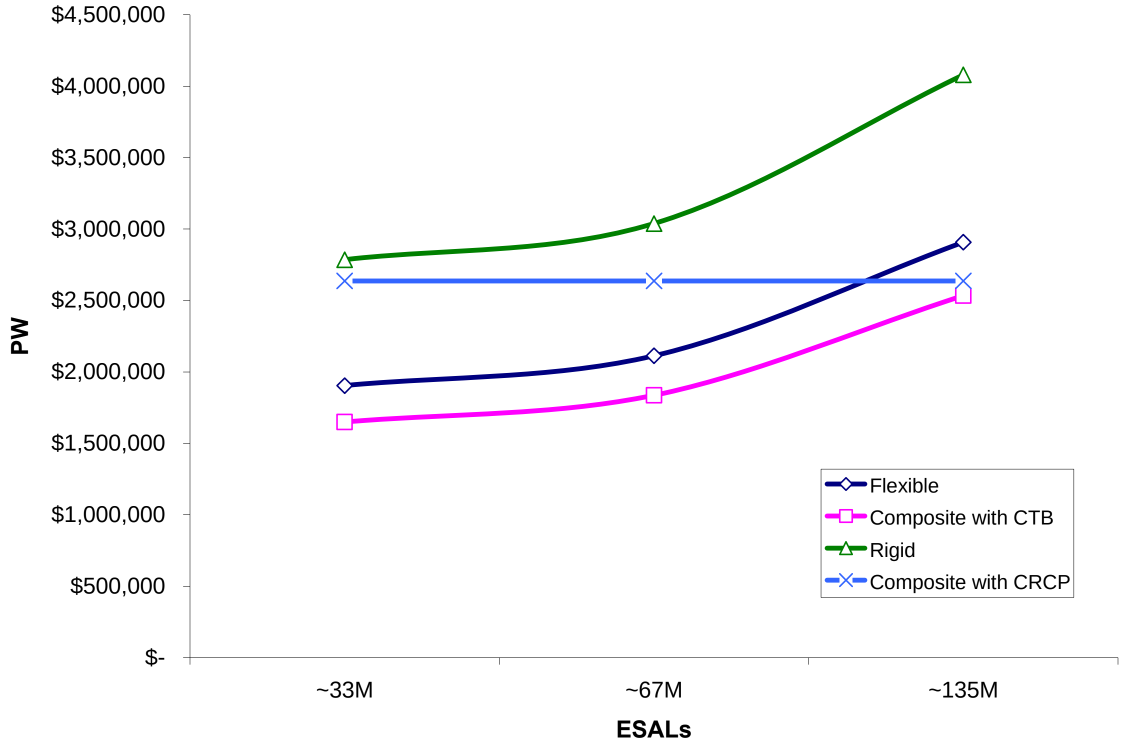

FIGURE 3-26 PW Computation of Pavement Alternatives at Different Design ESALs

It can be observed that as the ESALs increase, the PW of all alternatives increase as well, except for the composite with CRCP base ("true" composite) which stays at a constant PW throughout. The "true" composite pavement remains with a constant PW cost because as long as a functional mill and replace activity takes place every 10 years, this type of pavement should not require any major rehabilitations and may accommodate very high volumes of traffic—400,000,000 ESALs (UK 2006). Therefore, "true" composite pavements have the potential to save significant agency costs when considered for high-volume high-priority highways.

CHAPTER 4 FINDINGS AND CONCLUSIONS

4.1 Summary

Composite pavements were investigated in this study using technical and economic evaluations. Various potential technical and economic benefits have been proposed and supported by modeling of pavement responses and distresses and performing an LCCA. The following section summarizes the main findings and conclusions of this thesis and provides recommendations for implementation of these results and for future research to further investigate this topic.

4.2 Findings

The main findings of this study concerning the technical and economic evaluations of composite pavement systems to be used during the PTS process are the following:

- According to the literature many countries (e.g., the U.K., Spain) that have used composite pavement systems in their main road network have had a positive experience in terms of functional and structural performance.
- Although a composite pavement involves the combination of a flexible and a rigid layer in no particular placement order (i.e., HMA on top or PCC on top), the most commonly accepted definition of a composite pavement system includes the combination of a flexible (HMA) layer on top of a rigid base course. A cement-bound layer (e.g., CTB, lean mix, PCC) could be considered a rigid base, mainly because a rigid base would tend to behave like a concrete slab as it hardens during the pavement service life.
- There is a fairly large variation in the computed thicknesses of the HMA layers for the various composite pavements designed according to the different methodologies available for a traffic level of 50,000,000 ESALs. The HMA layer thicknesses ranged from 3.5 in. (Thogersen et al. 2004) to 8 in. (AASHTO 1993 alternatives). One of the countries with more experience concerning composite pavements is the U.K., which had an HMA layer thickness of 7 in. The rigid base layer thickness was more uniform for the various final composite pavement designs, ranging from 8 to 10 in.
- The minimum thicknesses for HMA and rigid base suggested by this study are 4 and 8 in., respectively, based on the structures designed following the available design methodologies. This suggestion is based on the results obtained from the designed

composite structures following established design methodologies and procedures from various transportation agencies. In addition, 4 in. of HMA surface course is considered the minimum thickness to retard or mitigate reflective cracking distress. The use of some kind of reflective cracking treatment such as a stress-relief interlayer, geocomposite, or geotextile is always strongly recommended as documented by the literature. The thickness of the HMA layer has a significant impact on the mitigation of reflective cracking; however, the mechanism of this particular distress is still not well understood. Therefore it is believed that the combination of a thick HMA overlay and a reflective cracking mitigation technique such as the aforementioned would increase the possibility of preventing reflective cracks.

- The use of a high-stiffness base layer for the HMA surface course provided the following benefits:
    - Deflections at the HMA surface are significantly reduced as the stiffness of the base layer increases.
    - Flexural fatigue (bottom-up) in the HMA due to high tensile strain concentration at the bottom of the layer is greatly minimized, and in some cases the number of repetitions to fatigue cracking was determined to be unlimited.
    - The HMA layer's top-down fatigue life generally increases as the rigidity of the base course increases.
    - Permanent deformations (rutting) due to vertical compressive strains and stresses in the unbound subbase and, most importantly, subgrade layer are significantly minimized.
- Permanent deformations within the HMA layer tend to increase as the stiffness of the base increases.
- The model used for reflective cracking suggests that the thickness of the HMA layer has an important influence on the number of load repetitions required to achieve reflective cracking; as the HMA layer increases in thickness, the number of load repetitions required to achieve a specific percentage of reflective cracking increases as well.
- Preserving the rigid base's structural soundness is a critical factor in maintaining the longevity of the rigid layer elastic modulus (rigidity). To prevent damage in the rigid layer, its thickness may be increased, a higher HMA modulus surface layer may be used,

or a thicker HMA layer may be constructed. By doing this, the tensile stresses at the bottom of the base will be reduced, thus decreasing the load-associated damage of the rigid layer.

- The HMA surface layer does noticeably reduce the temperature gradient in a PCC slab. The sensitivity analysis performed regarding this reduction of temperature gradient showed that a 4-in. HMA overlay reduced the temperature gradient of the PCC slab by 43 percent. No literature regarding reduction of temperature gradients in a concrete slab was found for thicker HMA overlays; however, a thicker overlay (e.g., 7 in.) should reduce the temperature gradient of the slab even further.
- The deterministic agency-cost LCCA of the composite pavement with CRB resulted in the lowest cost when compared to the typical flexible and rigid pavement alternatives. Comparing the composite with CRB to the flexible pavement, the lower HMA thickness required in the composite due to the high support provided by the cementious base, resulted in lower costs throughout the life of the pavement.
- A sensitivity analysis of the agency-costs over the life-cycle of the pavements, suggest that "true" composite pavements (i.e., composite pavement with CRCP base) have the potential to become a cost-effective alternative for high-traffic high-priority highways.

4.3 Conclusions

Composite pavement systems have the potential to become a cost-effective pavement alternative during the PTS process of transportation agencies worldwide because of the functional, structural, and economic benefits they provide during their service life. A long-life pavement that offers good serviceability levels and rapid and cost-effective maintenance operations as part of an infrastructure network is much desired, especially for high-volume, high-priority corridors.

At the technical level, composite pavements mitigate various structural and functional problems that typical flexible or rigid pavements tend to present, such as HMA flexural fatigue failure, HMA rutting due to subgrade vertical deformations, PCC erosion, and PCC loss of friction, among others. At the same time, though, other types of distresses such as reflective cracking and rutting within the HMA layer need to be considered because they affect composite pavement systems more than the typical pavement structures. Premium HMA surfaces may be required to mitigate these potential problems.

At the economic level, the results of the deterministic agency-cost LCCA suggest that the use of a composite pavement with a CTB results in the most cost-effective alternative for a typical Interstate traffic. Alternatively, the life cycle work schedule for the composite pavement with CRCP base suggests that as long as functional milling and overlaying maintenance operations are performed on the surface course, the pavement will provide good levels of serviceability and structural adequacy for a long, albeit indeterminate, time, as is mentioned by Parry et al. (1997).

4.4 Contribution

The potential of composite pavements was presented to encourage their consideration in the PTS process. With advances of pavement technology, the PTS protocol should be broadened to include different types of pavement alternatives so that the most cost-effective option may be selected. This study proposed the inclusion of composite pavements in the PTS process and showed the potential benefits that nontraditional pavement structures offer to transportation agencies. Furthermore, the inclusion of this new type of pavement may also encourage consideration of other new pavement systems, such as perpetual pavements and other innovative pavement technology.

Through mechanistic modeling, the pavement responses at various (increasing) stiffness levels of the base course underneath an HMA layer were studied. The behavior of the pavement structure and distribution of stresses and strains at different depths were investigated. In addition, the benefits and limitations in terms of typical distresses, such as fatigue cracking, rutting, and reflective cracking, were presented and discussed. These analyses enhance the understanding of the performance of composite pavement systems.

An LCCA was performed to understand and assess the economic implications of implementing a composite pavement alternative to typical flexible and rigid pavements. This economic analysis found that these types of pavement systems may be cost-effective for high-traffic highways.

4.5 Recommendations of the Study

The traditional PTS process should include more alternatives than just flexible and rigid pavements. As this study demonstrates, composite pavements can be a potential candidate for high-priority, high-volume roads in the United States and around the world. Third-world, developing countries can also make use of composite pavement technology to obtain long-lasting roads in their infrastructure network.

This study shows the use of a composite pavement with CTB to be cost effective and thus recommendable as a highly viable pavement alternative. It is important to mention that as new technologies and studies emerge, appropriate methods should be used to mitigate reflective cracking on the HMA surface course because it is considered a major type of distress in any composite structure.

A composite pavement with a CRCP base, or "true" composite pavement, could be considered as the only composite alternative that would not need any type of reflective cracking prevention system. This is because CRCP does not have any joints, and any transversal or longitudinal cracks are believed to be reflected through the HMA layer as very fine reflective cracks that would not affect the functionality, serviceability, or structural adequacy of the pavement system. In addition, this type of composite pavement could be considered for high-traffic highways due to their relatively low-maintenance needs even under high traffic volumes.

4.6 Recommendations for Future Research

The modeling of composite pavements is difficult due to the very different behaviors inherent in asphalt and concrete. Their mechanical behavior is very complex, and their mechanical responses under traffic and environmental conditions are hard to predict with accuracy (Nishizawa et al. 2000). Consequently, a finite element method should be used to model the responses and behaviors, considering factors such as loading condition, bonding (total, partial, none), layer delamination, reflective cracking, discontinuities (cracks, joints), and interface distribution of stresses and strains.

Research studies that model reflective cracking distress are particularly important. Such modeling could include the applicability of Paris' crack growth law, temperature variation effects on the initiation of cracking (bottom-up and top-down), and effectiveness of interlayer systems on the mitigation of reflective cracking.

The study presented herein did not account for the presence of joints or wide cracks that would act as joints in the rigid base layer. Therefore future research should also focus on the modeling of the stress and strain concentration variation when a load is applied on top of the HMA surface course in the vicinity of any joint or wide cracks in the rigid base, as is also mentioned by Balbo and Cintra (1994).

In terms of the economic analysis, an LCCA that includes the computation of user costs should be conducted. In addition, the use of a probabilistic-based LCCA should be considered as well because it would provide a more realistic evaluation of the alternatives to be compared at the economic level. An LCCA similar to the one performed in this study should be performed to investigate the cost implications of any variations (e.g., layer thicknesses) on the composite pavement design and performance.

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APPENDIX A - EXCEL SPREADSHEETS USED FOR DESIGNING COMPOSITE PAVEMENTS

FLEXIBLE PAVEMENT DESIGN

Input Data		**Given Parameters**	
Equivalent Single Axle Load (ESAL):	*50,000,000*	Reliability, R:	*95%*
M_R of Asphalt Concrete @ 68F:	*500,000 psi*	Standard Normal Deviate, Z_R:	*-1.645*
E of Base Material:	-	Standard Deviation, S_o:	*0.45*
M_R of Subbase Course Material:	*20,000 psi*	Initial Serviceability, p_i:	*4.50*
M_R of Subgrade Material:	*7,500 psi*	Terminal Serviceability, p_t:	*3.00*
		Layer 1 Coefficient, a_1:	*0.47*
		Layer 2 Coefficient, a_2:	***0.27***
		Layer 3 Coefficient, a_3:	*0.04*
		Drainage Coefficients, m_n:	*1.00*

Additional Information

Water is drained within a week, i.e., fair condition.

Design Parameters

Layer 1 Thickness, D_1:	***8.0 in.***	HMA
Layer 2 Thickness, D_2:	***10.0 in.***	CTB
Layer 3 Thickness, D_3:	***8.0 in.***	SUBBASE

Calculations

Log(W_{18}):	*7.70*
Computed log(W_{18}):	*7.72*
Structural Number, SN:	6.79

Comments:

- The Cement Treated Base "structural coefficients" ranged from 0.12 (for a 500,000 psi base) to 0.27 (for a 1,000,000 psi base)

CTB = 1,000,000 psi --> therefore a2 = 0.27

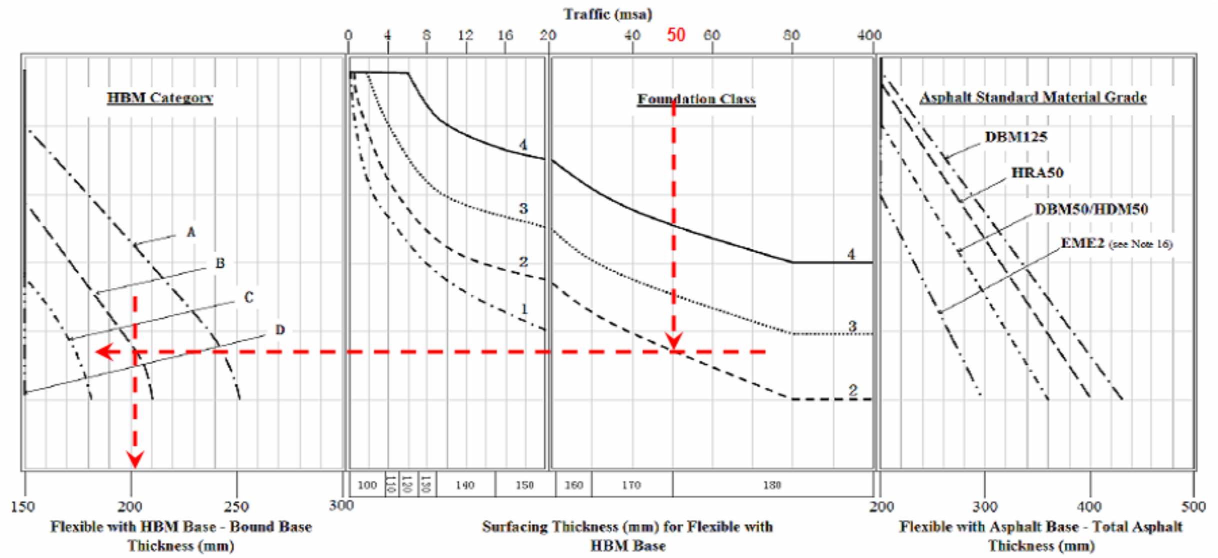
COMPOSITE (AC OVERLAY OF PCC) - 40 YRS

Reliability, R =	95
Standard Normal Deviate, Z_R =	-1.645
Standard Deviation, S_o =	0.38
Initial Serviceability, p_i =	4.5
Terminal Serviceability, p_t =	3.0
J =	3.2
Sc =	650
Cd =	1
***k* =**	***391***
Subbase Thickness, D_{SB} =	8 inches
Subbase Elastic Modulus, E_{SB} =	20,000 psi
Subgrade Resilient Modulus, MR =	12,000 psi
Elastic Modulus of Concrete, Ec =	4,000,000 psi
Slab Thickness, D =	**13.5** inches
W18 Computed =	7.6990 **OK!**
W18 Calculated =	7.7696
ESALs =	**50,000,000**

Layer	Thickness
AC	7.7816 in.
PCC	10 in.
SUBBASE	8 in.
SUBGRADE	

Assume Deff = Df = D
For every 2 in. of AC, the PCC thickness decreases by 1-in.
this is because of the Eq. 13.36 where A = 2.2233 after Df = Deff.
Instead of 2.2233 as the factor, 2 is chosen to be conservative

New Slab Thickness =	**10**
AC Overlay Thickness =	**8**



Surface Thickness = **171.1** **7 in.**

Foundation Class = 2 ==> Granular Subbase

Thickness of HBM base = 200 **8**

Traffic = **50 msa**

225 mm of type 1 Subbase on a subgrade with CBR = 5% 9 IN.

Layer		Number of Equivalent 10 ton Axles (million)							
		0.2	0.5	1	2	5	10	20	50
Asphalt Surfacing and Binder	E = 2,500 MPa, Thickness in mm	60		80					
Cement Treated Base	Allowable initial strain (str)	65	57	51					
Einitial = 12,000 MPa	Required thickness (mm)	215	235	245					
Cement Treated Base	Allowable initial strain (str)			75	69	62	57	52	47
Einitial = 16,000 MPa	Required thickness (mm)			150	165	180	190	205	225
Gravel base	E = 300 MPa	Thickness 150 mm							
Subbase	E = 100 MPa	Thickness minimum 200 mm							
Subgrade	E = 40 MPa	-							

This table was created using E-terminal = 3,000 Mpa

22,727,273

2.2

8	8 in. BASE
3.5	3.5 in. HMA

$E_{INITIAL}$	$E_{TERMINAL}$	Equation
8000 MPa	1000 MPa	$\varepsilon_{PERMISSIBLE} = 83\ \mu str \times (N/10^6)^{-0.196}$
8000 MPa	3000 MPa	$\varepsilon_{PERMISSIBLE} = 31\ \mu str \times (N/10^6)^{-0.191}$
8000 MPa	5000 MPa	$\varepsilon_{PERMISSIBLE} = 23\ \mu str \times (N/10^6)^{-0.189}$
12000 MPa	1000 MPa	$\varepsilon_{PERMISSIBLE} = 138\ \mu str \times (N/10^6)^{-0.150}$
12000 MPa	3000 MPa	$\varepsilon_{PERMISSIBLE} = \boxed{51\ \mu str \times (N/10^6)^{-0.146}}$
12000 MPa	5000 MPa	$\varepsilon_{PERMISSIBLE} = 38\ \mu str \times (N/10^6)^{-0.145}$
16000 MPa	3000 MPa	$\varepsilon_{PERMISSIBLE} = \boxed{75\ \mu str \times (N/10^6)^{-0.118}}$
16000 MPa	5000 MPa	$\varepsilon_{PERMISSIBLE} = 55\ \mu str \times (N/10^6)^{-0.117}$
20000 MPa	3000 MPa	$\varepsilon_{PERMISSIBLE} = 100\ \mu str \times (N/10^6)^{-0.099}$
20000 MPa	5000 MPa	$\varepsilon_{PERMISSIBLE} = 74\ \mu str \times (N/10^6)^{-0.098}$

IDOT COMPOSITE PAVEMENT DESIGN

Design Period, DP =	40	years
ADT =	58,230	on the design lane
ADTT (Truck Traffic) =	6,988	13% assumed as truck percentage
Classification of Road =	**Class I**	

Passenger Vehicles (cars), PV =	0	0%	negligeable
Single-Unit Trucks, SU =	3,703	53%	
Multi-Unit Trucks, MU =	3,284	47%	

Truck Factor, TF =	**56.4**	*Using Fig. 37-5B*
Subbase MINIMUM Thickness =	**6**	**inches**
Subbase should be stabilized!		
Percent Reliability =	95	
HMA Minimum Thickness =	3	inches
PCC Minimum Thickness =	6	inches
Structural Number, S_{NC} =	**5.4**	
Subgrade IBV =	15	
New PCC base course thickness, D_B =	**8**	**inches**
HMA surface thickness, D_S =	**6.9**	**inches**

AC	7.0 in.
PCC	8 in.
SUBBASE	6 in.
SUBGRADE	CBR >= 15

IBV Values
Fine Grained Material (silt and clay) = 3 - 15
Sandy soil or sand = 10 - 40
Subgrade should have a minimum IBV of 10

$$\boxed{ESAL = ADT_O * T * T_f * G * D * L * 365 * Y}$$

ESAL =	50,000,000		
T	0.12		
Tf	0.52	growth rate =	3%
G	75.40126		
D	0.5		
L	1		
Y	40	years	
ADT	**58,230**		

APPENDIX B - PAVEMENT MECHANISTIC RESPONSES WITH VARIOUS RIGID BASES

	DEPTH	0	-0.2	-0.5	-0.9	-1.2	-1.6	-1.9	-2.3	-2.6	-3	-3.3	-3.7	-4	-4.4	-4.7	-5.1	-5.4	-5.8	-6.1	-6.5	-6.8	-7	-7	-7.3	-7.8	-8.3	-8.9	-9.4	-9.9	-10.5	-11	-11.5	-12.1
Soil Cement	R. disp.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vert. disp.	-1.10E-02	-1.10E-02	-1.10E-02	-1.10E-02	-1.09E-02	-1.09E-02	-1.08E-02	-1.08E-02	-1.08E-02	-1.07E-02	-1.07E-02	-1.06E-02	-1.06E-02	-1.05E-02	-1.05E-02	-1.04E-02	-1.04E-02	-1.03E-02	-1.03E-02	-1.03E-02	-1.02E-02	-1.02E-02	-1.02E-02	-1.02E-02	-1.02E-02	-1.01E-02	-1.01E-02	-1.00E-02	-1.00E-02	-9.98E-03	-9.96E-03	-9.93E-03	-9.91E-03
	R. strs.	-134.39	-127.47	-113.95	-101.07	-89.01	-77.92	-67.89	-58.95	-51.07	-44.18	-38.19	-33	-28.5	-24.59	-21.17	-18.18	-15.55	-13.23	-11.18	-9.36	-7.76	-7.04	3.28	4.17	5.91	7.66	9.45	11.29	13.23	15.28	17.47	19.83	22.38
	Tang. strs.	-134.39	-127.47	-113.95	-101.07	-89.01	-77.92	-67.89	-58.95	-51.07	-44.18	-38.19	-33	-28.5	-24.59	-21.17	-18.18	-15.55	-13.23	-11.18	-9.36	-7.76	-7.04	3.28	4.17	5.91	7.66	9.45	11.29	13.23	15.28	17.47	19.83	22.38
	Vert. strs.	-120	-119.93	-120.04	-119.39	-118.18	-116.33	-113.75	-110.51	-106.65	-102.28	-97.53	-92.53	-87.41	-82.27	-77.18	-72.18	-67.34	-62.66	-58.17	-53.85	-49.7	-47.67	-47.67	-44.67	-39.19	-34.23	-29.75	-25.7	-22.03	-18.72	-15.74	-13.09	-10.73
	Shear strs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R. stns.	-9.09E-05	-8.17E-05	-6.41E-05	-4.77E-05	-3.29E-05	-1.97E-05	-8.42E-06	9.71E-07	8.55E-06	1.45E-05	1.90E-05	2.23E-05	2.46E-05	2.61E-05	2.70E-05	2.75E-05	2.75E-05	2.73E-05	2.69E-05	2.62E-05	2.54E-05	2.50E-05	2.50E-05	2.53E-05	2.59E-05	2.68E-05	2.79E-05	2.93E-05	3.10E-05	3.30E-05	3.53E-05	3.81E-05	4.13E-05
	Tang. stns.	-9.09E-05	-8.17E-05	-6.41E-05	-4.77E-05	-3.29E-05	-1.97E-05	-8.42E-06	9.71E-07	8.55E-06	1.45E-05	1.90E-05	2.23E-05	2.46E-05	2.61E-05	2.70E-05	2.75E-05	2.75E-05	2.73E-05	2.69E-05	2.62E-05	2.54E-05	2.50E-05	2.50E-05	2.53E-05	2.59E-05	2.68E-05	2.79E-05	2.93E-05	3.10E-05	3.30E-05	3.53E-05	3.81E-05	4.13E-05
	Vert. stns.	-5.09E-05	-6.14E-05	-8.06E-05	-9.73E-05	-1.12E-04	-1.24E-04	-1.33E-04	-1.39E-04	-1.42E-04	-1.43E-04	-1.42E-04	-1.39E-04	-1.35E-04	-1.30E-04	-1.25E-04	-1.19E-04	-1.13E-04	-1.07E-04	-1.01E-04	-9.47E-05	-8.86E-05	-8.56E-05	-9.71E-05	-9.19E-05	-8.23E-05	-7.37E-05	-6.62E-05	-5.95E-05	-5.37E-05	-4.86E-05	-4.44E-05	-4.09E-05	-3.82E-05
	Shear stn.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CTB	R. disp.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vert. disp.	-9.46E-03	-9.44E-03	-9.41E-03	-9.38E-03	-9.34E-03	-9.29E-03	-9.24E-03	-9.19E-03	-9.14E-03	-9.09E-03	-9.04E-03	-8.98E-03	-8.93E-03	-8.89E-03	-8.84E-03	-8.80E-03	-8.76E-03	-8.72E-03	-8.68E-03	-8.65E-03	-8.62E-03	-8.61E-03	-8.61E-03	-8.59E-03	-8.57E-03	-8.55E-03	-8.53E-03	-8.51E-03	-8.49E-03	-8.48E-03	-8.46E-03	-8.45E-03	-8.44E-03
	R. strs.	-121.51	-115.51	-103.73	-92.43	-81.86	-72.18	-63.48	-55.84	-49.23	-43.61	-38.9	-35.01	-31.85	-29.36	-27.46	-26.1	-25.25	-24.89	-25.02	-25.64	-26.8	-27.59	-9.93	-7.77	-3.71	0.12	3.84	7.53	11.24	15.02	18.92	22.98	27.26
	Tang. strs.	-121.51	-115.51	-103.73	-92.43	-81.86	-72.18	-63.48	-55.84	-49.23	-43.61	-38.9	-35.01	-31.85	-29.36	-27.46	-26.1	-25.25	-24.89	-25.02	-25.64	-26.8	-27.59	-9.93	-7.77	-3.71	0.12	3.84	7.53	11.24	15.02	18.92	22.98	27.26
	Vert. strs.	-120	-120.01	-120.19	-119.76	-118.88	-117.43	-115.32	-112.58	-109.27	-105.47	-101.32	-96.93	-92.41	-87.85	-83.31	-78.82	-74.41	-70.07	-65.8	-61.52	-57.15	-54.99	-54.99	-51.77	-45.68	-40.01	-34.79	-30.01	-25.63	-21.62	-17.98	-14.7	-11.76
	Shear strs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R. stns.	-7.41E-05	-6.61E-05	-5.07E-05	-3.62E-05	-2.31E-05	-1.15E-05	-1.59E-06	6.46E-06	1.28E-05	1.75E-05	2.07E-05	2.27E-05	2.37E-05	2.38E-05	2.31E-05	2.18E-05	1.99E-05	1.73E-05	1.42E-05	1.04E-05	5.91E-06	3.44E-06	3.44E-06	4.51E-06	6.57E-06	8.52E-06	1.05E-05	1.25E-05	1.46E-05	1.69E-05	1.93E-05	2.19E-05	2.48E-05
	Tang. stns.	-7.41E-05	-6.61E-05	-5.07E-05	-3.62E-05	-2.31E-05	-1.15E-05	-1.59E-06	6.46E-06	1.28E-05	1.75E-05	2.07E-05	2.27E-05	2.37E-05	2.38E-05	2.31E-05	2.18E-05	1.99E-05	1.73E-05	1.42E-05	1.04E-05	5.91E-06	3.44E-06	3.44E-06	4.51E-06	6.57E-06	8.52E-06	1.05E-05	1.25E-05	1.46E-05	1.69E-05	1.93E-05	2.19E-05	2.48E-05
	Vert. stns.	-6.92E-05	-7.83E-05	-9.52E-05	-1.10E-04	-1.23E-04	-1.34E-04	-1.42E-04	-1.47E-04	-1.50E-04	-1.50E-04	-1.48E-04	-1.45E-04	-1.40E-04	-1.35E-04	-1.28E-04	-1.21E-04	-1.14E-04	-1.05E-04	-9.66E-05	-8.72E-05	-7.68E-05	-7.12E-05	-5.06E-05	-4.83E-05	-4.38E-05	-3.96E-05	-3.59E-05	-3.26E-05	-2.96E-05	-2.71E-05	-2.50E-05	-2.33E-05	-2.21E-05
	Shear stn.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lean Mix	R. disp.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vert. disp.	-8.01E-03	-7.99E-03	-7.96E-03	-7.92E-03	-7.87E-03	-7.83E-03	-7.77E-03	-7.72E-03	-7.67E-03	-7.61E-03	-7.56E-03	-7.50E-03	-7.45E-03	-7.40E-03	-7.35E-03	-7.31E-03	-7.26E-03	-7.22E-03	-7.19E-03	-7.15E-03	-7.13E-03	-7.11E-03	-7.11E-03	-7.11E-03	-7.09E-03	-7.08E-03	-7.07E-03	-7.06E-03	-7.05E-03	-7.05E-03	-7.04E-03	-7.03E-03	-7.03E-03
	R. strs.	-110.93	-105.57	-94.97	-84.78	-75.22	-66.49	-58.7	-51.93	-46.18	-41.41	-37.54	-34.51	-32.24	-30.68	-29.76	-29.46	-29.76	-30.66	-32.19	-34.38	-37.31	-39.07	-28.45	-24.74	-17.88	-11.54	-5.47	0.45	6.29	12.16	18.1	24.19	30.52
	Tang. strs.	-110.93	-105.57	-94.97	-84.78	-75.22	-66.49	-58.7	-51.93	-46.18	-41.41	-37.54	-34.51	-32.24	-30.68	-29.76	-29.46	-29.76	-30.66	-32.19	-34.38	-37.31	-39.07	-28.45	-24.74	-17.88	-11.54	-5.47	0.45	6.29	12.16	18.1	24.19	30.52
	Vert. strs.	-120	-120.06	-120.29	-120.04	-119.39	-118.21	-116.43	-114.06	-111.15	-107.78	-104.07	-100.13	-96.06	-91.96	-87.85	-83.77	-79.73	-75.71	-71.67	-67.54	-63.16	-60.98	-60.98	-57.68	-51.33	-45.18	-39.44	-34.09	-29.12	-24.5	-20.27	-16.42	-12.92
	Shear strs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R. stns.	-6.04E-05	-5.32E-05	-3.92E-05	-2.61E-05	-1.41E-05	-3.51E-06	5.40E-06	1.26E-05	1.81E-05	2.19E-05	2.44E-05	2.56E-05	2.58E-05	2.50E-05	2.33E-05	2.09E-05	1.77E-05	1.38E-05	9.00E-06	3.28E-06	-3.55E-06	-7.27E-06	-7.27E-06	-5.97E-06	-3.52E-06	-1.27E-06	8.94E-07	3.02E-06	5.15E-06	7.31E-06	9.53E-06	1.18E-05	1.43E-05
	Tang. stns.	-6.04E-05	-5.32E-05	-3.92E-05	-2.61E-05	-1.41E-05	-3.51E-06	5.40E-06	1.26E-05	1.81E-05	2.19E-05	2.44E-05	2.56E-05	2.58E-05	2.50E-05	2.33E-05	2.09E-05	1.77E-05	1.38E-05	9.00E-06	3.28E-06	-3.55E-06	-7.27E-06	-7.27E-06	-5.97E-06	-3.52E-06	-1.27E-06	8.94E-07	3.02E-06	5.15E-06	7.31E-06	9.53E-06	1.18E-05	1.43E-05
	Vert. stns.	-8.42E-05	-9.23E-05	-1.08E-04	-1.21E-04	-1.34E-04	-1.43E-04	-1.51E-04	-1.55E-04	-1.58E-04	-1.58E-04	-1.56E-04	-1.52E-04	-1.47E-04	-1.41E-04	-1.34E-04	-1.26E-04	-1.18E-04	-1.09E-04	-9.83E-05	-8.70E-05	-7.42E-05	-6.71E-05	-2.60E-05	-2.49E-05	-2.28E-05	-2.06E-05	-1.86E-05	-1.68E-05	-1.52E-05	-1.38E-05	-1.25E-05	-1.15E-05	-1.07E-05
	Shear stn.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RCC	R. disp.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vert. disp.	-6.96E-03	-6.94E-03	-6.90E-03	-6.86E-03	-6.81E-03	-6.76E-03	-6.70E-03	-6.65E-03	-6.59E-03	-6.53E-03	-6.48E-03	-6.42E-03	-6.37E-03	-6.31E-03	-6.26E-03	-6.22E-03	-6.17E-03	-6.13E-03	-6.09E-03	-6.06E-03	-6.03E-03	-6.02E-03	-6.02E-03	-6.01E-03	-6.00E-03	-6.00E-03	-5.99E-03	-5.99E-03	-5.98E-03	-5.98E-03	-5.97E-03	-5.97E-03	-5.97E-03
	R. strs.	-103.72	-98.69	-88.74	-79.13	-70.11	-61.89	-54.59	-48.28	-42.98	-38.64	-35.21	-32.62	-30.79	-29.69	-29.24	-29.44	-30.28	-31.77	-33.94	-36.85	-40.57	-42.76	-50.64	-45.19	-35.11	-25.84	-16.99	-8.41	0	8.35	16.75	25.28	34.04
	Tang. strs.	-103.72	-98.69	-88.74	-79.13	-70.11	-61.89	-54.59	-48.28	-42.98	-38.64	-35.21	-32.62	-30.79	-29.69	-29.24	-29.44	-30.28	-31.77	-33.94	-36.85	-40.57	-42.76	-50.64	-45.19	-35.11	-25.84	-16.99	-8.41	0	8.35	16.75	25.28	34.04
	Vert. strs.	-120	-120.09	-120.35	-120.18	-119.65	-118.63	-117.02	-114.85	-112.16	-109.02	-105.55	-101.87	-98.07	-94.23	-90.39	-86.58	-82.79	-79.01	-75.17	-71.21	-66.96	-64.83	-64.83	-61.59	-55.21	-48.85	-42.81	-37.11	-31.75	-26.73	-22.06	-17.77	-13.89
	Shear strs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R. stns.	-5.10E-05	-4.42E-05	-3.11E-05	-1.87E-05	-7.26E-06	2.75E-06	1.12E-05	1.79E-05	2.29E-05	2.64E-05	2.85E-05	2.93E-05	2.91E-05	2.79E-05	2.58E-05	2.29E-05	1.92E-05	1.46E-05	9.16E-06	2.64E-06	-5.14E-06	-9.37E-06	-9.37E-06	-8.21E-06	-6.03E-06	-4.04E-06	-2.14E-06	-2.96E-07	1.53E-06	3.35E-06	5.20E-06	7.09E-06	9.06E-06
	Tang. stns.	-5.10E-05	-4.42E-05	-3.11E-05	-1.87E-05	-7.26E-06	2.75E-06	1.12E-05	1.79E-05	2.29E-05	2.64E-05	2.85E-05	2.93E-05	2.91E-05	2.79E-05	2.58E-05	2.29E-05	1.92E-05	1.46E-05	9.16E-06	2.64E-06	-5.14E-06	-9.37E-06	-9.37E-06	-8.21E-06	-6.03E-06	-4.04E-06	-2.14E-06	-2.96E-07	1.53E-06	3.35E-06	5.20E-06	7.09E-06	9.06E-06
	Vert. stns.	-9.44E-05	-1.02E-04	-1.17E-04	-1.30E-04	-1.41E-04	-1.51E-04	-1.58E-04	-1.62E-04	-1.64E-04	-1.64E-04	-1.62E-04	-1.58E-04	-1.53E-04	-1.47E-04	-1.40E-04	-1.32E-04	-1.23E-04	-1.14E-04	-1.03E-04	-9.09E-05	-7.72E-05	-6.95E-05	-1.40E-05	-1.36E-05	-1.26E-05	-1.16E-05	-1.06E-05	-9.72E-06	-8.90E-06	-8.18E-06	-7.56E-06	-7.06E-06	-6.69E-06
	Shear stn.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCC	R. disp.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vert. disp.	-6.77E-03	-6.75E-03	-6.71E-03	-6.67E-03	-6.62E-03	-6.57E-03	-6.52E-03	-6.46E-03	-6.40E-03	-6.34E-03	-6.29E-03	-6.23E-03	-6.17E-03	-6.12E-03	-6.07E-03	-6.02E-03	-5.98E-03	-5.93E-03	-5.90E-03	-5.86E-03	-5.83E-03	-5.82E-03	-5.82E-03	-5.82E-03	-5.81E-03	-5.80E-03	-5.80E-03	-5.79E-03	-5.79E-03	-5.79E-03	-5.78E-03	-5.78E-03	-5.78E-03
	R. strs.	-102.07	-97.11	-87.28	-77.79	-68.88	-60.76	-53.55	-47.34	-42.13	-37.87	-34.53	-32.02	-30.28	-29.26	-28.91	-29.2	-30.14	-31.74	-34.03	-37.07	-40.93	-43.2	-56.35	-50.46	-39.58	-29.56	-20.01	-10.76	-1.7	7.3	16.33	25.48	34.86
	Tang. strs.	-102.07	-97.11	-87.28	-77.79	-68.88	-60.76	-53.55	-47.34	-42.13	-37.87	-34.53	-32.02	-30.28	-29.26	-28.91	-29.2	-30.14	-31.74	-34.03	-37.07	-40.93	-43.2	-56.35	-50.46	-39.58	-29.56	-20.01	-10.76	-1.7	7.3	16.33	25.48	34.86
	Vert. strs.	-120	-120.09	-120.36	-120.2	-119.7	-118.71	-117.14	-115	-112.35	-109.26	-105.84	-102.21	-98.46	-94.68	-90.89	-87.13	-83.39	-79.66	-75.87	-71.95	-67.73	-65.61	-65.61	-62.38	-56.02	-49.62	-43.56	-37.78	-32.33	-27.19	-22.46	-18.07	-14.1
	Shear strs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R. stns.	-4.88E-05	-4.22E-05	-2.92E-05	-1.69E-05	-5.62E-06	4.28E-06	1.26E-05	1.92E-05	2.42E-05	2.76E-05	2.96E-05	3.03E-05	3.00E-05	2.87E-05	2.66E-05	2.36E-05	1.98E-05	1.51E-05	9.53E-06	2.87E-06	-5.06E-06	-9.38E-06	-9.38E-06	-8.28E-06	-6.19E-06	-4.30E-06	-2.49E-06	-7.32E-07	9.97E-07	2.72E-06	4.47E-06	6.26E-06	8.11E-06
	Tang. stns.	-4.88E-05	-4.22E-05	-2.92E-05	-1.69E-05	-5.62E-06	4.28E-06	1.26E-05	1.92E-05	2.42E-05	2.76E-05	2.96E-05	3.03E-05	3.00E-05	2.87E-05	2.66E-05	2.36E-05	1.98E-05	1.51E-05	9.53E-06	2.87E-06	-5.06E-06	-9.38E-06	-9.38E-06	-8.28E-06	-6.19E-06	-4.30E-06	-2.49E-06	-7.32E-07	9.97E-07	2.72E-06	4.47E-06	6.26E-06	8.11E-06
	Vert. stns.	-9.67E-05	-1.04E-04	-1.19E-04	-1.32E-04	-1.43E-04	-1.52E-04	-1.59E-04	-1.64E-04	-1.66E-04	-1.66E-04	-1.63E-04	-1.60E-04	-1.55E-04	-1.48E-04	-1.41E-04	-1.33E-04	-1.25E-04	-1.15E-04	-1.04E-04	-9.21E-05	-7.82E-05	-7.05E-05	-1.20E-05	-1.17E-05	-1.09E-05	-1.01E-05	-9.26E-06	-8.50E-06	-7.81E-06	-7.19E-06	-6.68E-06	-6.26E-06	-5.97E-06
	Shear stn.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GRANULAR	R. disp.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Vert. disp.	-1.85E-02	-1.85E-02	-1.85E-02	-1.85E-02	-1.85E-02	-1.84E-02	-1.84E-02	-1.84E-02	-1.83E-02	-1.83E-02	-1.83E-02	-1.82E-02	-1.82E-02	-1.81E-02	-1.81E-02	-1.80E-02	-1.80E-02	-1.79E-02	-1.79E-02	-1.78E-02	-1.77E-02	-1.77E-02	-1.77E-02	-1.76E-02	-1.73E-02	-1.70E-02	-1.68E-02	-1.66E-02	-1.64E-02	-1.62E-02	-1.60E-02	-1.59E-02	-1.57E-02
	R. strs.	-213.36	-200.36	-175.35	-151.7	-129.46	-108.64	-89.19	-71.05	-54.08	-38.11	-22.95	-8.4	5.77	19.74	33.77	48.06	62.81	78.29	94.74	112.48	131.81	142.16	0.38	0.4	0.47	0.54	0.63	0.72	0.82	0.92	1.04	1.16	1.3
	Tang. strs.	-213.36	-200.36	-175.35	-151.7	-129.46	-108.64	-89.19	-71.05	-54.08	-38.11	-22.95	-8.4	5.77	19.74	33.77	48.06	62.81	78.29	94.74	112.48	131.81	142.16	0.38	0.4	0.47	0.54	0.63	0.72	0.82	0.92	1.04	1.16	1.3
	Vert. strs.	-120	-119.53	-119.32	-117.42	-114.49	-110.56	-105.59	-99.7	-93.04	-85.75	-78.03	-70.08	-62.07	-54.23	-46.65	-39.51	-33	-27.23	-22.4	-18.7	-16.97	-16.15	-16.15	-15.07	-13.96	-12.99	-12.11	-11.32	-10.6	-9.94	-9.34	-8.8	-8.31
	Shear strs.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	R. stns.	-1.94E-04	-1.77E-04	-1.44E-04	-1.15E-04	-8.80E-05	-6.37E-05	-4.18E-05	-2.23E-05	-4.89E-06	1.08E-05	2.52E-05	3.85E-05	5.14E-05	6.41E-05	7.71E-05	9.07E-05	1.05E-04	1.22E-04	1.40E-04	1.60E-04	1.84E-04	1.97E-04	1.97E-04	1.91E-04	1.80E-04	1.70E-04	1.62E-04	1.56E-04	1.50E-04	1.45E-04	1.41E-04	1.37E-04	1.35E-04
	Tang. stns.	-1.94E-04	-1.77E-04	-1.44E-04	-1.15E-04	-8.80E-05	-6.37E-05	-4.18E-05	-2.23E-05	-4.89E-06	1.08E-05	2.52E-05	3.85E-05	5.14E-05	6.41E-05	7.71E-05	9.07E-05	1.05E-04	1.22E-04	1.40E-04	1.60E-04	1.84E-04	1.97E-04	1.97E-04	1.91E-04	1.80E-04	1.70E-04	1.62E-04	1.56E-04	1.50E-04	1.45E-04	1.41E-04	1.37E-04	1.35E-04
	Vert. stns.	6.11E-05	4.15E-05	6.84E-06	-2.25E-05	-4.78E-05	-6.90E-05	-8.63E-05	-1.00E-04	-1.10E-04	-1.18E-04	-1.24E-04	-1.28E-04	-1.32E-04	-1.36E-04	-1.41E-04	-1.46E-04	-1.54E-04	-1.64E-04	-1.78E-04	-1.95E-04	-2.19E-04	-2.33E-04	-5.26E-04	-5.05E-04	-4.70E-04	-4.39E-04	-4.11E-04	-3.86E-04	-3.64E-04	-3.44E-04	-3.27E-04	-3.11E-04	-2.97E-04
	Shear stn.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

-12.6	-13.1	-13.7	-14.2	-14.7	-15	-15	-15.8	-17.3	-18.8	-20.3	-21.8	-23.3	-24	-24	-26.7	-32
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-9.89E-03	-9.87E-03	-9.85E-03	-9.84E-03	-9.82E-03	-9.81E-03	-9.81E-03	-9.70E-03	-9.49E-03	-9.30E-03	-9.13E-03	-8.97E-03	-8.80E-03	-8.72E-03	-8.72E-03	-8.34E-03	-7.65E-03
25.16	28.22	31.59	35.35	39.63	42.01	-0.29	-0.32	-0.36	-0.36	-0.34	-0.29	-0.21	-0.16	-1.16	-1.27	-1.49
25.16	28.22	31.59	35.35	39.63	42.01	-0.29	-0.32	-0.36	-0.36	-0.34	-0.29	-0.21	-0.16	-1.16	-1.27	-1.49
-8.68	-6.95	-5.55	-4.51	-3.96	-3.81	-3.81	-3.66	-3.43	-3.27	-3.16	-3.1	-3.09	-3.09	-3.09	-3.15	-3.33
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.50E-05	4.92E-05	5.41E-05	5.98E-05	6.64E-05	7.01E-05	7.01E-05	6.67E-05	6.13E-05	5.82E-05	5.70E-05	5.76E-05	6.00E-05	6.17E-05	6.17E-05	5.56E-05	4.56E-05
4.50E-05	4.92E-05	5.41E-05	5.98E-05	6.64E-05	7.01E-05	7.01E-05	6.67E-05	6.13E-05	5.82E-05	5.70E-05	5.76E-05	6.00E-05	6.17E-05	6.17E-05	5.56E-05	4.56E-05
-3.63E-05	-3.52E-05	-3.51E-05	-3.59E-05	-3.82E-05	-4.00E-05	-1.55E-04	-1.45E-04	-1.30E-04	-1.19E-04	-1.12E-04	-1.09E-04	-1.09E-04	-1.11E-04	-1.58E-04	-1.42E-04	-1.16E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-8.43E-03	-8.42E-03	-8.40E-03	-8.39E-03	-8.38E-03	-8.37E-03	-8.37E-03	-8.30E-03	-8.15E-03	-8.01E-03	-7.88E-03	-7.75E-03	-7.63E-03	-7.57E-03	-7.57E-03	-7.26E-03	-6.71E-03
31.82	36.72	42.03	47.84	54.37	57.96	-0.63	-0.64	-0.66	-0.66	-0.64	-0.61	-0.55	-0.52	-1.21	-1.31	-1.52
31.82	36.72	42.03	47.84	54.37	57.96	-0.63	-0.64	-0.66	-0.66	-0.64	-0.61	-0.55	-0.52	-1.21	-1.31	-1.52
-9.21	-7.03	-5.28	-3.98	-3.35	-3.19	-3.19	-3.1	-2.97	-2.89	-2.85	-2.84	-2.86	-2.88	-2.88	-2.97	-3.2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.79E-05	3.14E-05	3.53E-05	3.98E-05	4.49E-05	4.77E-05	4.77E-05	4.59E-05	4.31E-05	4.18E-05	4.17E-05	4.28E-05	4.52E-05	4.67E-05	4.67E-05	4.28E-05	3.62E-05
2.79E-05	3.14E-05	3.53E-05	3.98E-05	4.49E-05	4.77E-05	4.77E-05	4.59E-05	4.31E-05	4.18E-05	4.17E-05	4.28E-05	4.52E-05	4.67E-05	4.67E-05	4.28E-05	3.62E-05
-2.13E-05	-2.11E-05	-2.14E-05	-2.24E-05	-2.44E-05	-2.58E-05	-1.10E-04	-1.04E-04	-9.46E-05	-8.85E-05	-8.47E-05	-8.33E-05	-8.43E-05	-8.57E-05	-1.25E-04	-1.13E-04	-9.54E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-7.02E-03	-7.02E-03	-7.01E-03	-7.01E-03	-7.00E-03	-7.00E-03	-7.00E-03	-6.94E-03	-6.84E-03	-6.73E-03	-6.64E-03	-6.54E-03	-6.45E-03	-6.40E-03	-6.40E-03	-6.16E-03	-5.72E-03
37.14	44.15	51.65	59.77	68.78	73.71	-0.82	-0.83	-0.85	-0.85	-0.85	-0.83	-0.8	-0.78	-1.23	-1.33	-1.53
37.14	44.15	51.65	59.77	68.78	73.71	-0.82	-0.83	-0.85	-0.85	-0.85	-0.83	-0.8	-0.78	-1.23	-1.33	-1.53
-9.87	-7.26	-5.14	-3.56	-2.85	-2.68	-2.68	-2.65	-2.6	-2.58	-2.59	-2.61	-2.66	-2.69	-2.69	-2.81	-3.07
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.69E-05	1.97E-05	2.27E-05	2.61E-05	2.99E-05	3.19E-05	3.19E-05	3.11E-05	3.00E-05	2.98E-05	3.04E-05	3.16E-05	3.38E-05	3.51E-05	3.51E-05	3.26E-05	2.85E-05
1.69E-05	1.97E-05	2.27E-05	2.61E-05	2.99E-05	3.19E-05	3.19E-05	3.11E-05	3.00E-05	2.98E-05	3.04E-05	3.16E-05	3.38E-05	3.51E-05	3.51E-05	3.26E-05	2.85E-05
-1.02E-05	-9.88E-06	-9.93E-06	-1.03E-05	-1.13E-05	-1.21E-05	-7.71E-05	-7.37E-05	-6.85E-05	-6.52E-05	-6.34E-05	-6.31E-05	-6.44E-05	-6.57E-05	-9.71E-05	-8.94E-05	-7.70E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-5.96E-03	-5.96E-03	-5.96E-03	-5.95E-03	-5.95E-03	-5.95E-03	-5.95E-03	-5.90E-03	-5.82E-03	-5.75E-03	-5.67E-03	-5.60E-03	-5.52E-03	-5.49E-03	-5.49E-03	-5.29E-03	-4.93E-03
43.11	52.62	62.67	73.43	85.26	91.69	-0.91	-0.92	-0.94	-0.96	-0.96	-0.96	-0.95	-0.94	-1.23	-1.33	-1.53
43.11	52.62	62.67	73.43	85.26	91.69	-0.91	-0.92	-0.94	-0.96	-0.96	-0.96	-0.95	-0.94	-1.23	-1.33	-1.53
-10.43	-7.48	-5.08	-3.29	-2.49	-2.32	-2.32	-2.34	-2.34	-2.36	-2.4	-2.45	-2.51	-2.55	-2.55	-2.68	-2.97
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.11E-05	1.33E-05	1.57E-05	1.82E-05	2.11E-05	2.26E-05	2.26E-05	2.23E-05	2.20E-05	2.23E-05	2.31E-05	2.44E-05	2.62E-05	2.73E-05	2.73E-05	2.58E-05	2.30E-05
1.11E-05	1.33E-05	1.57E-05	1.82E-05	2.11E-05	2.26E-05	2.26E-05	2.23E-05	2.20E-05	2.23E-05	2.31E-05	2.44E-05	2.62E-05	2.73E-05	2.73E-05	2.58E-05	2.30E-05
-6.47E-06	-6.43E-06	-6.60E-06	-7.01E-06	-7.78E-06	-8.35E-06	-5.69E-05	-5.48E-05	-5.18E-05	-5.01E-05	-4.93E-05	-4.96E-05	-5.10E-05	-5.21E-05	-7.80E-05	-7.25E-05	-6.37E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-5.77E-03	-5.77E-03	-5.77E-03	-5.76E-03	-5.76E-03	-5.76E-03	-5.76E-03	-5.72E-03	-5.64E-03	-5.57E-03	-5.50E-03	-5.43E-03	-5.36E-03	-5.33E-03	-5.33E-03	-5.14E-03	-4.80E-03
44.56	54.7	65.4	76.83	89.36	96.16	-0.93	-0.94	-0.96	-0.98	-0.99	-0.99	-0.99	-0.98	-1.23	-1.33	-1.53
44.56	54.7	65.4	76.83	89.36	96.16	-0.93	-0.94	-0.96	-0.98	-0.99	-0.99	-0.99	-0.98	-1.23	-1.33	-1.53
-10.56	-7.53	-5.07	-3.23	-2.45	-2.27	-2.27	-2.28	-2.29	-2.32	-2.36	-2.41	-2.48	-2.52	-2.52	-2.66	-2.95
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.01E-05	1.21E-05	1.43E-05	1.67E-05	1.93E-05	2.07E-05	2.07E-05	2.05E-05	2.03E-05	2.07E-05	2.15E-05	2.28E-05	2.46E-05	2.56E-05	2.56E-05	2.42E-05	2.18E-05
1.01E-05	1.21E-05	1.43E-05	1.67E-05	1.93E-05	2.07E-05	2.07E-05	2.05E-05	2.03E-05	2.07E-05	2.15E-05	2.28E-05	2.46E-05	2.56E-05	2.56E-05	2.42E-05	2.18E-05
-5.80E-06	-5.80E-06	-5.98E-06	-6.37E-06	-7.11E-06	-7.65E-06	-5.27E-05	-5.09E-05	-4.83E-05	-4.68E-05	-4.63E-05	-4.66E-05	-4.79E-05	-4.90E-05	-7.37E-05	-6.87E-05	-6.06E-05
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-1.56E-02	-1.54E-02	-1.53E-02	-1.51E-02	-1.50E-02	-1.49E-02	-1.49E-02	-1.47E-02	-1.43E-02	-1.39E-02	-1.36E-02	-1.32E-02	-1.29E-02	-1.27E-02	-1.27E-02	-1.20E-02	-1.07E-02
1.45	1.62	1.8	2	2.23	2.35	0.25	0.28	0.38	0.51	0.68	0.91	1.2	1.37	-1.03	-1.15	-1.39
1.45	1.62	1.8	2	2.23	2.35	0.25	0.28	0.38	0.51	0.68	0.91	1.2	1.37	-1.03	-1.15	-1.39
-7.86	-7.45	-7.09	-6.76	-6.47	-6.34	-6.34	-6.02	-5.46	-5.01	-4.66	-4.4	-4.23	-4.17	-4.17	-4.08	-4.02
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.33E-04	1.33E-04	1.33E-04	1.34E-04	1.36E-04	1.37E-04	1.37E-04	1.32E-04	1.24E-04	1.19E-04	1.18E-04	1.19E-04	1.25E-04	1.29E-04	1.29E-04	1.14E-04	9.00E-05
1.33E-04	1.33E-04	1.33E-04	1.34E-04	1.36E-04	1.37E-04	1.37E-04	1.32E-04	1.24E-04	1.19E-04	1.18E-04	1.19E-04	1.25E-04	1.29E-04	1.29E-04	1.14E-04	9.00E-05
-2.86E-04	-2.76E-04	-2.67E-04	-2.61E-04	-2.56E-04	-2.54E-04	-3.03E-04	-2.87E-04	-2.60E-04	-2.41E-04	-2.28E-04	-2.22E-04	-2.23E-04	-2.26E-04	-3.16E-04	-2.77E-04	-2.18E-04
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TITLE

FILENAMES

```
Data file used for this run: C:\Pavements\MFPDS\TH_GRANULAR_2nd.med
Name of this output file   : TH_GRANULAR_2nd.mpo
Unit                       : English
Route                      :
Region                     :
Control Section            :
Lane                       :
Job No.                    :
Trial No.                  :
Description                :
```

INITIAL DATA

```
Number of layers = 4
Wheel load =    9000.0 lb.
Tire pressure =  120.00 psi.
Radius of loaded area (a) =      4.886 inches
```

LAYER TYPE

1 asphalt; 2 granular; 3 cohese

Layer number (from top)	Type (1,2,or3)
1	1
2	1
3	1
4	1

MATERIAL PROPERTIES

Asphalt Material Properties

Layer	Name of Layer	Thickness (inches)	Modulus (psi)	Poisson's ratio	Density (lb/cu.ft)	Ko
1	HMA	7.0	500000.0	0.35	150.0	1.50
2	Granular	8.0	30000.0	0.40	130.0	1.00
3	Subbase	9.0	20000.0	0.40	130.0	0.75
4	Subgrade	32.0	7500.0	0.40	120.0	0.60

Layer 4 actually semi-infinite, but thickness controls depth to which displacements/stresses are computed.

CROSS SECTIONS FOR CALCULATION OF RESULTS

Number of horizontal sections = 1   Number of vertical sections = 1

Depth for horizontal sections (inches) = 0.00

Radial distance for vertical sections (inches) = 0.00

DIVISION OF FINITE ELEMENT MESH

Number of Elements in Vertical Direction

Layer	Thickness	Number of elements
1. HMA	7.0	20
2. Granular	8.0	15
3. Subbase	9.0	6
4. Subgrade	32.0	6

Number of Elements in Horizontal Direction

Range (a: contact radius)	Number of elements
1. R = 0 - a	9
2. R = a - 3a	9
3. R = 3a - 6a	9
4. R = 6a - 40a	72

FINAL DISPLACEMENTS, STRESSES AND STRAINS

Horizontal Section 1 at Depth of 0.00 mm

	Displacements		Stresses				Strains			
R. Dist.	R. Disp.	Vert. Disp.	R. Strs.	Tang. Strs.	Vert. Strs.	Shear Strs.	Rad. S.	Tang. Stn.	Vert. Stn.	Shear Stn.
0.0	0.0000E+00	-.1850E-01								
0.3	-.5283E-04	-.1850E-01	-222.34	-222.336	-120.000	1.492	-.1946E-03	-.1946E-03	0.4151E-04	0.8055E-05
0.8	-.1574E-03	-.1846E-01	-219.33	-220.316	-120.000	0.532	-.1906E-03	-.1933E-03	0.3973E-04	0.2871E-05
1.4	-.2602E-03	-.1841E-01	-217.62	-218.972	-120.000	0.674	-.1881E-03	-.1917E-03	0.3733E-04	0.3637E-05
1.9	-.3613E-03	-.1832E-01	-215.45	-217.543	-120.000	0.872	-.1845E-03	-.1902E-03	0.3419E-04	0.4710E-05
2.4	-.4603E-03	-.1820E-01	-212.80	-215.930	-120.000	1.084	-.1800E-03	-.1884E-03	0.3012E-04	0.5856E-05
3.0	-.5564E-03	-.1806E-01	-209.83	-214.271	-120.000	1.248	-.1744E-03	-.1864E-03	0.2455E-04	0.6738E-05
3.5	-.6495E-03	-.1787E-01	-206.96	-212.672	-120.000	1.706	-.1686E-03	-.1841E-03	0.1829E-04	0.9211E-05
4.1	-.7379E-03	-.1765E-01	-203.63	-212.695	-120.000	1.404	-.1567E-03	-.1812E-03	0.1058E-05	0.7579E-05
4.6	-.8124E-03	-.1734E-01	-156.09	-177.620	-99.893	29.153	-.1179E-03	-.1761E-03	0.3381E-04	0.1574E-03
5.4	-.8838E-03	-.1685E-01	-84.20	-117.660	-19.418	12.120	-.7245E-04	-.1628E-03	0.1025E-03	0.6545E-04

6.5	-.9494E-03	-.1632E-01	-54.71	-90.709	0.000	-0.678	-.4854E-04	-.1457E-03	0.1093E-03	-.3659E-05
7.6	-.9983E-03	-.1588E-01	-51.40	-84.680	-2.897	1.656	-.4150E-04	-.1313E-03	0.8946E-04	0.8940E-05
8.7	-.1038E-02	-.1546E-01	-43.41	-75.753	-2.262	1.443	-.3221E-04	-.1195E-03	0.7889E-04	0.7793E-05
9.8	-.1068E-02	-.1506E-01	-36.00	-68.020	-2.174	1.373	-.2287E-04	-.1093E-03	0.6847E-04	0.7416E-05
10.9	-.1088E-02	-.1467E-01	-29.21	-61.009	-1.890	1.234	-.1439E-04	-.1002E-03	0.5937E-04	0.6663E-05
11.9	-.1100E-02	-.1429E-01	-23.24	-54.754	-1.619	1.088	-.7017E-05	-.9211E-04	0.5136E-04	0.5873E-05
13.0	-.1104E-02	-.1392E-01	-18.09	-49.184	-1.355	0.953	-.8030E-06	-.8476E-04	0.4438E-04	0.5144E-05
14.1	-.1102E-02	-.1355E-01	-13.68	-44.237	-1.139	0.828	0.4400E-05	-.7810E-04	0.3827E-04	0.4471E-05
15.5	-.1093E-02	-.1311E-01	-9.81	-39.124	-1.054	0.756	0.8512E-05	-.7065E-04	0.3214E-04	0.4084E-05
17.1	-.1076E-02	-.1260E-01	-5.54	-33.621	-0.664	0.519	0.1291E-04	-.6290E-04	0.2609E-04	0.2803E-05
18.7	-.1052E-02	-.1211E-01	-2.50	-29.155	-0.548	0.428	0.1580E-04	-.5618E-04	0.2106E-04	0.2310E-05
20.4	-.1025E-02	-.1164E-01	-0.18	-25.379	-0.413	0.340	0.1770E-04	-.5035E-04	0.1707E-04	0.1834E-05
22.0	-.9952E-03	-.1119E-01	1.55	-22.198	-0.316	0.273	0.1887E-04	-.4526E-04	0.1382E-04	0.1473E-05
23.6	-.9639E-03	-.1076E-01	2.86	-19.493	-0.240	0.223	0.1952E-04	-.4082E-04	0.1117E-04	0.1203E-05
25.2	-.9319E-03	-.1036E-01	3.84	-17.173	-0.167	0.183	0.1981E-04	-.3691E-04	0.9001E-05	0.9894E-06
26.9	-.8996E-03	-.9970E-02	4.54	-15.200	-0.144	0.138	0.1982E-04	-.3348E-04	0.7174E-05	0.7428E-06
28.5	-.8673E-03	-.9601E-02	5.26	-13.359	0.000	0.198	0.1985E-04	-.3043E-04	0.5748E-05	0.1069E-05
30.5	-.8296E-03	-.9180E-02	5.14	-11.854	-0.114	0.144	0.1866E-04	-.2723E-04	0.4470E-05	0.7788E-06
32.8	-.7871E-03	-.8715E-02	5.57	-10.054	0.000	0.059	0.1818E-04	-.2401E-04	0.3154E-05	0.3164E-06
35.1	-.7461E-03	-.8281E-02	5.67	-8.641	0.000	0.046	0.1739E-04	-.2127E-04	0.2107E-05	0.2484E-06
37.4	-.7070E-03	-.7875E-02	5.67	-7.457	0.000	0.032	0.1654E-04	-.1891E-04	0.1318E-05	0.1740E-06
39.7	-.6698E-03	-.7495E-02	5.60	-6.460	0.000	0.026	0.1569E-04	-.1687E-04	0.6949E-06	0.1396E-06
42.0	-.6345E-03	-.7140E-02	5.49	-5.613	0.000	0.018	0.1486E-04	-.1511E-04	0.2019E-06	0.9854E-07
44.3	-.6012E-03	-.6808E-02	5.34	-4.893	0.000	0.012	0.1406E-04	-.1357E-04	-.1865E-06	0.6679E-07
46.6	-.5696E-03	-.6497E-02	5.16	-4.280	0.000	0.007	0.1327E-04	-.1222E-04	-.4876E-06	0.3948E-07
48.9	-.5399E-03	-.6205E-02	4.98	-3.750	0.000	0.006	0.1253E-04	-.1103E-04	-.7155E-06	0.3390E-07
51.2	-.5118E-03	-.5932E-02	4.77	-3.298	0.000	-0.001	0.1180E-04	-.9989E-05	-.8839E-06	-.5818E-08
53.5	-.4854E-03	-.5676E-02	4.56	-2.913	0.000	0.000	0.1111E-04	-.9065E-05	-.1017E-05	0.8853E-09
55.8	-.4605E-03	-.5435E-02	4.36	-2.570	0.000	0.000	0.1048E-04	-.8245E-05	-.1113E-05	0.1276E-08
58.2	-.4370E-03	-.5209E-02	4.15	-2.280	0.000	-0.007	0.9853E-05	-.7514E-05	-.1174E-05	-.3609E-07
60.5	-.4150E-03	-.4997E-02	3.94	-2.028	0.000	-0.003	0.9261E-05	-.6863E-05	-.1210E-05	-.1485E-07
62.8	-.3942E-03	-.4797E-02	3.75	-1.806	0.000	-0.006	0.8711E-05	-.6280E-05	-.1228E-05	-.3263E-07
65.1	-.3747E-03	-.4609E-02	3.55	-1.614	0.000	-0.005	0.8193E-05	-.5758E-05	-.1235E-05	-.2599E-07
67.4	-.3564E-03	-.4431E-02	3.37	-1.445	0.000	-0.006	0.7710E-05	-.5289E-05	-.1232E-05	-.3453E-07
69.7	-.3391E-03	-.4264E-02	3.20	-1.295	0.000	-0.005	0.7263E-05	-.4866E-05	-.1223E-05	-.2478E-07
72.0	-.3228E-03	-.4107E-02	3.04	-1.159	0.000	-0.005	0.6853E-05	-.4484E-05	-.1208E-05	-.2567E-07
74.3	-.3075E-03	-.3958E-02	2.88	-1.042	0.000	-0.007	0.6457E-05	-.4138E-05	-.1183E-05	-.3747E-07
76.6	-.2930E-03	-.3817E-02	2.73	-0.940	0.000	-0.005	0.6081E-05	-.3824E-05	-.1156E-05	-.2918E-07
78.9	-.2794E-03	-.3684E-02	2.59	-0.847	0.000	-0.005	0.5741E-05	-.3540E-05	-.1128E-05	-.2899E-07
81.2	-.2665E-03	-.3558E-02	2.47	-0.759	0.000	-0.002	0.5444E-05	-.3280E-05	-.1108E-05	-.1307E-07
83.5	-.2542E-03	-.3439E-02	2.36	-0.680	0.000	-0.005	0.5166E-05	-.3043E-05	-.1087E-05	-.2781E-07
85.8	-.2426E-03	-.3326E-02	2.25	-0.611	0.000	-0.004	0.4897E-05	-.2826E-05	-.1063E-05	-.2132E-07
88.2	-.2316E-03	-.3219E-02	2.15	-0.548	0.000	-0.004	0.4650E-05	-.2627E-05	-.1038E-05	-.2133E-07
90.5	-.2211E-03	-.3117E-02	2.05	-0.492	0.000	-0.004	0.4418E-05	-.2445E-05	-.1016E-05	-.2225E-07
92.8	-.2112E-03	-.3021E-02	1.97	-0.437	0.000	-0.002	0.4213E-05	-.2276E-05	-.9963E-06	-.1079E-07
95.1	-.2017E-03	-.2930E-02	1.89	-0.386	0.000	-0.003	0.4025E-05	-.2121E-05	-.9792E-06	-.1783E-07
97.4	-.1926E-03	-.2844E-02	1.82	-0.341	0.000	-0.002	0.3846E-05	-.1978E-05	-.9627E-06	-.1324E-07
99.7	-.1839E-03	-.2762E-02	1.75	-0.299	0.000	-0.003	0.3677E-05	-.1845E-05	-.9424E-06	-.1532E-07
102.0	-.1756E-03	-.2684E-02	1.67	-0.263	0.000	-0.003	0.3508E-05	-.1722E-05	-.9197E-06	-.1762E-07
104.3	-.1677E-03	-.2610E-02	1.60	-0.233	0.000	-0.004	0.3340E-05	-.1608E-05	-.8931E-06	-.2017E-07
106.6	-.1602E-03	-.2540E-02	1.52	-0.209	0.000	-0.004	0.3171E-05	-.1503E-05	-.8628E-06	-.2403E-07

108.9	-.1531E-03	-.2474E-02	1.46	-0.184	0.000	-0.002	0.3021E-05	-.1405E-05	-.8360E-06	-.9601E-08
111.2	-.1463E-03	-.2411E-02	1.40	-0.158	0.000	-0.003	0.2889E-05	-.1315E-05	-.8131E-06	-.1623E-07
113.5	-.1397E-03	-.2351E-02	1.34	-0.137	0.000	-0.002	0.2761E-05	-.1231E-05	-.7917E-06	-.1345E-07
115.8	-.1335E-03	-.2294E-02	1.29	-0.118	0.000	-0.003	0.2638E-05	-.1153E-05	-.7700E-06	-.1700E-07
118.1	-.1276E-03	-.2240E-02	1.24	-0.099	0.000	-0.001	0.2525E-05	-.1080E-05	-.7484E-06	-.8042E-08
120.5	-.1219E-03	-.2189E-02	1.19	-0.083	0.000	-0.003	0.2415E-05	-.1012E-05	-.7281E-06	-.1889E-07
122.8	-.1164E-03	-.2140E-02	1.14	-0.067	0.000	-0.001	0.2314E-05	-.9482E-06	-.7093E-06	-.5936E-08
125.1	-.1112E-03	-.2094E-02	1.11	-0.050	0.000	-0.001	0.2231E-05	-.8888E-06	-.6947E-06	-.7062E-08
127.4	-.1061E-03	-.2050E-02	1.07	-0.036	0.000	-0.002	0.2146E-05	-.8330E-06	-.6816E-06	-.1280E-07
129.7	-.1013E-03	-.2008E-02	1.03	-0.024	0.000	-0.002	0.2062E-05	-.7808E-06	-.6671E-06	-.8223E-08
132.0	-.9658E-04	-.1969E-02	1.00	-0.011	0.000	-0.002	0.1988E-05	-.7317E-06	-.6532E-06	-.8645E-08
134.3	-.9207E-04	-.1931E-02	0.97	0.002	0.000	-0.001	0.1919E-05	-.6856E-06	-.6412E-06	-.5237E-08
136.6	-.8772E-04	-.1895E-02	0.94	0.013	0.000	-0.002	0.1853E-05	-.6421E-06	-.6310E-06	-.1100E-07
138.9	-.8351E-04	-.1861E-02	0.91	0.024	0.000	0.000	0.1796E-05	-.6012E-06	-.6229E-06	-.5340E-09
141.2	-.7942E-04	-.1829E-02	0.89	0.037	0.000	-0.001	0.1747E-05	-.5624E-06	-.6172E-06	-.5594E-08
143.5	-.7545E-04	-.1798E-02	0.87	0.047	0.000	-0.001	0.1697E-05	-.5257E-06	-.6113E-06	-.6067E-08
145.8	-.7158E-04	-.1769E-02	0.85	0.059	0.000	0.000	0.1657E-05	-.4908E-06	-.6085E-06	0.1764E-08
148.1	-.6780E-04	-.1742E-02	0.84	0.071	0.000	-0.001	0.1621E-05	-.4577E-06	-.6064E-06	-.5645E-08
150.4	-.6410E-04	-.1716E-02	0.83	0.082	0.000	0.000	0.1585E-05	-.4261E-06	-.6049E-06	-.1279E-09
152.8	-.6048E-04	-.1692E-02	0.82	0.093	0.000	0.000	0.1556E-05	-.3959E-06	-.6059E-06	-.1967E-08
155.1	-.5692E-04	-.1669E-02	0.81	0.104	0.000	0.000	0.1528E-05	-.3671E-06	-.6063E-06	0.1601E-09
157.4	-.5342E-04	-.1647E-02	0.80	0.115	0.000	0.000	0.1504E-05	-.3395E-06	-.6080E-06	-.6346E-09
159.7	-.4998E-04	-.1627E-02	0.79	0.126	0.000	0.000	0.1484E-05	-.3130E-06	-.6120E-06	0.6195E-10
162.0	-.4657E-04	-.1609E-02	0.79	0.138	0.000	0.001	0.1470E-05	-.2875E-06	-.6171E-06	0.4207E-08
164.3	-.4319E-04	-.1591E-02	0.79	0.150	0.000	0.000	0.1458E-05	-.2629E-06	-.6236E-06	0.6999E-09
166.6	-.3984E-04	-.1575E-02	0.78	0.160	0.000	0.000	0.1442E-05	-.2392E-06	-.6285E-06	-.2860E-09
168.9	-.3653E-04	-.1560E-02	0.78	0.170	0.000	0.000	0.1427E-05	-.2163E-06	-.6330E-06	0.1519E-08
171.2	-.3325E-04	-.1547E-02	0.78	0.180	0.000	0.000	0.1416E-05	-.1942E-06	-.6387E-06	0.1504E-08
173.5	-.2999E-04	-.1534E-02	0.78	0.191	0.000	0.001	0.1409E-05	-.1729E-06	-.6461E-06	0.3494E-08
175.8	-.2675E-04	-.1523E-02	0.78	0.202	0.000	0.000	0.1403E-05	-.1521E-06	-.6531E-06	0.2303E-08
178.1	-.2352E-04	-.1514E-02	0.78	0.212	0.000	0.000	0.1395E-05	-.1321E-06	-.6597E-06	0.1231E-08
180.4	-.2032E-04	-.1505E-02	0.78	0.221	0.000	0.000	0.1385E-05	-.1126E-06	-.6656E-06	0.1204E-08
182.8	-.1713E-04	-.1498E-02	0.77	0.230	0.000	0.001	0.1377E-05	-.9373E-07	-.6712E-06	0.3011E-08
185.1	-.1396E-04	-.1492E-02	0.77	0.239	0.000	0.000	0.1368E-05	-.7545E-07	-.6753E-06	0.2722E-10
187.4	-.1082E-04	-.1487E-02	0.77	0.247	0.000	0.001	0.1359E-05	-.5773E-07	-.6800E-06	0.3324E-08
189.7	-.7691E-05	-.1483E-02	0.77	0.255	0.000	0.000	0.1350E-05	-.4055E-07	-.6839E-06	-.1055E-08
192.0	-.4591E-05	-.1481E-02	0.77	0.262	0.000	0.000	0.1337E-05	-.2392E-07	-.6857E-06	0.1955E-08
194.3	-.1525E-05	-.1480E-02	0.76	0.268	0.000	-0.001	0.1322E-05	-.7847E-08	-.6873E-06	-.3885E-08

Vertical Section 1 at Radial Distance of 0.00 mm

	Displacements		Stresses				Strains			
Depth	R. disp.	Vert. disp.	R. strs.	Tang. strs.	Vert. strs.	Shear strs.	R. stns.	Tang. stns.	Vert. stns.	Shear stn.
0.0	0.0000E+00	-.1850E-01	-213.98	-213.98	-120.00	0.00	-.1946E-03	-.1946E-03	0.6199E-04	0.0000E+00
-0.2	0.0000E+00	-.1851E-01	-200.91	-200.91	-119.53	0.00	-.1775E-03	-.1775E-03	0.4222E-04	0.0000E+00
-0.5	0.0000E+00	-.1852E-01	-175.79	-175.79	-119.32	0.00	-.1450E-03	-.1450E-03	0.7471E-05	0.0000E+00
-0.9	0.0000E+00	-.1852E-01	-152.05	-152.05	-117.41	0.00	-.1154E-03	-.1154E-03	-.2197E-04	0.0000E+00
-1.2	0.0000E+00	-.1851E-01	-129.71	-129.71	-114.47	0.00	-.8836E-04	-.8836E-04	-.4735E-04	0.0000E+00
-1.6	0.0000E+00	-.1849E-01	-108.80	-108.80	-110.52	0.00	-.6391E-04	-.6391E-04	-.6874E-04	0.0000E+00

-1.9	0.0000E+00	-.1846E-01	-89.25	-89.25	-105.53	0.00	-.4195E-04	-.4195E-04	-.8612E-04	0.0000E+00
-2.3	0.0000E+00	-.1843E-01	-71.02	-71.02	-99.63	0.00	-.2233E-04	-.2233E-04	-.9986E-04	0.0000E+00
-2.6	0.0000E+00	-.1839E-01	-53.96	-53.96	-92.95	0.00	-.4797E-05	-.4797E-05	-.1104E-03	0.0000E+00
-3.0	0.0000E+00	-.1835E-01	-37.90	-37.90	-85.64	0.00	0.1100E-04	0.1100E-04	-.1183E-03	0.0000E+00
-3.3	0.0000E+00	-.1831E-01	-22.65	-22.65	-77.91	0.00	0.2545E-04	0.2545E-04	-.1241E-03	0.0000E+00
-3.7	0.0000E+00	-.1826E-01	-8.00	-8.00	-69.93	0.00	0.3895E-04	0.3895E-04	-.1287E-03	0.0000E+00
-4.0	0.0000E+00	-.1822E-01	6.26	6.26	-61.92	0.00	0.5191E-04	0.5191E-04	-.1326E-03	0.0000E+00
-4.4	0.0000E+00	-.1817E-01	20.33	20.33	-54.05	0.00	0.6474E-04	0.6474E-04	-.1366E-03	0.0000E+00
-4.7	0.0000E+00	-.1812E-01	34.47	34.47	-46.47	0.00	0.7785E-04	0.7785E-04	-.1412E-03	0.0000E+00
-5.1	0.0000E+00	-.1807E-01	48.86	48.86	-39.33	0.00	0.9160E-04	0.9160E-04	-.1471E-03	0.0000E+00
-5.4	0.0000E+00	-.1802E-01	63.74	63.74	-32.80	0.00	0.1064E-03	0.1064E-03	-.1549E-03	0.0000E+00
-5.8	0.0000E+00	-.1796E-01	79.34	79.34	-27.03	0.00	0.1227E-03	0.1227E-03	-.1652E-03	0.0000E+00
-6.1	0.0000E+00	-.1790E-01	95.93	95.93	-22.20	0.00	0.1409E-03	0.1409E-03	-.1788E-03	0.0000E+00
-6.5	0.0000E+00	-.1784E-01	113.81	113.81	-18.52	0.00	0.1616E-03	0.1616E-03	-.1964E-03	0.0000E+00
-6.8	0.0000E+00	-.1776E-01	133.31	133.31	-16.81	0.00	0.1858E-03	0.1858E-03	-.2203E-03	0.0000E+00
-7.0	0.0000E+00	-.1772E-01	143.76	143.76	-16.02	0.00	0.1989E-03	0.1989E-03	-.2352E-03	0.0000E+00
-7.0	0.0000E+00	-.1772E-01	-0.64	-0.64	-16.02	0.00	0.1989E-03	0.1989E-03	-.4987E-03	0.0000E+00
-7.3	0.0000E+00	-.1760E-01	-0.54	-0.54	-14.98	0.00	0.1931E-03	0.1931E-03	-.4807E-03	0.0000E+00
-7.8	0.0000E+00	-.1735E-01	-0.36	-0.36	-13.90	0.00	0.1826E-03	0.1826E-03	-.4493E-03	0.0000E+00
-8.3	0.0000E+00	-.1712E-01	-0.20	-0.20	-12.97	0.00	0.1737E-03	0.1737E-03	-.4224E-03	0.0000E+00
-8.9	0.0000E+00	-.1690E-01	-0.04	-0.04	-12.12	0.00	0.1659E-03	0.1659E-03	-.3981E-03	0.0000E+00
-9.4	0.0000E+00	-.1669E-01	0.12	0.12	-11.35	0.00	0.1590E-03	0.1590E-03	-.3763E-03	0.0000E+00
-9.9	0.0000E+00	-.1650E-01	0.29	0.29	-10.64	0.00	0.1531E-03	0.1531E-03	-.3568E-03	0.0000E+00
-10.5	0.0000E+00	-.1631E-01	0.45	0.45	-10.00	0.00	0.1480E-03	0.1480E-03	-.3394E-03	0.0000E+00
-11.0	0.0000E+00	-.1613E-01	0.61	0.61	-9.41	0.00	0.1438E-03	0.1438E-03	-.3239E-03	0.0000E+00
-11.5	0.0000E+00	-.1596E-01	0.79	0.79	-8.87	0.00	0.1404E-03	0.1404E-03	-.3104E-03	0.0000E+00
-12.1	0.0000E+00	-.1580E-01	0.97	0.97	-8.38	0.00	0.1377E-03	0.1377E-03	-.2986E-03	0.0000E+00
-12.6	0.0000E+00	-.1564E-01	1.16	1.16	-7.93	0.00	0.1359E-03	0.1359E-03	-.2886E-03	0.0000E+00
-13.1	0.0000E+00	-.1549E-01	1.36	1.36	-7.53	0.00	0.1348E-03	0.1348E-03	-.2802E-03	0.0000E+00
-13.7	0.0000E+00	-.1535E-01	1.58	1.58	-7.16	0.00	0.1346E-03	0.1346E-03	-.2736E-03	0.0000E+00
-14.2	0.0000E+00	-.1520E-01	1.82	1.82	-6.83	0.00	0.1352E-03	0.1352E-03	-.2687E-03	0.0000E+00
-14.7	0.0000E+00	-.1506E-01	2.08	2.08	-6.54	0.00	0.1368E-03	0.1368E-03	-.2656E-03	0.0000E+00
-15.0	0.0000E+00	-.1499E-01	2.21	2.21	-6.41	0.00	0.1378E-03	0.1378E-03	-.2649E-03	0.0000E+00
-15.0	0.0000E+00	-.1499E-01	0.23	0.23	-6.41	0.00	0.1378E-03	0.1378E-03	-.3057E-03	0.0000E+00
-15.8	0.0000E+00	-.1477E-01	0.27	0.27	-6.08	0.00	0.1329E-03	0.1329E-03	-.2895E-03	0.0000E+00
-17.3	0.0000E+00	-.1436E-01	0.37	0.37	-5.51	0.00	0.1248E-03	0.1248E-03	-.2628E-03	0.0000E+00
-18.8	0.0000E+00	-.1398E-01	0.51	0.51	-5.05	0.00	0.1201E-03	0.1201E-03	-.2432E-03	0.0000E+00
-20.3	0.0000E+00	-.1362E-01	0.69	0.69	-4.70	0.00	0.1186E-03	0.1186E-03	-.2302E-03	0.0000E+00
-21.8	0.0000E+00	-.1328E-01	0.92	0.92	-4.43	0.00	0.1205E-03	0.1205E-03	-.2240E-03	0.0000E+00
-23.3	0.0000E+00	-.1294E-01	1.22	1.22	-4.26	0.00	0.1262E-03	0.1262E-03	-.2249E-03	0.0000E+00
-24.0	0.0000E+00	-.1278E-01	1.40	1.40	-4.20	0.00	0.1302E-03	0.1302E-03	-.2283E-03	0.0000E+00
-24.0	0.0000E+00	-.1278E-01	-1.03	-1.03	-4.20	0.00	0.1302E-03	0.1302E-03	-.3193E-03	0.0000E+00
-26.7	0.0000E+00	-.1203E-01	-1.15	-1.15	-4.10	0.00	0.1156E-03	0.1156E-03	-.2803E-03	0.0000E+00
-32.0	0.0000E+00	-.1069E-01	-1.39	-1.39	-4.03	0.00	0.9090E-04	0.9090E-04	-.2203E-03	0.0000E+00
-37.3	0.0000E+00	-.9629E-02	-1.63	-1.63	-4.10	0.00	0.7372E-04	0.7372E-04	-.1787E-03	0.0000E+00
-42.7	0.0000E+00	-.8756E-02	-1.86	-1.86	-4.26	0.00	0.6133E-04	0.6133E-04	-.1487E-03	0.0000E+00
-48.0	0.0000E+00	-.8023E-02	-2.09	-2.09	-4.47	0.00	0.5200E-04	0.5200E-04	-.1265E-03	0.0000E+00
-53.3	0.0000E+00	-.7399E-02	-2.33	-2.33	-4.71	0.00	0.4371E-04	0.4371E-04	-.1073E-03	0.0000E+00
-56.0	0.0000E+00	-.7113E-02	-2.45	-2.45	-4.83	0.00	0.3951E-04	0.3951E-04	-.9765E-04	0.0000E+00

TECHNICAL INFORMATION

Total number of elements = 4653   Total number of nodes = 4800
Number of equations = 9504
Bandwidth = 202
Number of iterations to reach convergence = 1
Elastic modulus of spring along bottom boundary = 7500.0 psi Poisson's ratio of spring = 0.40
Relative error of convergence = 0.00000E+00

EQUIVALENT RESILIENT MODULUS FOR EACH LAYER

Layer	Name	Modulus (Psi.)
1	HMA	500000.
2	Granular	30000.
3	Subbase	20000.
4	Subgrade	7500.

FATIGUE LIFE & RUT DEPTH DATA

Average annual temperature = 0.00 (Fahrenheit)
Kinematic viscosity = 0.00 centistoke
Allowable rut depth = 0.00 inches
Allowable fatigue damage = 0. %

SUMMARY

Maximum tensile (radial) strain in the asphalt layer = 1.989E-04

Compressive (vertical) strain at the top of base = 4.987E-04

Compressive (vertical) strain at top of roadbed = 3.193E-04

Allowable ESAL applications based on fatigue life = 0.000E+00

Allowable ESAL applications based on rut depth = 0.000E+00

TITLE

FILENAMES

Data file used for this run: C:\Pavements\MFPDS\TH_SC_2nd.med
Name of this output file : TH_SC_2nd.mpo
Unit : English
Route :
Region :
Control Section :
Lane :
Job No. :
Trial No. :
Description :

INITIAL DATA

Number of layers = 4
Wheel load = 9000.0 lb.
Tire pressure = 120.00 psi.
Radius of loaded area (a) = 4.886 inches

LAYER TYPE

1 asphalt; 2 granular; 3 cohese

Layer number (from top)	Type (1,2,or3)
1	1
2	1
3	1
4	1

MATERIAL PROPERTIES

Asphalt Material Properties

Layer	Name of Layer	Thickness (inches)	Modulus (psi)	Poisson's ratio	Density (lb/cu.ft)	Ko
1	HMA	7.0	500000.0	0.35	150.0	1.50
2	SoilCement	8.0	500000.0	0.20	130.0	1.00
3	Subbase	9.0	20000.0	0.40	130.0	0.75
4	Subgrade	32.0	7500.0	0.40	120.0	0.60

Layer 4 actually semi-infinite, but thickness controls depth to which displacements/stresses are computed.

CROSS SECTIONS FOR CALCULATION OF RESULTS

Number of horizontal sections = 1   Number of vertical sections = 1

Depth for horizontal sections (inches) =   0.00

Radial distance for vertical sections (inches) =   0.00

DIVISION OF FINITE ELEMENT MESH

Number of Elements in Vertical Direction

Layer	Thickness	Number of elements
1. HMA	7.0	20
2. SoilCement	8.0	15
3. Subbase	9.0	6
4. Subgrade	32.0	6

Number of Elements in Horizontal Direction

Range (a: contact radius)	Number of elements
1. R = 0 - a	9
2. R = a - 3a	9
3. R = 3a - 6a	9
4. R = 6a - 40a	72

FINAL DISPLACEMENTS, STRESSES AND STRAINS

Horizontal Section 1 at Depth of   0.00 mm

	Displacements		Stresses				Strains			
R. Dist.	R. Disp.	Vert. Disp.	R. Strs.	Tang. Strs.	Vert. Strs.	Shear Strs.	Rad. S.	Tang. Stn.	Vert. Stn.	Shear Stn.
0.0	0.0000E+00	-.1103E-01								
0.3	-.2468E-04	-.1103E-01	-138.89	-138.895	-120.000	0.730	-.9092E-04	-.9092E-04	-.6167E-04	0.3939E-05
0.8	-.7365E-04	-.1101E-01	-137.79	-138.142	-120.000	0.118	-.8949E-04	-.9044E-04	-.6225E-04	0.6378E-06
1.4	-.1222E-03	-.1098E-01	-137.73	-138.000	-120.000	0.086	-.8930E-04	-.9002E-04	-.6289E-04	0.4668E-06
1.9	-.1706E-03	-.1094E-01	-137.82	-138.073	-120.000	0.094	-.8909E-04	-.8979E-04	-.6370E-04	0.5091E-06
2.4	-.2189E-03	-.1087E-01	-138.06	-138.328	-120.000	0.125	-.8887E-04	-.8961E-04	-.6484E-04	0.6776E-06
3.0	-.2670E-03	-.1079E-01	-138.51	-138.885	-120.000	0.130	-.8841E-04	-.8943E-04	-.6692E-04	0.7030E-06
3.5	-.3151E-03	-.1068E-01	-139.54	-139.809	-120.000	0.455	-.8856E-04	-.8929E-04	-.6919E-04	0.2459E-05
4.1	-.3616E-03	-.1054E-01	-140.44	-142.612	-120.000	0.055	-.8295E-04	-.8882E-04	-.8215E-04	0.2945E-06
4.6	-.3978E-03	-.1032E-01	-96.71	-109.976	-94.349	28.112	-.5039E-04	-.8621E-04	-.4402E-04	0.1518E-03
5.4	-.4212E-03	-.9988E-02	-33.85	-55.945	-15.142	10.563	-.1795E-04	-.7759E-04	0.3257E-04	0.5704E-04
6.5	-.4352E-03	-.9683E-02	-13.86	-35.709	0.000	-2.267	-.7813E-05	-.6681E-04	0.4924E-04	-.1224E-04

7.6	-.4473E-03	-.9491E-02	-19.88	-36.360	0.000	0.127	-.1434E-04	-.5885E-04	0.3947E-04	0.6879E-06
8.7	-.4644E-03	-.9337E-02	-20.44	-33.846	0.000	0.055	-.1728E-04	-.5347E-04	0.3824E-04	0.2964E-06
9.8	-.4838E-03	-.9201E-02	-20.53	-32.038	-0.276	0.154	-.1844E-04	-.4951E-04	0.3625E-04	0.8311E-06
10.9	-.5039E-03	-.9077E-02	-20.07	-30.367	-0.393	0.192	-.1860E-04	-.4641E-04	0.3452E-04	0.1037E-05
11.9	-.5238E-03	-.8958E-02	-19.28	-28.838	-0.455	0.215	-.1806E-04	-.4386E-04	0.3278E-04	0.1163E-05
13.0	-.5429E-03	-.8843E-02	-18.30	-27.402	-0.463	0.228	-.1710E-04	-.4167E-04	0.3107E-04	0.1233E-05
14.1	-.5608E-03	-.8730E-02	-17.28	-26.095	-0.516	0.205	-.1593E-04	-.3973E-04	0.2933E-04	0.1107E-05
15.5	-.5811E-03	-.8590E-02	-15.87	-24.509	-0.498	0.243	-.1424E-04	-.3756E-04	0.2727E-04	0.1315E-05
17.1	-.6025E-03	-.8423E-02	-14.11	-22.701	-0.415	0.212	-.1205E-04	-.3523E-04	0.2494E-04	0.1143E-05
18.7	-.6204E-03	-.8256E-02	-12.48	-21.067	-0.391	0.205	-.9939E-05	-.3312E-04	0.2270E-04	0.1109E-05
20.4	-.6350E-03	-.8090E-02	-10.94	-19.549	-0.352	0.190	-.7958E-05	-.3119E-04	0.2064E-04	0.1025E-05
22.0	-.6465E-03	-.7924E-02	-9.54	-18.151	-0.319	0.175	-.6145E-05	-.2940E-04	0.1874E-04	0.9428E-06
23.6	-.6551E-03	-.7760E-02	-8.25	-16.859	-0.289	0.161	-.4495E-05	-.2774E-04	0.1700E-04	0.8712E-06
25.2	-.6612E-03	-.7595E-02	-7.08	-15.665	-0.260	0.148	-.3010E-05	-.2619E-04	0.1540E-04	0.7981E-06
26.9	-.6651E-03	-.7433E-02	-6.02	-14.563	-0.229	0.134	-.1695E-05	-.2475E-04	0.1395E-04	0.7220E-06
28.5	-.6669E-03	-.7271E-02	-5.07	-13.549	-0.218	0.125	-.4993E-06	-.2340E-04	0.1260E-04	0.6740E-06
30.5	-.6665E-03	-.7079E-02	-4.10	-12.446	-0.207	0.120	0.6506E-06	-.2187E-04	0.1117E-04	0.6461E-06
32.8	-.6636E-03	-.6856E-02	-3.05	-11.242	-0.149	0.096	0.1876E-05	-.2025E-04	0.9706E-05	0.5190E-06
35.1	-.6581E-03	-.6637E-02	-2.17	-10.185	-0.131	0.084	0.2879E-05	-.1876E-04	0.8386E-05	0.4549E-06
37.4	-.6505E-03	-.6423E-02	-1.42	-9.236	-0.113	0.073	0.3702E-05	-.1740E-04	0.7234E-05	0.3956E-06
39.7	-.6412E-03	-.6214E-02	-0.77	-8.379	-0.096	0.067	0.4392E-05	-.1615E-04	0.6212E-05	0.3598E-06
42.0	-.6304E-03	-.6009E-02	-0.20	-7.603	-0.080	0.059	0.4972E-05	-.1501E-04	0.5304E-05	0.3172E-06
44.3	-.6184E-03	-.5810E-02	0.28	-6.901	-0.065	0.051	0.5445E-05	-.1395E-04	0.4500E-05	0.2781E-06
46.6	-.6054E-03	-.5616E-02	0.70	-6.268	-0.056	0.045	0.5822E-05	-.1298E-04	0.3787E-05	0.2415E-06
48.9	-.5916E-03	-.5428E-02	1.05	-5.691	-0.043	0.042	0.6124E-05	-.1209E-04	0.3160E-05	0.2248E-06
51.2	-.5772E-03	-.5245E-02	1.35	-5.172	-0.032	0.032	0.6340E-05	-.1127E-04	0.2612E-05	0.1751E-06
53.5	-.5624E-03	-.5068E-02	1.59	-4.704	-0.028	0.031	0.6499E-05	-.1050E-04	0.2121E-05	0.1687E-06
55.8	-.5473E-03	-.4896E-02	1.81	-4.271	-0.018	0.029	0.6626E-05	-.9799E-05	0.1686E-05	0.1572E-06
58.2	-.5319E-03	-.4729E-02	1.98	-3.884	-0.013	0.021	0.6692E-05	-.9146E-05	0.1305E-05	0.1119E-06
60.5	-.5164E-03	-.4569E-02	2.12	-3.531	-0.009	0.022	0.6719E-05	-.8541E-05	0.9706E-06	0.1202E-06
62.8	-.5009E-03	-.4413E-02	2.24	-3.208	-0.002	0.017	0.6721E-05	-.7980E-05	0.6753E-06	0.9331E-07
65.1	-.4854E-03	-.4263E-02	2.33	-2.915	0.000	0.016	0.6694E-05	-.7459E-05	0.4136E-06	0.8750E-07
67.4	-.4701E-03	-.4118E-02	2.40	-2.647	0.000	0.013	0.6646E-05	-.6975E-05	0.1823E-06	0.7012E-07
69.7	-.4548E-03	-.3978E-02	2.45	-2.402	0.000	0.013	0.6583E-05	-.6526E-05	-.2263E-07	0.7014E-07
72.0	-.4397E-03	-.3843E-02	2.50	-2.175	0.000	0.011	0.6511E-05	-.6107E-05	-.2034E-06	0.5985E-07
74.3	-.4248E-03	-.3714E-02	2.52	-1.971	0.000	0.008	0.6414E-05	-.5716E-05	-.3586E-06	0.4219E-07
76.6	-.4101E-03	-.3589E-02	2.53	-1.786	0.000	0.008	0.6298E-05	-.5353E-05	-.4917E-06	0.4127E-07
78.9	-.3957E-03	-.3468E-02	2.53	-1.616	0.000	0.006	0.6180E-05	-.5014E-05	-.6087E-06	0.3304E-07
81.2	-.3816E-03	-.3353E-02	2.53	-1.456	0.000	0.008	0.6070E-05	-.4698E-05	-.7151E-06	0.4075E-07
83.5	-.3677E-03	-.3241E-02	2.52	-1.310	0.000	0.004	0.5952E-05	-.4402E-05	-.8089E-06	0.2154E-07
85.8	-.3541E-03	-.3135E-02	2.50	-1.179	0.000	0.004	0.5819E-05	-.4125E-05	-.8859E-06	0.2280E-07
88.2	-.3409E-03	-.3032E-02	2.48	-1.057	0.000	0.003	0.5686E-05	-.3867E-05	-.9517E-06	0.1697E-07
90.5	-.3279E-03	-.2933E-02	2.45	-0.948	0.000	0.002	0.5546E-05	-.3625E-05	-.1008E-05	0.1109E-07
92.8	-.3153E-03	-.2839E-02	2.42	-0.845	0.000	0.003	0.5412E-05	-.3398E-05	-.1055E-05	0.1713E-07
95.1	-.3029E-03	-.2748E-02	2.38	-0.750	0.000	0.001	0.5278E-05	-.3186E-05	-.1096E-05	0.6436E-08
97.4	-.2909E-03	-.2662E-02	2.35	-0.665	0.000	0.001	0.5139E-05	-.2987E-05	-.1129E-05	0.7983E-08
99.7	-.2792E-03	-.2578E-02	2.31	-0.585	0.000	0.001	0.5002E-05	-.2801E-05	-.1154E-05	0.4509E-08
102.0	-.2678E-03	-.2499E-02	2.26	-0.513	0.000	0.000	0.4860E-05	-.2626E-05	-.1171E-05	0.4865E-09
104.3	-.2568E-03	-.2423E-02	2.21	-0.450	0.000	-0.001	0.4714E-05	-.2462E-05	-.1182E-05	-.2704E-08
106.6	-.2461E-03	-.2350E-02	2.15	-0.393	0.000	-0.002	0.4562E-05	-.2308E-05	-.1185E-05	-.8707E-08
108.9	-.2357E-03	-.2281E-02	2.10	-0.339	0.000	0.000	0.4421E-05	-.2164E-05	-.1187E-05	0.2349E-08

111.2	-.2257E-03	-.2214E-02	2.05	-0.288	0.000	-0.001	0.4290E-05	-.2029E-05	-.1187E-05	-.5988E-08
113.5	-.2159E-03	-.2151E-02	2.00	-0.242	0.000	-0.001	0.4155E-05	-.1902E-05	-.1184E-05	-.4897E-08
115.8	-.2065E-03	-.2090E-02	1.95	-0.202	0.000	-0.002	0.4021E-05	-.1783E-05	-.1177E-05	-.9763E-08
118.1	-.1974E-03	-.2032E-02	1.90	-0.163	0.000	-0.001	0.3892E-05	-.1671E-05	-.1168E-05	-.2930E-08
120.5	-.1885E-03	-.1977E-02	1.84	-0.130	0.000	-0.003	0.3764E-05	-.1565E-05	-.1157E-05	-.1417E-07
122.8	-.1800E-03	-.1925E-02	1.79	-0.098	0.000	-0.001	0.3640E-05	-.1466E-05	-.1145E-05	-.3376E-08
125.1	-.1717E-03	-.1875E-02	1.75	-0.066	0.000	-0.001	0.3530E-05	-.1373E-05	-.1133E-05	-.5463E-08
127.4	-.1637E-03	-.1827E-02	1.70	-0.039	0.000	-0.002	0.3418E-05	-.1285E-05	-.1122E-05	-.1097E-07
129.7	-.1560E-03	-.1782E-02	1.66	-0.015	0.000	-0.001	0.3307E-05	-.1203E-05	-.1108E-05	-.6998E-08
132.0	-.1484E-03	-.1739E-02	1.61	0.009	0.000	-0.001	0.3205E-05	-.1125E-05	-.1095E-05	-.8032E-08
134.3	-.1412E-03	-.1698E-02	1.57	0.032	0.000	-0.001	0.3108E-05	-.1051E-05	-.1083E-05	-.5092E-08
136.6	-.1341E-03	-.1659E-02	1.53	0.052	0.000	-0.002	0.3014E-05	-.9817E-06	-.1071E-05	-.1061E-07
138.9	-.1272E-03	-.1622E-02	1.49	0.072	0.000	0.000	0.2926E-05	-.9160E-06	-.1059E-05	-.2558E-08
141.2	-.1206E-03	-.1587E-02	1.46	0.091	0.000	-0.001	0.2845E-05	-.8539E-06	-.1048E-05	-.7373E-08
143.5	-.1141E-03	-.1554E-02	1.43	0.108	0.000	-0.001	0.2763E-05	-.7951E-06	-.1037E-05	-.7561E-08
145.8	-.1078E-03	-.1523E-02	1.40	0.125	0.000	0.000	0.2690E-05	-.7394E-06	-.1028E-05	-.1605E-08
148.1	-.1017E-03	-.1494E-02	1.37	0.142	0.000	-0.001	0.2621E-05	-.6865E-06	-.1019E-05	-.7680E-08
150.4	-.9573E-04	-.1466E-02	1.34	0.156	0.000	-0.001	0.2554E-05	-.6363E-06	-.1011E-05	-.3211E-08
152.8	-.8991E-04	-.1440E-02	1.31	0.171	0.000	-0.001	0.2492E-05	-.5886E-06	-.1003E-05	-.5192E-08
155.1	-.8423E-04	-.1416E-02	1.29	0.185	0.000	-0.001	0.2432E-05	-.5432E-06	-.9951E-06	-.3224E-08
157.4	-.7868E-04	-.1393E-02	1.26	0.198	0.000	-0.001	0.2376E-05	-.5000E-06	-.9882E-06	-.4356E-08
159.7	-.7326E-04	-.1372E-02	1.24	0.211	0.000	-0.001	0.2323E-05	-.4588E-06	-.9829E-06	-.3872E-08
162.0	-.6795E-04	-.1353E-02	1.22	0.224	0.000	0.000	0.2277E-05	-.4195E-06	-.9789E-06	-.2049E-09
164.3	-.6275E-04	-.1334E-02	1.21	0.238	0.000	0.000	0.2235E-05	-.3819E-06	-.9755E-06	-.2579E-08
166.6	-.5764E-04	-.1318E-02	1.19	0.249	0.000	-0.001	0.2191E-05	-.3460E-06	-.9723E-06	-.3756E-08
168.9	-.5263E-04	-.1302E-02	1.17	0.260	0.000	0.000	0.2150E-05	-.3116E-06	-.9691E-06	-.1317E-08
171.2	-.4771E-04	-.1288E-02	1.16	0.272	0.000	0.000	0.2114E-05	-.2787E-06	-.9675E-06	-.1681E-08
173.5	-.4287E-04	-.1276E-02	1.15	0.283	0.000	0.000	0.2083E-05	-.2471E-06	-.9676E-06	0.2523E-09
175.8	-.3810E-04	-.1265E-02	1.14	0.295	0.000	0.000	0.2054E-05	-.2167E-06	-.9678E-06	-.6344E-09
178.1	-.3340E-04	-.1255E-02	1.13	0.306	0.000	0.000	0.2025E-05	-.1875E-06	-.9684E-06	-.1117E-08
180.4	-.2876E-04	-.1246E-02	1.11	0.316	0.000	0.000	0.1997E-05	-.1594E-06	-.9688E-06	-.7760E-09
182.8	-.2418E-04	-.1239E-02	1.11	0.327	0.000	0.000	0.1971E-05	-.1323E-06	-.9695E-06	0.6755E-09
185.1	-.1966E-04	-.1233E-02	1.10	0.336	0.000	0.000	0.1946E-05	-.1062E-06	-.9696E-06	-.1548E-08
187.4	-.1520E-04	-.1228E-02	1.09	0.346	0.000	0.000	0.1922E-05	-.8113E-07	-.9699E-06	0.1539E-08
189.7	-.1079E-04	-.1224E-02	1.08	0.355	0.000	0.000	0.1899E-05	-.5690E-07	-.9711E-06	-.2199E-08
192.0	-.6437E-05	-.1222E-02	1.07	0.364	0.000	0.000	0.1876E-05	-.3353E-07	-.9708E-06	0.1290E-08
194.3	-.2137E-05	-.1221E-02	1.06	0.372	0.000	-0.001	0.1852E-05	-.1100E-07	-.9718E-06	-.4445E-08

Vertical Section 1 at Radial Distance of 0.00 mm

	Displacements		Stresses				Strains			
Depth	R. disp.	Vert. disp.	R. strs.	Tang. strs.	Vert. strs.	Shear strs.	R. stns.	Tang. stns.	Vert. stns.	Shear stn.
0.0	0.0000E+00	-.1103E-01	-134.39	-134.39	-120.00	0.00	-.9092E-04	-.9092E-04	-.5090E-04	0.0000E+00
-0.2	0.0000E+00	-.1102E-01	-127.47	-127.47	-119.93	0.00	-.8173E-04	-.8173E-04	-.6141E-04	0.0000E+00
-0.5	0.0000E+00	-.1100E-01	-113.95	-113.95	-120.04	0.00	-.6405E-04	-.6405E-04	-.8055E-04	0.0000E+00
-0.9	0.0000E+00	-.1097E-01	-101.07	-101.07	-119.39	0.00	-.4772E-04	-.4772E-04	-.9729E-04	0.0000E+00
-1.2	0.0000E+00	-.1093E-01	-89.01	-89.01	-118.18	0.00	-.3285E-04	-.3285E-04	-.1118E-03	0.0000E+00
-1.6	0.0000E+00	-.1089E-01	-77.92	-77.92	-116.33	0.00	-.1970E-04	-.1970E-04	-.1236E-03	0.0000E+00
-1.9	0.0000E+00	-.1084E-01	-67.89	-67.89	-113.75	0.00	-.8415E-05	-.8415E-05	-.1325E-03	0.0000E+00

-2.3	0.0000E+00	-.1080E-01	-58.95	-58.95	-110.51	0.00	0.9706E-06	0.9706E-06	-.1385E-03	0.0000E+00
-2.6	0.0000E+00	-.1075E-01	-51.07	-51.07	-106.65	0.00	0.8546E-05	0.8546E-05	-.1418E-03	0.0000E+00
-3.0	0.0000E+00	-.1070E-01	-44.18	-44.18	-102.28	0.00	0.1448E-04	0.1448E-04	-.1427E-03	0.0000E+00
-3.3	0.0000E+00	-.1065E-01	-38.19	-38.19	-97.53	0.00	0.1898E-04	0.1898E-04	-.1416E-03	0.0000E+00
-3.7	0.0000E+00	-.1060E-01	-33.00	-33.00	-92.53	0.00	0.2227E-04	0.2227E-04	-.1389E-03	0.0000E+00
-4.0	0.0000E+00	-.1055E-01	-28.50	-28.50	-87.41	0.00	0.2458E-04	0.2458E-04	-.1350E-03	0.0000E+00
-4.4	0.0000E+00	-.1051E-01	-24.59	-24.59	-82.27	0.00	0.2611E-04	0.2611E-04	-.1302E-03	0.0000E+00
-4.7	0.0000E+00	-.1046E-01	-21.17	-21.17	-77.18	0.00	0.2702E-04	0.2702E-04	-.1248E-03	0.0000E+00
-5.1	0.0000E+00	-.1042E-01	-18.18	-18.18	-72.18	0.00	0.2745E-04	0.2745E-04	-.1190E-03	0.0000E+00
-5.4	0.0000E+00	-.1038E-01	-15.55	-15.55	-67.34	0.00	0.2751E-04	0.2751E-04	-.1129E-03	0.0000E+00
-5.8	0.0000E+00	-.1034E-01	-13.23	-13.23	-62.66	0.00	0.2729E-04	0.2729E-04	-.1069E-03	0.0000E+00
-6.1	0.0000E+00	-.1030E-01	-11.18	-11.18	-58.17	0.00	0.2685E-04	0.2685E-04	-.1007E-03	0.0000E+00
-6.5	0.0000E+00	-.1027E-01	-9.36	-9.36	-53.85	0.00	0.2623E-04	0.2623E-04	-.9466E-04	0.0000E+00
-6.8	0.0000E+00	-.1024E-01	-7.76	-7.76	-49.70	0.00	0.2544E-04	0.2544E-04	-.8860E-04	0.0000E+00
-7.0	0.0000E+00	-.1022E-01	-7.04	-7.04	-47.67	0.00	0.2500E-04	0.2500E-04	-.8558E-04	0.0000E+00
-7.0	0.0000E+00	-.1022E-01	3.28	3.28	-47.67	0.00	0.2500E-04	0.2500E-04	-.9712E-04	0.0000E+00
-7.3	0.0000E+00	-.1020E-01	4.17	4.17	-44.67	0.00	0.2529E-04	0.2529E-04	-.9191E-04	0.0000E+00
-7.8	0.0000E+00	-.1015E-01	5.91	5.91	-39.19	0.00	0.2594E-04	0.2594E-04	-.8231E-04	0.0000E+00
-8.3	0.0000E+00	-.1011E-01	7.66	7.66	-34.23	0.00	0.2680E-04	0.2680E-04	-.7374E-04	0.0000E+00
-8.9	0.0000E+00	-.1007E-01	9.45	9.45	-29.75	0.00	0.2791E-04	0.2791E-04	-.6616E-04	0.0000E+00
-9.4	0.0000E+00	-.1004E-01	11.29	11.29	-25.70	0.00	0.2929E-04	0.2929E-04	-.5948E-04	0.0000E+00
-9.9	0.0000E+00	-.1001E-01	13.23	13.23	-22.03	0.00	0.3098E-04	0.3098E-04	-.5365E-04	0.0000E+00
-10.5	0.0000E+00	-.9980E-02	15.28	15.28	-18.72	0.00	0.3298E-04	0.3298E-04	-.4863E-04	0.0000E+00
-11.0	0.0000E+00	-.9955E-02	17.47	17.47	-15.74	0.00	0.3534E-04	0.3534E-04	-.4437E-04	0.0000E+00
-11.5	0.0000E+00	-.9932E-02	19.83	19.83	-13.09	0.00	0.3810E-04	0.3810E-04	-.4089E-04	0.0000E+00
-12.1	0.0000E+00	-.9911E-02	22.38	22.38	-10.73	0.00	0.4129E-04	0.4129E-04	-.3818E-04	0.0000E+00
-12.6	0.0000E+00	-.9892E-02	25.16	25.16	-8.68	0.00	0.4497E-04	0.4497E-04	-.3626E-04	0.0000E+00
-13.1	0.0000E+00	-.9872E-02	28.22	28.22	-6.95	0.00	0.4921E-04	0.4921E-04	-.3519E-04	0.0000E+00
-13.7	0.0000E+00	-.9854E-02	31.59	31.59	-5.55	0.00	0.5410E-04	0.5410E-04	-.3505E-04	0.0000E+00
-14.2	0.0000E+00	-.9835E-02	35.35	35.35	-4.51	0.00	0.5975E-04	0.5975E-04	-.3593E-04	0.0000E+00
-14.7	0.0000E+00	-.9815E-02	39.63	39.63	-3.96	0.00	0.6643E-04	0.6643E-04	-.3820E-04	0.0000E+00
-15.0	0.0000E+00	-.9805E-02	42.01	42.01	-3.81	0.00	0.7007E-04	0.7007E-04	-.3997E-04	0.0000E+00
-15.0	0.0000E+00	-.9805E-02	-0.29	-0.29	-3.81	0.00	0.7007E-04	0.7007E-04	-.1546E-03	0.0000E+00
-15.8	0.0000E+00	-.9696E-02	-0.32	-0.32	-3.66	0.00	0.6670E-04	0.6670E-04	-.1448E-03	0.0000E+00
-17.3	0.0000E+00	-.9490E-02	-0.36	-0.36	-3.43	0.00	0.6129E-04	0.6129E-04	-.1295E-03	0.0000E+00
-18.8	0.0000E+00	-.9304E-02	-0.36	-0.36	-3.27	0.00	0.5820E-04	0.5820E-04	-.1191E-03	0.0000E+00
-20.3	0.0000E+00	-.9131E-02	-0.34	-0.34	-3.16	0.00	0.5698E-04	0.5698E-04	-.1123E-03	0.0000E+00
-21.8	0.0000E+00	-.8965E-02	-0.29	-0.29	-3.10	0.00	0.5755E-04	0.5755E-04	-.1090E-03	0.0000E+00
-23.3	0.0000E+00	-.8801E-02	-0.21	-0.21	-3.09	0.00	0.5998E-04	0.5998E-04	-.1093E-03	0.0000E+00
-24.0	0.0000E+00	-.8719E-02	-0.16	-0.16	-3.09	0.00	0.6168E-04	0.6168E-04	-.1107E-03	0.0000E+00
-24.0	0.0000E+00	-.8719E-02	-1.16	-1.16	-3.09	0.00	0.6168E-04	0.6168E-04	-.1581E-03	0.0000E+00
-26.7	0.0000E+00	-.8341E-02	-1.27	-1.27	-3.15	0.00	0.5562E-04	0.5562E-04	-.1415E-03	0.0000E+00
-32.0	0.0000E+00	-.7654E-02	-1.49	-1.49	-3.33	0.00	0.4559E-04	0.4559E-04	-.1163E-03	0.0000E+00
-37.3	0.0000E+00	-.7080E-02	-1.71	-1.71	-3.57	0.00	0.3880E-04	0.3880E-04	-.9904E-04	0.0000E+00
-42.7	0.0000E+00	-.6585E-02	-1.93	-1.93	-3.84	0.00	0.3387E-04	0.3387E-04	-.8631E-04	0.0000E+00
-48.0	0.0000E+00	-.6151E-02	-2.15	-2.15	-4.14	0.00	0.3000E-04	0.3000E-04	-.7659E-04	0.0000E+00
-53.3	0.0000E+00	-.5767E-02	-2.37	-2.37	-4.44	0.00	0.2614E-04	0.2614E-04	-.6726E-04	0.0000E+00
-56.0	0.0000E+00	-.5588E-02	-2.49	-2.49	-4.60	0.00	0.2403E-04	0.2403E-04	-.6260E-04	0.0000E+00

TECHNICAL INFORMATION

Total number of elements = 4653 Total number of nodes = 4800
Number of equations = 9504
Bandwidth = 202
Number of iterations to reach convergence = 1
Elastic modulus of spring along bottom boundary = 7500.0 psi Poisson's ratio of spring = 0.40
Relative error of convergence = 0.00000E+00

EQUIVALENT RESILIENT MODULUS FOR EACH LAYER

Layer	Name	Modulus (Psi.)
1	HMA	500000.
2	SoilCement	500000.
3	Subbase	20000.
4	Subgrade	7500.

FATIGUE LIFE & RUT DEPTH DATA

Average annual temperature = 0.00 (Fahrenheit)
Kinematic viscosity = 0.00 centistoke
Allowable rut depth = 0.00 inches
Allowable fatigue damage = 0. %

SUMMARY

Maximum tensile (radial) strain in the asphalt layer = 2.500E-05

Compressive (vertical) strain at the top of base = 9.712E-05

Compressive (vertical) strain at top of roadbed = 1.581E-04

Allowable ESAL applications based on fatigue life = 0.000E+00

Allowable ESAL applications based on rut depth = 0.000E+00

TITLE

FILENAMES

```
Data file used for this run: C:\Pavements\MFPDS\TH_CTB_2nd.med
Name of this output file   : TH_CTB_2nd.mpo
Unit                       : English
Route                      :
Region                     :
Control Section            :
Lane                       :
Job No.                    :
Trial No.                  :
Description                :
```

INITIAL DATA

```
Number of layers = 4
Wheel load =    9000.0 lb.
Tire pressure =  120.00 psi.
Radius of loaded area (a) =      4.886 inches
```

LAYER TYPE

1 asphalt; 2 granular; 3 cohese

Layer number (from top)	Type (1,2,or3)
1	1
2	1
3	1
4	1

MATERIAL PROPERTIES

Asphalt Material Properties

Layer	Name of Layer	Thickness (inches)	Modulus (psi)	Poisson's ratio	Density (lb/cu.ft)	Ko
1	HMA	7.0	500000.0	0.35	150.0	1.50
2	CTB	8.0	1000000.0	0.20	130.0	1.00
3	Subbase	9.0	20000.0	0.40	130.0	0.75
4	Subgrade	32.0	7500.0	0.40	120.0	0.60

Layer 4 actually semi-infinite, but thickness controls depth to which displacements/stresses are computed.

CROSS SECTIONS FOR CALCULATION OF RESULTS

Number of horizontal sections = 1   Number of vertical sections = 1

Depth for horizontal sections (inches) = 0.00

Radial distance for vertical sections (inches) = 0.00

DIVISION OF FINITE ELEMENT MESH

Number of Elements in Vertical Direction

Layer	Thickness	Number of elements
1. HMA	7.0	20
2. CTB	8.0	15
3. Subbase	9.0	6
4. Subgrade	32.0	6

Number of Elements in Horizontal Direction

Range (a: contact radius)	Number of elements
1. R = 0 - a	9
2. R = a - 3a	9
3. R = 3a - 6a	9
4. R = 6a - 40a	72

FINAL DISPLACEMENTS, STRESSES AND STRAINS

Horizontal Section 1 at Depth of 0.00 mm

	Displacements		Stresses				Strains			
R. Dist.	R. Disp.	Vert. Disp.	R. Strs.	Tang. Strs.	Vert. Strs.	Shear Strs.	Rad. S.	Tang. Stn.	Vert. Stn.	Shear Stn.
0.0	0.0000E+00	-.9456E-02								
0.3	-.2012E-04	-.9452E-02	-125.43	-125.435	-120.000	0.610	-.7413E-04	-.7413E-04	-.7849E-04	0.3294E-05
0.8	-.6010E-04	-.9438E-02	-124.65	-124.894	-120.000	0.043	-.7314E-04	-.7380E-04	-.7884E-04	0.2332E-06
1.4	-.9987E-04	-.9411E-02	-124.90	-124.970	-120.000	-0.022	-.7339E-04	-.7359E-04	-.7916E-04	-.1198E-06
1.9	-.1398E-03	-.9370E-02	-125.41	-125.322	-120.000	-0.051	-.7382E-04	-.7359E-04	-.7954E-04	-.2752E-06
2.4	-.1801E-03	-.9314E-02	-126.18	-125.923	-120.000	-0.053	-.7440E-04	-.7371E-04	-.8014E-04	-.2848E-06
3.0	-.2206E-03	-.9239E-02	-127.27	-126.889	-120.000	-0.076	-.7489E-04	-.7388E-04	-.8156E-04	-.4129E-06
3.5	-.2616E-03	-.9141E-02	-129.02	-128.280	-120.000	0.225	-.7612E-04	-.7413E-04	-.8309E-04	0.1218E-05
4.1	-.3017E-03	-.9012E-02	-130.70	-131.596	-120.000	-0.193	-.7167E-04	-.7410E-04	-.9528E-04	-.1041E-05
4.6	-.3321E-03	-.8810E-02	-87.68	-99.421	-93.575	27.913	-.4026E-04	-.7196E-04	-.5618E-04	0.1507E-03
5.4	-.3484E-03	-.8500E-02	-26.35	-46.409	-14.561	10.280	-.1001E-04	-.6418E-04	0.2181E-04	0.5551E-04
6.5	-.3551E-03	-.8228E-02	-8.01	-27.357	0.000	-2.538	-.2267E-05	-.5451E-04	0.4019E-04	-.1370E-04

7.6	-.3623E-03	-.8071E-02	-15.56	-29.140	0.000	-0.122	-.1101E-04	-.4767E-04	0.3210E-04	-.6604E-06
8.7	-.3769E-03	-.7951E-02	-17.47	-27.675	0.000	-0.160	-.1584E-04	-.4339E-04	0.3237E-04	-.8655E-06
9.8	-.3955E-03	-.7851E-02	-18.65	-26.794	-0.077	-0.023	-.1850E-04	-.4048E-04	0.3166E-04	-.1257E-06
10.9	-.4163E-03	-.7761E-02	-19.04	-25.921	-0.245	0.051	-.1976E-04	-.3834E-04	0.3098E-04	0.2743E-06
11.9	-.4379E-03	-.7676E-02	-18.89	-25.062	-0.342	0.106	-.1999E-04	-.3666E-04	0.3008E-04	0.5745E-06
13.0	-.4593E-03	-.7593E-02	-18.35	-24.181	-0.373	0.146	-.1952E-04	-.3525E-04	0.2903E-04	0.7873E-06
14.1	-.4801E-03	-.7511E-02	-17.65	-23.343	-0.455	0.137	-.1865E-04	-.3401E-04	0.2779E-04	0.7380E-06
15.5	-.5040E-03	-.7408E-02	-16.42	-22.184	-0.429	0.195	-.1700E-04	-.3258E-04	0.2616E-04	0.1051E-05
17.1	-.5300E-03	-.7284E-02	-14.83	-20.813	-0.369	0.185	-.1482E-04	-.3099E-04	0.2421E-04	0.1001E-05
18.7	-.5523E-03	-.7157E-02	-13.26	-19.506	-0.348	0.186	-.1262E-04	-.2949E-04	0.2224E-04	0.1006E-05
20.4	-.5711E-03	-.7030E-02	-11.76	-18.251	-0.313	0.175	-.1052E-04	-.2805E-04	0.2038E-04	0.9470E-06
22.0	-.5867E-03	-.6901E-02	-10.36	-17.069	-0.285	0.163	-.8580E-05	-.2668E-04	0.1863E-04	0.8796E-06
23.6	-.5992E-03	-.6771E-02	-9.09	-15.958	-0.259	0.151	-.6822E-05	-.2537E-04	0.1701E-04	0.8158E-06
25.2	-.6091E-03	-.6641E-02	-7.93	-14.919	-0.233	0.139	-.5245E-05	-.2413E-04	0.1553E-04	0.7495E-06
26.9	-.6165E-03	-.6511E-02	-6.88	-13.949	-0.205	0.127	-.3849E-05	-.2294E-04	0.1417E-04	0.6853E-06
28.5	-.6217E-03	-.6381E-02	-5.94	-13.061	-0.210	0.112	-.2599E-05	-.2181E-04	0.1288E-04	0.6063E-06
30.5	-.6254E-03	-.6225E-02	-4.94	-12.058	-0.188	0.112	-.1317E-05	-.2052E-04	0.1153E-04	0.6031E-06
32.8	-.6269E-03	-.6043E-02	-3.89	-10.975	-0.140	0.093	-.8123E-08	-.1913E-04	0.1013E-04	0.5000E-06
35.1	-.6256E-03	-.5863E-02	-3.00	-10.011	-0.126	0.082	0.1089E-05	-.1783E-04	0.8859E-05	0.4422E-06
37.4	-.6221E-03	-.5686E-02	-2.23	-9.137	-0.109	0.072	0.2009E-05	-.1664E-04	0.7741E-05	0.3887E-06
39.7	-.6165E-03	-.5511E-02	-1.56	-8.343	-0.095	0.066	0.2794E-05	-.1553E-04	0.6740E-05	0.3556E-06
42.0	-.6093E-03	-.5339E-02	-0.96	-7.617	-0.080	0.059	0.3466E-05	-.1450E-04	0.5844E-05	0.3164E-06
44.3	-.6007E-03	-.5171E-02	-0.44	-6.956	-0.068	0.052	0.4031E-05	-.1355E-04	0.5044E-05	0.2798E-06
46.6	-.5908E-03	-.5006E-02	0.00	-6.356	-0.060	0.046	0.4499E-05	-.1267E-04	0.4327E-05	0.2472E-06
48.9	-.5800E-03	-.4845E-02	0.40	-5.804	-0.048	0.043	0.4891E-05	-.1185E-04	0.3689E-05	0.2306E-06
51.2	-.5683E-03	-.4687E-02	0.73	-5.304	-0.039	0.034	0.5201E-05	-.1109E-04	0.3124E-05	0.1853E-06
53.5	-.5560E-03	-.4534E-02	1.01	-4.850	-0.035	0.033	0.5449E-05	-.1039E-04	0.2614E-05	0.1787E-06
55.8	-.5432E-03	-.4385E-02	1.27	-4.427	-0.025	0.031	0.5662E-05	-.9727E-05	0.2157E-05	0.1670E-06
58.2	-.5300E-03	-.4240E-02	1.48	-4.045	-0.021	0.023	0.5811E-05	-.9113E-05	0.1752E-05	0.1253E-06
60.5	-.5165E-03	-.4098E-02	1.66	-3.696	-0.016	0.024	0.5918E-05	-.8542E-05	0.1393E-05	0.1306E-06
62.8	-.5027E-03	-.3962E-02	1.81	-3.373	-0.010	0.019	0.5994E-05	-.8009E-05	0.1072E-05	0.1051E-06
65.1	-.4888E-03	-.3829E-02	1.94	-3.079	-0.006	0.018	0.6038E-05	-.7511E-05	0.7854E-06	0.9848E-07
67.4	-.4749E-03	-.3700E-02	2.04	-2.810	-0.004	0.015	0.6057E-05	-.7047E-05	0.5287E-06	0.8214E-07
69.7	-.4609E-03	-.3575E-02	2.13	-2.561	-0.001	0.015	0.6056E-05	-.6613E-05	0.2986E-06	0.8003E-07
72.0	-.4470E-03	-.3454E-02	2.21	-2.330	0.000	0.013	0.6042E-05	-.6208E-05	0.9399E-07	0.7113E-07
74.3	-.4331E-03	-.3338E-02	2.26	-2.120	0.000	0.010	0.6002E-05	-.5828E-05	-.8556E-07	0.5374E-07
76.6	-.4193E-03	-.3225E-02	2.30	-1.929	0.000	0.010	0.5942E-05	-.5473E-05	-.2434E-06	0.5215E-07
78.9	-.4057E-03	-.3116E-02	2.33	-1.752	0.000	0.008	0.5874E-05	-.5140E-05	-.3839E-06	0.4290E-07
81.2	-.3922E-03	-.3011E-02	2.35	-1.587	0.000	0.009	0.5807E-05	-.4828E-05	-.5129E-06	0.4916E-07
83.5	-.3789E-03	-.2909E-02	2.37	-1.434	0.000	0.006	0.5730E-05	-.4535E-05	-.6260E-06	0.3049E-07
85.8	-.3658E-03	-.2812E-02	2.37	-1.296	0.000	0.006	0.5636E-05	-.4261E-05	-.7226E-06	0.3155E-07
88.2	-.3529E-03	-.2718E-02	2.37	-1.167	0.000	0.005	0.5541E-05	-.4003E-05	-.8073E-06	0.2505E-07
90.5	-.3402E-03	-.2627E-02	2.36	-1.050	0.000	0.004	0.5437E-05	-.3761E-05	-.8830E-06	0.2008E-07
92.8	-.3278E-03	-.2540E-02	2.35	-0.939	0.000	0.004	0.5337E-05	-.3533E-05	-.9490E-06	0.2427E-07
95.1	-.3156E-03	-.2456E-02	2.33	-0.837	0.000	0.003	0.5233E-05	-.3319E-05	-.1007E-05	0.1415E-07
97.4	-.3036E-03	-.2375E-02	2.31	-0.744	0.000	0.003	0.5124E-05	-.3118E-05	-.1057E-05	0.1472E-07
99.7	-.2919E-03	-.2298E-02	2.28	-0.658	0.000	0.002	0.5013E-05	-.2928E-05	-.1097E-05	0.1140E-07
102.0	-.2805E-03	-.2224E-02	2.25	-0.579	0.000	0.001	0.4897E-05	-.2750E-05	-.1130E-05	0.7757E-08
104.3	-.2693E-03	-.2152E-02	2.22	-0.507	0.000	0.001	0.4777E-05	-.2582E-05	-.1155E-05	0.4175E-08
106.6	-.2585E-03	-.2084E-02	2.18	-0.443	0.000	0.000	0.4649E-05	-.2424E-05	-.1173E-05	-.2101E-08
108.9	-.2479E-03	-.2019E-02	2.14	-0.383	0.000	0.001	0.4528E-05	-.2276E-05	-.1188E-05	0.6867E-08

111.2	-.2376E-03	-.1956E-02	2.10	-0.325	0.000	0.000	0.4412E-05	-.2136E-05	-.1199E-05	-.1299E-08
113.5	-.2275E-03	-.1896E-02	2.06	-0.275	0.000	0.000	0.4292E-05	-.2004E-05	-.1206E-05	-.6021E-09
115.8	-.2178E-03	-.1839E-02	2.01	-0.229	0.000	-0.001	0.4171E-05	-.1880E-05	-.1209E-05	-.5305E-08
118.1	-.2083E-03	-.1785E-02	1.97	-0.185	0.000	0.000	0.4054E-05	-.1763E-05	-.1208E-05	0.2293E-09
120.5	-.1990E-03	-.1732E-02	1.92	-0.146	0.000	-0.002	0.3935E-05	-.1652E-05	-.1205E-05	-.9812E-08
122.8	-.1901E-03	-.1683E-02	1.88	-0.110	0.000	0.000	0.3820E-05	-.1549E-05	-.1199E-05	-.9891E-09
125.1	-.1814E-03	-.1635E-02	1.84	-0.074	0.000	-0.001	0.3714E-05	-.1450E-05	-.1193E-05	-.3613E-08
127.4	-.1730E-03	-.1590E-02	1.79	-0.044	0.000	-0.002	0.3607E-05	-.1358E-05	-.1186E-05	-.8176E-08
129.7	-.1648E-03	-.1547E-02	1.75	-0.016	0.000	-0.001	0.3500E-05	-.1271E-05	-.1177E-05	-.5505E-08
132.0	-.1568E-03	-.1506E-02	1.71	0.011	0.000	-0.001	0.3399E-05	-.1188E-05	-.1167E-05	-.6251E-08
134.3	-.1491E-03	-.1467E-02	1.67	0.037	0.000	-0.001	0.3304E-05	-.1110E-05	-.1158E-05	-.3992E-08
136.6	-.1416E-03	-.1430E-02	1.63	0.059	0.000	-0.002	0.3209E-05	-.1036E-05	-.1147E-05	-.9192E-08
138.9	-.1343E-03	-.1395E-02	1.59	0.081	0.000	0.000	0.3120E-05	-.9665E-06	-.1137E-05	-.2696E-08
141.2	-.1272E-03	-.1362E-02	1.56	0.102	0.000	-0.001	0.3035E-05	-.9004E-06	-.1127E-05	-.6957E-08
143.5	-.1203E-03	-.1330E-02	1.52	0.120	0.000	-0.001	0.2949E-05	-.8379E-06	-.1115E-05	-.7426E-08
145.8	-.1135E-03	-.1301E-02	1.49	0.138	0.000	0.000	0.2871E-05	-.7786E-06	-.1105E-05	-.2171E-08
148.1	-.1070E-03	-.1273E-02	1.46	0.156	0.000	-0.001	0.2797E-05	-.7223E-06	-.1095E-05	-.7745E-08
150.4	-.1006E-03	-.1247E-02	1.43	0.171	0.000	-0.001	0.2724E-05	-.6689E-06	-.1085E-05	-.3921E-08
152.8	-.9443E-04	-.1222E-02	1.40	0.186	0.000	-0.001	0.2655E-05	-.6182E-06	-.1076E-05	-.5674E-08
155.1	-.8838E-04	-.1199E-02	1.37	0.201	0.000	-0.001	0.2589E-05	-.5699E-06	-.1066E-05	-.4011E-08
157.4	-.8247E-04	-.1177E-02	1.34	0.214	0.000	-0.001	0.2527E-05	-.5241E-06	-.1057E-05	-.4968E-08
159.7	-.7671E-04	-.1157E-02	1.32	0.227	0.000	-0.001	0.2467E-05	-.4804E-06	-.1049E-05	-.4627E-08
162.0	-.7108E-04	-.1139E-02	1.30	0.240	0.000	0.000	0.2414E-05	-.4388E-06	-.1043E-05	-.1680E-08
164.3	-.6557E-04	-.1122E-02	1.28	0.253	0.000	-0.001	0.2364E-05	-.3991E-06	-.1037E-05	-.3677E-08
166.6	-.6017E-04	-.1106E-02	1.25	0.264	0.000	-0.001	0.2314E-05	-.3612E-06	-.1031E-05	-.4155E-08
168.9	-.5489E-04	-.1091E-02	1.24	0.275	0.000	0.000	0.2266E-05	-.3250E-06	-.1025E-05	-.2474E-08
171.2	-.4971E-04	-.1078E-02	1.22	0.287	0.000	0.000	0.2224E-05	-.2903E-06	-.1021E-05	-.2508E-08
173.5	-.4462E-04	-.1066E-02	1.20	0.298	0.000	0.000	0.2185E-05	-.2572E-06	-.1018E-05	-.1015E-08
175.8	-.3962E-04	-.1056E-02	1.19	0.309	0.000	0.000	0.2150E-05	-.2253E-06	-.1016E-05	-.1509E-08
178.1	-.3470E-04	-.1046E-02	1.17	0.319	0.000	0.000	0.2115E-05	-.1948E-06	-.1014E-05	-.1958E-08
180.4	-.2986E-04	-.1038E-02	1.16	0.329	0.000	0.000	0.2082E-05	-.1655E-06	-.1012E-05	-.1485E-08
182.8	-.2509E-04	-.1031E-02	1.15	0.339	0.000	0.000	0.2052E-05	-.1373E-06	-.1011E-05	-.2056E-09
185.1	-.2039E-04	-.1026E-02	1.14	0.349	0.000	0.000	0.2022E-05	-.1102E-06	-.1010E-05	-.1786E-08
187.4	-.1576E-04	-.1021E-02	1.13	0.359	0.000	0.000	0.1995E-05	-.8409E-07	-.1009E-05	0.6540E-09
189.7	-.1118E-04	-.1018E-02	1.12	0.368	0.000	0.000	0.1969E-05	-.5896E-07	-.1009E-05	-.2210E-08
192.0	-.6669E-05	-.1015E-02	1.11	0.376	0.000	0.000	0.1944E-05	-.3474E-07	-.1008E-05	0.9003E-09
194.3	-.2213E-05	-.1014E-02	1.10	0.384	0.000	-0.001	0.1919E-05	-.1139E-07	-.1009E-05	-.4344E-08

Vertical Section 1 at Radial Distance of 0.00 mm

	Displacements		Stresses				Strains			
Depth	R. disp.	Vert. disp.	R. strs.	Tang. strs.	Vert. strs.	Shear strs.	R. stns.	Tang. stns.	Vert. stns.	Shear stn.
0.0	0.0000E+00	-.9456E-02	-121.51	-121.51	-120.00	0.00	-.7413E-04	-.7413E-04	-.6918E-04	0.0000E+00
-0.2	0.0000E+00	-.9443E-02	-115.51	-115.51	-120.01	0.00	-.6613E-04	-.6613E-04	-.7831E-04	0.0000E+00
-0.5	0.0000E+00	-.9412E-02	-103.73	-103.73	-120.19	0.00	-.5066E-04	-.5066E-04	-.9517E-04	0.0000E+00
-0.9	0.0000E+00	-.9376E-02	-92.43	-92.43	-119.76	0.00	-.3624E-04	-.3624E-04	-.1101E-03	0.0000E+00
-1.2	0.0000E+00	-.9336E-02	-81.86	-81.86	-118.88	0.00	-.2307E-04	-.2307E-04	-.1232E-03	0.0000E+00
-1.6	0.0000E+00	-.9291E-02	-72.18	-72.18	-117.43	0.00	-.1146E-04	-.1146E-04	-.1338E-03	0.0000E+00
-1.9	0.0000E+00	-.9242E-02	-63.48	-63.48	-115.32	0.00	-.1594E-05	-.1594E-05	-.1418E-03	0.0000E+00

-2.3	0.0000E+00	-.9192E-02	-55.84	-55.84	-112.58	0.00	0.6463E-05	0.6463E-05	-.1470E-03	0.0000E+00
-2.6	0.0000E+00	-.9140E-02	-49.23	-49.23	-109.27	0.00	0.1277E-04	0.1277E-04	-.1496E-03	0.0000E+00
-3.0	0.0000E+00	-.9087E-02	-43.61	-43.61	-105.47	0.00	0.1746E-04	0.1746E-04	-.1499E-03	0.0000E+00
-3.3	0.0000E+00	-.9035E-02	-38.90	-38.90	-101.32	0.00	0.2072E-04	0.2072E-04	-.1482E-03	0.0000E+00
-3.7	0.0000E+00	-.8984E-02	-35.01	-35.01	-96.93	0.00	0.2274E-04	0.2274E-04	-.1449E-03	0.0000E+00
-4.0	0.0000E+00	-.8934E-02	-31.85	-31.85	-92.41	0.00	0.2371E-04	0.2371E-04	-.1403E-03	0.0000E+00
-4.4	0.0000E+00	-.8886E-02	-29.36	-29.36	-87.85	0.00	0.2380E-04	0.2380E-04	-.1346E-03	0.0000E+00
-4.7	0.0000E+00	-.8840E-02	-27.46	-27.46	-83.31	0.00	0.2313E-04	0.2313E-04	-.1282E-03	0.0000E+00
-5.1	0.0000E+00	-.8796E-02	-26.10	-26.10	-78.82	0.00	0.2179E-04	0.2179E-04	-.1211E-03	0.0000E+00
-5.4	0.0000E+00	-.8755E-02	-25.25	-25.25	-74.41	0.00	0.1985E-04	0.1985E-04	-.1135E-03	0.0000E+00
-5.8	0.0000E+00	-.8717E-02	-24.89	-24.89	-70.07	0.00	0.1732E-04	0.1732E-04	-.1054E-03	0.0000E+00
-6.1	0.0000E+00	-.8682E-02	-25.02	-25.02	-65.80	0.00	0.1420E-04	0.1420E-04	-.9662E-04	0.0000E+00
-6.5	0.0000E+00	-.8649E-02	-25.64	-25.64	-61.52	0.00	0.1043E-04	0.1043E-04	-.8720E-04	0.0000E+00
-6.8	0.0000E+00	-.8621E-02	-26.80	-26.80	-57.15	0.00	0.5909E-05	0.5909E-05	-.7684E-04	0.0000E+00
-7.0	0.0000E+00	-.8607E-02	-27.59	-27.59	-54.99	0.00	0.3435E-05	0.3435E-05	-.7124E-04	0.0000E+00
-7.0	0.0000E+00	-.8607E-02	-9.93	-9.93	-54.99	0.00	0.3435E-05	0.3435E-05	-.5062E-04	0.0000E+00
-7.3	0.0000E+00	-.8594E-02	-7.77	-7.77	-51.77	0.00	0.4511E-05	0.4511E-05	-.4828E-04	0.0000E+00
-7.8	0.0000E+00	-.8570E-02	-3.71	-3.71	-45.68	0.00	0.6566E-05	0.6566E-05	-.4379E-04	0.0000E+00
-8.3	0.0000E+00	-.8548E-02	0.12	0.12	-40.01	0.00	0.8518E-05	0.8518E-05	-.3963E-04	0.0000E+00
-8.9	0.0000E+00	-.8528E-02	3.84	3.84	-34.79	0.00	0.1048E-04	0.1048E-04	-.3588E-04	0.0000E+00
-9.4	0.0000E+00	-.8509E-02	7.53	7.53	-30.01	0.00	0.1250E-04	0.1250E-04	-.3255E-04	0.0000E+00
-9.9	0.0000E+00	-.8493E-02	11.24	11.24	-25.63	0.00	0.1461E-04	0.1461E-04	-.2963E-04	0.0000E+00
-10.5	0.0000E+00	-.8478E-02	15.02	15.02	-21.62	0.00	0.1686E-04	0.1686E-04	-.2711E-04	0.0000E+00
-11.0	0.0000E+00	-.8464E-02	18.92	18.92	-17.98	0.00	0.1927E-04	0.1927E-04	-.2500E-04	0.0000E+00
-11.5	0.0000E+00	-.8451E-02	22.98	22.98	-14.70	0.00	0.2189E-04	0.2189E-04	-.2332E-04	0.0000E+00
-12.1	0.0000E+00	-.8439E-02	27.26	27.26	-11.76	0.00	0.2476E-04	0.2476E-04	-.2208E-04	0.0000E+00
-12.6	0.0000E+00	-.8427E-02	31.82	31.82	-9.21	0.00	0.2792E-04	0.2792E-04	-.2132E-04	0.0000E+00
-13.1	0.0000E+00	-.8416E-02	36.72	36.72	-7.03	0.00	0.3142E-04	0.3142E-04	-.2108E-04	0.0000E+00
-13.7	0.0000E+00	-.8404E-02	42.03	42.03	-5.28	0.00	0.3534E-04	0.3534E-04	-.2142E-04	0.0000E+00
-14.2	0.0000E+00	-.8393E-02	47.84	47.84	-3.98	0.00	0.3976E-04	0.3976E-04	-.2243E-04	0.0000E+00
-14.7	0.0000E+00	-.8380E-02	54.37	54.37	-3.35	0.00	0.4488E-04	0.4488E-04	-.2438E-04	0.0000E+00
-15.0	0.0000E+00	-.8374E-02	57.96	57.96	-3.19	0.00	0.4765E-04	0.4765E-04	-.2580E-04	0.0000E+00
-15.0	0.0000E+00	-.8374E-02	-0.63	-0.63	-3.19	0.00	0.4765E-04	0.4765E-04	-.1099E-03	0.0000E+00
-15.8	0.0000E+00	-.8296E-02	-0.64	-0.64	-3.10	0.00	0.4585E-04	0.4585E-04	-.1038E-03	0.0000E+00
-17.3	0.0000E+00	-.8147E-02	-0.66	-0.66	-2.97	0.00	0.4310E-04	0.4310E-04	-.9460E-04	0.0000E+00
-18.8	0.0000E+00	-.8010E-02	-0.66	-0.66	-2.89	0.00	0.4182E-04	0.4182E-04	-.8845E-04	0.0000E+00
-20.3	0.0000E+00	-.7880E-02	-0.64	-0.64	-2.85	0.00	0.4173E-04	0.4173E-04	-.8472E-04	0.0000E+00
-21.8	0.0000E+00	-.7754E-02	-0.61	-0.61	-2.84	0.00	0.4283E-04	0.4283E-04	-.8330E-04	0.0000E+00
-23.3	0.0000E+00	-.7628E-02	-0.55	-0.55	-2.86	0.00	0.4519E-04	0.4519E-04	-.8427E-04	0.0000E+00
-24.0	0.0000E+00	-.7565E-02	-0.52	-0.52	-2.88	0.00	0.4670E-04	0.4670E-04	-.8569E-04	0.0000E+00
-24.0	0.0000E+00	-.7565E-02	-1.21	-1.21	-2.88	0.00	0.4670E-04	0.4670E-04	-.1246E-03	0.0000E+00
-26.7	0.0000E+00	-.7263E-02	-1.31	-1.31	-2.97	0.00	0.4280E-04	0.4280E-04	-.1131E-03	0.0000E+00
-32.0	0.0000E+00	-.6707E-02	-1.52	-1.52	-3.20	0.00	0.3623E-04	0.3623E-04	-.9540E-04	0.0000E+00
-37.3	0.0000E+00	-.6232E-02	-1.73	-1.73	-3.47	0.00	0.3161E-04	0.3161E-04	-.8280E-04	0.0000E+00
-42.7	0.0000E+00	-.5816E-02	-1.94	-1.94	-3.76	0.00	0.2813E-04	0.2813E-04	-.7320E-04	0.0000E+00
-48.0	0.0000E+00	-.5446E-02	-2.16	-2.16	-4.07	0.00	0.2528E-04	0.2528E-04	-.6569E-04	0.0000E+00
-53.3	0.0000E+00	-.5115E-02	-2.38	-2.38	-4.38	0.00	0.2226E-04	0.2226E-04	-.5818E-04	0.0000E+00
-56.0	0.0000E+00	-.4960E-02	-2.49	-2.49	-4.54	0.00	0.2057E-04	0.2057E-04	-.5442E-04	0.0000E+00

TECHNICAL INFORMATION

Total number of elements = 4653   Total number of nodes = 4800
Number of equations = 9504
Bandwidth = 202
Number of iterations to reach convergence = 1
Elastic modulus of spring along bottom boundary = 7500.0 psi Poisson's ratio of spring = 0.40
Relative error of convergence = 0.00000E+00

EQUIVALENT RESILIENT MODULUS FOR EACH LAYER

Layer	Name	Modulus (Psi.)
1	HMA	500000.
2	CTB	1000000.
3	Subbase	20000.
4	Subgrade	7500.

FATIGUE LIFE & RUT DEPTH DATA

Average annual temperature = 0.00 (Fahrenheit)
Kinematic viscosity = 0.00 centistoke
Allowable rut depth = 0.00 inches
Allowable fatigue damage = 0. %

SUMMARY

Maximum tensile (radial) strain in the asphalt layer = 3.435E-06

Compressive (vertical) strain at the top of base = 5.062E-05

Compressive (vertical) strain at top of roadbed = 1.246E-04

Allowable ESAL applications based on fatigue life = 0.000E+00

Allowable ESAL applications based on rut depth = 0.000E+00

```
TITLE

 FILENAMES

 Data file used for this run: C:\Pavements\MFPDS\TH_LEAN_2nd.med
 Name of this output file   : TH_LEAN_2nd.mpo
 Unit                       : English
 Route                      :
 Region                     :
 Control Section            :
 Lane                       :
 Job No.                    :
 Trial No.                  :
 Description                :


 INITIAL DATA

 Number of layers = 4
 Wheel load =    9000.0 lb.
 Tire pressure =  120.00 psi.
 Radius of loaded area (a) =      4.886 inches




LAYER TYPE

 1  asphalt;  2  granular;  3  cohese
 Layer number (from top)    Type (1,2,or3)
         1                        1
         2                        1
         3                        1
         4                        1


MATERIAL PROPERTIES
                          Asphalt Material Properties

   Layer  Name of Layer  Thickness   Modulus  Poisson's   Density       Ko
                          (inches)    (psi)     ratio   (lb/cu.ft)
      1  HMA               7.0     500000.0    0.35      150.0        1.50
      2  LeanMix           8.0    2000000.0    0.15      130.0        1.00
      3  Subbase           9.0      20000.0    0.40      130.0        0.75
      4  Subgrade         32.0       7500.0    0.40      120.0        0.60

 Layer 4 actually semi-infinite, but thickness controls depth to which displacements/stresses are computed.


 CROSS SECTIONS FOR CALCULATION OF RESULTS
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Number of horizontal sections = 1   Number of vertical sections = 1

Depth for horizontal sections (inches) = 0.00

Radial distance for vertical sections (inches) = 0.00

DIVISION OF FINITE ELEMENT MESH

Number of Elements in Vertical Direction

Layer	Thickness	Number of elements
1. HMA	7.0	20
2. LeanMix	8.0	15
3. Subbase	9.0	6
4. Subgrade	32.0	6

Number of Elements in Horizontal Direction

Range (a: contact radius)	Number of elements
1. R = 0 - a	9
2. R = a - 3a	9
3. R = 3a - 6a	9
4. R = 6a - 40a	72

FINAL DISPLACEMENTS, STRESSES AND STRAINS

Horizontal Section 1 at Depth of 0.00 mm

	Displacements		Stresses				Strains			
R. Dist.	R. Disp.	Vert. Disp.	R. Strs.	Tang. Strs.	Vert. Strs.	Shear Strs.	Rad. S.	Tang. Stn.	Vert. Stn.	Shear Stn.
0.0	0.0000E+00	-.8010E-02								
0.3	-.1638E-04	-.8006E-02	-114.46	-114.458	-120.000	0.528	-.6035E-04	-.6035E-04	-.9246E-04	0.2850E-05
0.8	-.4896E-04	-.7993E-02	-113.89	-114.064	-120.000	-0.010	-.5966E-04	-.6012E-04	-.9266E-04	-.5148E-07
1.4	-.8150E-04	-.7969E-02	-114.36	-114.291	-120.000	-0.099	-.6023E-04	-.6005E-04	-.9275E-04	-.5333E-06
1.9	-.1144E-03	-.7933E-02	-115.16	-114.840	-120.000	-0.153	-.6110E-04	-.6023E-04	-.9283E-04	-.8257E-06
2.4	-.1479E-03	-.7882E-02	-116.31	-115.684	-120.000	-0.178	-.6225E-04	-.6055E-04	-.9304E-04	-.9596E-06
3.0	-.1820E-03	-.7814E-02	-117.85	-116.938	-120.000	-0.223	-.6341E-04	-.6096E-04	-.9400E-04	-.1202E-05
3.5	-.2170E-03	-.7723E-02	-120.10	-118.657	-120.000	0.063	-.6539E-04	-.6149E-04	-.9502E-04	0.3421E-06
4.1	-.2515E-03	-.7602E-02	-122.33	-122.333	-120.000	-0.368	-.6176E-04	-.6177E-04	-.1066E-03	-.1986E-05
4.6	-.2767E-03	-.7409E-02	-79.81	-90.482	-93.037	27.773	-.3117E-04	-.5997E-04	-.6687E-04	0.1500E-03
5.4	-.2865E-03	-.7115E-02	-19.56	-38.190	-14.156	10.081	-.2478E-05	-.5278E-04	0.1211E-04	0.5444E-04
6.5	-.2859E-03	-.6866E-02	-2.39	-19.974	0.000	-2.730	0.3575E-05	-.4389E-04	0.3171E-04	-.1474E-04

7.6	-.2877E-03	-.6733E-02	-11.04	-22.560	0.000	-0.300	-.6756E-05	-.3785E-04	0.2483E-04	-.1620E-05
8.7	-.2984E-03	-.6638E-02	-13.91	-21.841	0.000	-0.315	-.1294E-04	-.3435E-04	0.2618E-04	-.1701E-05
9.8	-.3144E-03	-.6562E-02	-15.89	-21.625	0.000	-0.152	-.1669E-04	-.3218E-04	0.2641E-04	-.8216E-06
10.9	-.3337E-03	-.6497E-02	-16.91	-21.329	-0.127	-0.054	-.1880E-04	-.3073E-04	0.2651E-04	-.2905E-06
11.9	-.3546E-03	-.6436E-02	-17.24	-20.963	-0.247	0.023	-.1963E-04	-.2969E-04	0.2625E-04	0.1229E-06
13.0	-.3759E-03	-.6376E-02	-17.07	-20.501	-0.295	0.080	-.1958E-04	-.2885E-04	0.2571E-04	0.4294E-06
14.1	-.3968E-03	-.6317E-02	-16.64	-20.017	-0.388	0.083	-.1900E-04	-.2811E-04	0.2489E-04	0.4486E-06
15.5	-.4214E-03	-.6241E-02	-15.61	-19.208	-0.362	0.150	-.1752E-04	-.2723E-04	0.2365E-04	0.8114E-06
17.1	-.4483E-03	-.6148E-02	-14.24	-18.202	-0.318	0.156	-.1552E-04	-.2621E-04	0.2207E-04	0.8428E-06
18.7	-.4718E-03	-.6053E-02	-12.83	-17.189	-0.297	0.161	-.1341E-04	-.2519E-04	0.2042E-04	0.8701E-06
20.4	-.4920E-03	-.5955E-02	-11.45	-16.186	-0.268	0.154	-.1138E-04	-.2417E-04	0.1881E-04	0.8298E-06
22.0	-.5091E-03	-.5855E-02	-10.17	-15.222	-0.245	0.143	-.9514E-05	-.2315E-04	0.1728E-04	0.7745E-06
23.6	-.5232E-03	-.5754E-02	-9.00	-14.303	-0.223	0.134	-.7824E-05	-.2215E-04	0.1586E-04	0.7209E-06
25.2	-.5347E-03	-.5652E-02	-7.93	-13.436	-0.201	0.123	-.6314E-05	-.2118E-04	0.1455E-04	0.6618E-06
26.9	-.5439E-03	-.5549E-02	-6.97	-12.621	-0.178	0.112	-.4979E-05	-.2024E-04	0.1336E-04	0.6074E-06
28.5	-.5510E-03	-.5445E-02	-6.12	-11.874	-0.190	0.097	-.3792E-05	-.1933E-04	0.1222E-04	0.5213E-06
30.5	-.5570E-03	-.5320E-02	-5.18	-11.011	-0.165	0.098	-.2533E-05	-.1828E-04	0.1100E-04	0.5301E-06
32.8	-.5614E-03	-.5173E-02	-4.21	-10.081	-0.125	0.084	-.1272E-05	-.1713E-04	0.9753E-05	0.4520E-06
35.1	-.5631E-03	-.5027E-02	-3.37	-9.246	-0.113	0.074	-.1974E-06	-.1605E-04	0.8608E-05	0.4015E-06
37.4	-.5625E-03	-.4883E-02	-2.65	-8.484	-0.100	0.066	0.7130E-06	-.1504E-04	0.7592E-05	0.3552E-06
39.7	-.5600E-03	-.4739E-02	-2.01	-7.787	-0.089	0.060	0.1498E-05	-.1411E-04	0.6678E-05	0.3259E-06
42.0	-.5557E-03	-.4598E-02	-1.44	-7.145	-0.077	0.054	0.2180E-05	-.1323E-04	0.5854E-05	0.2931E-06
44.3	-.5500E-03	-.4458E-02	-0.94	-6.557	-0.067	0.048	0.2763E-05	-.1241E-04	0.5113E-05	0.2615E-06
46.6	-.5431E-03	-.4321E-02	-0.50	-6.019	-0.059	0.043	0.3259E-05	-.1165E-04	0.4444E-05	0.2325E-06
48.9	-.5351E-03	-.4186E-02	-0.11	-5.522	-0.048	0.041	0.3684E-05	-.1094E-04	0.3845E-05	0.2191E-06
51.2	-.5262E-03	-.4054E-02	0.23	-5.069	-0.040	0.033	0.4032E-05	-.1027E-04	0.3309E-05	0.1785E-06
53.5	-.5165E-03	-.3925E-02	0.52	-4.655	-0.037	0.032	0.4321E-05	-.9647E-05	0.2822E-05	0.1719E-06
55.8	-.5063E-03	-.3798E-02	0.78	-4.268	-0.028	0.030	0.4573E-05	-.9065E-05	0.2384E-05	0.1605E-06
58.2	-.4955E-03	-.3675E-02	1.00	-3.917	-0.023	0.023	0.4764E-05	-.8520E-05	0.1994E-05	0.1240E-06
60.5	-.4843E-03	-.3555E-02	1.19	-3.595	-0.020	0.024	0.4913E-05	-.8010E-05	0.1643E-05	0.1280E-06
62.8	-.4729E-03	-.3437E-02	1.36	-3.297	-0.014	0.019	0.5032E-05	-.7533E-05	0.1329E-05	0.1051E-06
65.1	-.4612E-03	-.3323E-02	1.50	-3.023	-0.011	0.018	0.5118E-05	-.7086E-05	0.1047E-05	0.9827E-07
67.4	-.4493E-03	-.3212E-02	1.62	-2.771	-0.008	0.015	0.5177E-05	-.6667E-05	0.7920E-06	0.8324E-07
69.7	-.4373E-03	-.3104E-02	1.72	-2.538	-0.006	0.015	0.5216E-05	-.6274E-05	0.5625E-06	0.8098E-07
72.0	-.4252E-03	-.3000E-02	1.81	-2.321	-0.002	0.013	0.5242E-05	-.5906E-05	0.3557E-06	0.7279E-07
74.3	-.4131E-03	-.2898E-02	1.88	-2.122	0.000	0.011	0.5243E-05	-.5560E-05	0.1718E-06	0.5723E-07
76.6	-.4011E-03	-.2799E-02	1.93	-1.940	0.000	0.010	0.5226E-05	-.5235E-05	0.6462E-08	0.5598E-07
78.9	-.3890E-03	-.2704E-02	1.98	-1.770	0.000	0.009	0.5201E-05	-.4929E-05	-.1423E-06	0.4844E-07
81.2	-.3771E-03	-.2612E-02	2.03	-1.609	0.000	0.010	0.5177E-05	-.4642E-05	-.2791E-06	0.5258E-07
83.5	-.3651E-03	-.2522E-02	2.06	-1.460	0.000	0.007	0.5141E-05	-.4371E-05	-.4037E-06	0.3706E-07
85.8	-.3533E-03	-.2436E-02	2.09	-1.325	0.000	0.007	0.5092E-05	-.4116E-05	-.5129E-06	0.3699E-07
88.2	-.3417E-03	-.2352E-02	2.10	-1.198	0.000	0.006	0.5038E-05	-.3876E-05	-.6118E-06	0.3176E-07
90.5	-.3301E-03	-.2272E-02	2.11	-1.081	0.000	0.005	0.4977E-05	-.3649E-05	-.7013E-06	0.2646E-07
92.8	-.3187E-03	-.2194E-02	2.12	-0.970	0.000	0.006	0.4916E-05	-.3435E-05	-.7805E-06	0.2991E-07
95.1	-.3074E-03	-.2119E-02	2.13	-0.867	0.000	0.004	0.4850E-05	-.3234E-05	-.8520E-06	0.2037E-07
97.4	-.2963E-03	-.2047E-02	2.12	-0.774	0.000	0.004	0.4776E-05	-.3043E-05	-.9148E-06	0.2016E-07
99.7	-.2854E-03	-.1977E-02	2.11	-0.685	0.000	0.003	0.4697E-05	-.2863E-05	-.9664E-06	0.1630E-07
102.0	-.2747E-03	-.1910E-02	2.10	-0.606	0.000	0.002	0.4611E-05	-.2693E-05	-.1012E-05	0.1242E-07
104.3	-.2641E-03	-.1846E-02	2.08	-0.532	0.000	0.002	0.4520E-05	-.2532E-05	-.1049E-05	0.9102E-08
106.6	-.2538E-03	-.1784E-02	2.05	-0.466	0.000	0.001	0.4420E-05	-.2381E-05	-.1078E-05	0.3452E-08
108.9	-.2437E-03	-.1725E-02	2.03	-0.404	0.000	0.002	0.4324E-05	-.2238E-05	-.1103E-05	0.1080E-07

111.2	-.2338E-03	-.1669E-02	2.00	-0.344	0.000	0.001	0.4232E-05	-.2102E-05	-.1124E-05	0.3507E-08
113.5	-.2242E-03	-.1614E-02	1.97	-0.291	0.000	0.001	0.4134E-05	-.1975E-05	-.1140E-05	0.2971E-08
115.8	-.2148E-03	-.1562E-02	1.94	-0.243	0.000	0.000	0.4033E-05	-.1854E-05	-.1152E-05	-.1063E-08
118.1	-.2056E-03	-.1513E-02	1.90	-0.197	0.000	0.001	0.3933E-05	-.1740E-05	-.1159E-05	0.2724E-08
120.5	-.1966E-03	-.1465E-02	1.87	-0.157	0.000	-0.001	0.3832E-05	-.1632E-05	-.1163E-05	-.5882E-08
122.8	-.1879E-03	-.1420E-02	1.83	-0.119	0.000	0.000	0.3732E-05	-.1531E-05	-.1164E-05	0.1108E-08
125.1	-.1794E-03	-.1376E-02	1.80	-0.082	0.000	0.000	0.3639E-05	-.1434E-05	-.1164E-05	-.8812E-09
127.4	-.1711E-03	-.1335E-02	1.76	-0.049	0.000	-0.001	0.3543E-05	-.1343E-05	-.1162E-05	-.5686E-08
129.7	-.1630E-03	-.1296E-02	1.72	-0.020	0.000	-0.001	0.3446E-05	-.1257E-05	-.1158E-05	-.3468E-08
132.0	-.1552E-03	-.1258E-02	1.69	0.008	0.000	-0.001	0.3354E-05	-.1176E-05	-.1151E-05	-.4923E-08
134.3	-.1476E-03	-.1222E-02	1.65	0.034	0.000	-0.001	0.3264E-05	-.1099E-05	-.1144E-05	-.3086E-08
136.6	-.1401E-03	-.1189E-02	1.61	0.057	0.000	-0.001	0.3174E-05	-.1026E-05	-.1136E-05	-.7587E-08
138.9	-.1329E-03	-.1157E-02	1.58	0.080	0.000	0.000	0.3088E-05	-.9569E-06	-.1127E-05	-.2568E-08
141.2	-.1259E-03	-.1126E-02	1.54	0.101	0.000	-0.001	0.3006E-05	-.8914E-06	-.1118E-05	-.5995E-08
143.5	-.1190E-03	-.1097E-02	1.51	0.119	0.000	-0.001	0.2924E-05	-.8294E-06	-.1108E-05	-.6520E-08
145.8	-.1124E-03	-.1070E-02	1.48	0.138	0.000	0.000	0.2848E-05	-.7706E-06	-.1099E-05	-.2223E-08
148.1	-.1059E-03	-.1045E-02	1.45	0.155	0.000	-0.001	0.2775E-05	-.7149E-06	-.1090E-05	-.7040E-08
150.4	-.9958E-04	-.1021E-02	1.42	0.170	0.000	-0.001	0.2704E-05	-.6619E-06	-.1080E-05	-.3719E-08
152.8	-.9342E-04	-.9981E-03	1.39	0.186	0.000	-0.001	0.2637E-05	-.6115E-06	-.1071E-05	-.5024E-08
155.1	-.8741E-04	-.9770E-03	1.36	0.200	0.000	-0.001	0.2573E-05	-.5637E-06	-.1062E-05	-.3700E-08
157.4	-.8154E-04	-.9572E-03	1.34	0.214	0.000	-0.001	0.2512E-05	-.5181E-06	-.1054E-05	-.4424E-08
159.7	-.7581E-04	-.9388E-03	1.31	0.227	0.000	-0.001	0.2454E-05	-.4748E-06	-.1047E-05	-.4309E-08
162.0	-.7021E-04	-.9217E-03	1.29	0.240	0.000	0.000	0.2400E-05	-.4335E-06	-.1040E-05	-.2011E-08
164.3	-.6474E-04	-.9060E-03	1.27	0.252	0.000	-0.001	0.2349E-05	-.3940E-06	-.1033E-05	-.3808E-08
166.6	-.5938E-04	-.8915E-03	1.25	0.263	0.000	-0.001	0.2298E-05	-.3564E-06	-.1027E-05	-.4109E-08
168.9	-.5413E-04	-.8782E-03	1.23	0.274	0.000	-0.001	0.2249E-05	-.3205E-06	-.1020E-05	-.2832E-08
171.2	-.4899E-04	-.8662E-03	1.21	0.285	0.000	-0.001	0.2205E-05	-.2861E-06	-.1015E-05	-.2792E-08
173.5	-.4395E-04	-.8554E-03	1.19	0.295	0.000	0.000	0.2164E-05	-.2533E-06	-.1011E-05	-.1651E-08
175.8	-.3900E-04	-.8457E-03	1.17	0.305	0.000	0.000	0.2126E-05	-.2218E-06	-.1007E-05	-.2214E-08
178.1	-.3414E-04	-.8371E-03	1.16	0.315	0.000	0.000	0.2088E-05	-.1917E-06	-.1003E-05	-.2327E-08
180.4	-.2936E-04	-.8297E-03	1.15	0.324	0.000	0.000	0.2053E-05	-.1627E-06	-.9999E-06	-.1984E-08
182.8	-.2466E-04	-.8234E-03	1.13	0.334	0.000	0.000	0.2020E-05	-.1350E-06	-.9975E-06	-.8209E-09
185.1	-.2004E-04	-.8182E-03	1.12	0.343	0.000	0.000	0.1989E-05	-.1083E-06	-.9950E-06	-.1941E-08
187.4	-.1548E-04	-.8141E-03	1.11	0.352	0.000	0.000	0.1961E-05	-.8263E-07	-.9934E-06	0.2726E-09
189.7	-.1099E-04	-.8110E-03	1.10	0.361	0.000	0.000	0.1935E-05	-.5793E-07	-.9927E-06	-.2034E-08
192.0	-.6552E-05	-.8090E-03	1.09	0.369	0.000	0.000	0.1909E-05	-.3413E-07	-.9916E-06	0.9425E-09
194.3	-.2175E-05	-.8079E-03	1.08	0.377	0.000	-0.001	0.1885E-05	-.1119E-07	-.9925E-06	-.3946E-08

Vertical Section 1 at Radial Distance of 0.00 mm

	Displacements		Stresses				Strains			
Depth	R. disp.	Vert. disp.	R. strs.	Tang. strs.	Vert. strs.	Shear strs.	R. stns.	Tang. stns.	Vert. stns.	Shear stn.
0.0	0.0000E+00	-.8010E-02	-110.93	-110.93	-120.00	0.00	-.6035E-04	-.6035E-04	-.8417E-04	0.0000E+00
-0.2	0.0000E+00	-.7994E-02	-105.57	-105.57	-120.06	0.00	-.5317E-04	-.5317E-04	-.9234E-04	0.0000E+00
-0.5	0.0000E+00	-.7959E-02	-94.97	-94.97	-120.29	0.00	-.3921E-04	-.3921E-04	-.1076E-03	0.0000E+00
-0.9	0.0000E+00	-.7919E-02	-84.78	-84.78	-120.04	0.00	-.2609E-04	-.2609E-04	-.1214E-03	0.0000E+00
-1.2	0.0000E+00	-.7874E-02	-75.22	-75.22	-119.39	0.00	-.1408E-04	-.1408E-04	-.1335E-03	0.0000E+00
-1.6	0.0000E+00	-.7826E-02	-66.49	-66.49	-118.21	0.00	-.3513E-05	-.3513E-05	-.1434E-03	0.0000E+00
-1.9	0.0000E+00	-.7774E-02	-58.70	-58.70	-116.43	0.00	0.5400E-05	0.5400E-05	-.1507E-03	0.0000E+00

-2.3	0.0000E+00	-.7720E-02	-51.93	-51.93	-114.06	0.00	0.1258E-04	0.1258E-04	-.1554E-03	0.0000E+00
-2.6	0.0000E+00	-.7666E-02	-46.18	-46.18	-111.15	0.00	0.1805E-04	0.1805E-04	-.1577E-03	0.0000E+00
-3.0	0.0000E+00	-.7611E-02	-41.41	-41.41	-107.78	0.00	0.2194E-04	0.2194E-04	-.1576E-03	0.0000E+00
-3.3	0.0000E+00	-.7556E-02	-37.54	-37.54	-104.07	0.00	0.2441E-04	0.2441E-04	-.1556E-03	0.0000E+00
-3.7	0.0000E+00	-.7502E-02	-34.51	-34.51	-100.13	0.00	0.2563E-04	0.2563E-04	-.1520E-03	0.0000E+00
-4.0	0.0000E+00	-.7450E-02	-32.24	-32.24	-96.06	0.00	0.2576E-04	0.2576E-04	-.1470E-03	0.0000E+00
-4.4	0.0000E+00	-.7399E-02	-30.68	-30.68	-91.96	0.00	0.2496E-04	0.2496E-04	-.1410E-03	0.0000E+00
-4.7	0.0000E+00	-.7351E-02	-29.76	-29.76	-87.85	0.00	0.2332E-04	0.2332E-04	-.1341E-03	0.0000E+00
-5.1	0.0000E+00	-.7305E-02	-29.46	-29.46	-83.77	0.00	0.2090E-04	0.2090E-04	-.1263E-03	0.0000E+00
-5.4	0.0000E+00	-.7263E-02	-29.76	-29.76	-79.73	0.00	0.1772E-04	0.1772E-04	-.1179E-03	0.0000E+00
-5.8	0.0000E+00	-.7223E-02	-30.66	-30.66	-75.71	0.00	0.1377E-04	0.1377E-04	-.1086E-03	0.0000E+00
-6.1	0.0000E+00	-.7187E-02	-32.19	-32.19	-71.67	0.00	0.8995E-05	0.8995E-05	-.9834E-04	0.0000E+00
-6.5	0.0000E+00	-.7154E-02	-34.38	-34.38	-67.54	0.00	0.3284E-05	0.3284E-05	-.8700E-04	0.0000E+00
-6.8	0.0000E+00	-.7126E-02	-37.31	-37.31	-63.16	0.00	-.3547E-05	-.3547E-05	-.7415E-04	0.0000E+00
-7.0	0.0000E+00	-.7113E-02	-39.07	-39.07	-60.98	0.00	-.7274E-05	-.7274E-05	-.6705E-04	0.0000E+00
-7.0	0.0000E+00	-.7113E-02	-28.45	-28.45	-60.98	0.00	-.7274E-05	-.7274E-05	-.2595E-04	0.0000E+00
-7.3	0.0000E+00	-.7107E-02	-24.74	-24.74	-57.68	0.00	-.5971E-05	-.5971E-05	-.2491E-04	0.0000E+00
-7.8	0.0000E+00	-.7094E-02	-17.88	-17.88	-51.33	0.00	-.3517E-05	-.3517E-05	-.2275E-04	0.0000E+00
-8.3	0.0000E+00	-.7082E-02	-11.54	-11.54	-45.18	0.00	-.1270E-05	-.1270E-05	-.2061E-04	0.0000E+00
-8.9	0.0000E+00	-.7072E-02	-5.47	-5.47	-39.44	0.00	0.8941E-06	0.8941E-06	-.1864E-04	0.0000E+00
-9.4	0.0000E+00	-.7062E-02	0.45	0.45	-34.09	0.00	0.3022E-05	0.3022E-05	-.1684E-04	0.0000E+00
-9.9	0.0000E+00	-.7054E-02	6.29	6.29	-29.12	0.00	0.5149E-05	0.5149E-05	-.1521E-04	0.0000E+00
-10.5	0.0000E+00	-.7046E-02	12.16	12.16	-24.50	0.00	0.7307E-05	0.7307E-05	-.1377E-04	0.0000E+00
-11.0	0.0000E+00	-.7039E-02	18.10	18.10	-20.27	0.00	0.9529E-05	0.9529E-05	-.1253E-04	0.0000E+00
-11.5	0.0000E+00	-.7033E-02	24.19	24.19	-16.42	0.00	0.1184E-04	0.1184E-04	-.1151E-04	0.0000E+00
-12.1	0.0000E+00	-.7027E-02	30.52	30.52	-12.92	0.00	0.1428E-04	0.1428E-04	-.1069E-04	0.0000E+00
-12.6	0.0000E+00	-.7021E-02	37.14	37.14	-9.87	0.00	0.1688E-04	0.1688E-04	-.1015E-04	0.0000E+00
-13.1	0.0000E+00	-.7016E-02	44.15	44.15	-7.26	0.00	0.1968E-04	0.1968E-04	-.9879E-05	0.0000E+00
-13.7	0.0000E+00	-.7011E-02	51.65	51.65	-5.14	0.00	0.2273E-04	0.2273E-04	-.9932E-05	0.0000E+00
-14.2	0.0000E+00	-.7005E-02	59.77	59.77	-3.56	0.00	0.2607E-04	0.2607E-04	-.1034E-04	0.0000E+00
-14.7	0.0000E+00	-.6999E-02	68.78	68.78	-2.85	0.00	0.2986E-04	0.2986E-04	-.1132E-04	0.0000E+00
-15.0	0.0000E+00	-.6996E-02	73.71	73.71	-2.68	0.00	0.3190E-04	0.3190E-04	-.1209E-04	0.0000E+00
-15.0	0.0000E+00	-.6996E-02	-0.82	-0.82	-2.68	0.00	0.3190E-04	0.3190E-04	-.7712E-04	0.0000E+00
-15.8	0.0000E+00	-.6941E-02	-0.83	-0.83	-2.65	0.00	0.3108E-04	0.3108E-04	-.7367E-04	0.0000E+00
-17.3	0.0000E+00	-.6835E-02	-0.85	-0.85	-2.60	0.00	0.2999E-04	0.2999E-04	-.6846E-04	0.0000E+00
-18.8	0.0000E+00	-.6734E-02	-0.85	-0.85	-2.58	0.00	0.2980E-04	0.2980E-04	-.6518E-04	0.0000E+00
-20.3	0.0000E+00	-.6638E-02	-0.85	-0.85	-2.59	0.00	0.3035E-04	0.3035E-04	-.6340E-04	0.0000E+00
-21.8	0.0000E+00	-.6543E-02	-0.83	-0.83	-2.61	0.00	0.3164E-04	0.3164E-04	-.6311E-04	0.0000E+00
-23.3	0.0000E+00	-.6447E-02	-0.80	-0.80	-2.66	0.00	0.3378E-04	0.3378E-04	-.6442E-04	0.0000E+00
-24.0	0.0000E+00	-.6399E-02	-0.78	-0.78	-2.69	0.00	0.3507E-04	0.3507E-04	-.6570E-04	0.0000E+00
-24.0	0.0000E+00	-.6399E-02	-1.23	-1.23	-2.69	0.00	0.3507E-04	0.3507E-04	-.9712E-04	0.0000E+00
-26.7	0.0000E+00	-.6161E-02	-1.33	-1.33	-2.81	0.00	0.3264E-04	0.3264E-04	-.8935E-04	0.0000E+00
-32.0	0.0000E+00	-.5717E-02	-1.53	-1.53	-3.07	0.00	0.2846E-04	0.2846E-04	-.7704E-04	0.0000E+00
-37.3	0.0000E+00	-.5330E-02	-1.74	-1.74	-3.36	0.00	0.2539E-04	0.2539E-04	-.6797E-04	0.0000E+00
-42.7	0.0000E+00	-.4987E-02	-1.95	-1.95	-3.67	0.00	0.2296E-04	0.2296E-04	-.6081E-04	0.0000E+00
-48.0	0.0000E+00	-.4678E-02	-2.16	-2.16	-3.99	0.00	0.2089E-04	0.2089E-04	-.5509E-04	0.0000E+00
-53.3	0.0000E+00	-.4400E-02	-2.38	-2.38	-4.32	0.00	0.1857E-04	0.1857E-04	-.4914E-04	0.0000E+00
-56.0	0.0000E+00	-.4269E-02	-2.49	-2.49	-4.48	0.00	0.1722E-04	0.1722E-04	-.4616E-04	0.0000E+00

TECHNICAL INFORMATION

```
Total number of elements =  4653      Total number of nodes =  4800
Number of equations =  9504
Bandwidth =   202
Number of iterations to reach convergence =  1
Elastic modulus of spring along bottom boundary =    7500.0 psi  Poisson's ratio of spring = 0.40
Relative error of convergence = 0.00000E+00
```

EQUIVALENT RESILIENT MODULUS FOR EACH LAYER

Layer	Name	Modulus (Psi.)
1	HMA	500000.
2	LeanMix	2000000.
3	Subbase	20000.
4	Subgrade	7500.

FATIGUE LIFE & RUT DEPTH DATA

```
Average annual temperature =   0.00 (Fahrenheit)
Kinematic viscosity =    0.00 centistoke
Allowable rut depth =  0.00 inches
Allowable fatigue damage =    0. %
```

SUMMARY

Maximum tensile (radial) strain in the asphalt layer = 7.274E-06

Compressive (vertical) strain at the top of base = 2.595E-05

Compressive (vertical) strain at top of roadbed = 9.712E-05

Allowable ESAL applications based on fatigue life = 0.000E+00

Allowable ESAL applications based on rut depth = 0.000E+00

TITLE

FILENAMES

Data file used for this run: C:\Pavements\MFPDS\TH_RCC_2nd.med
Name of this output file : TH_RCC_2nd.mpo
Unit : English
Route :
Region :
Control Section :
Lane :
Job No. :
Trial No. :
Description :

INITIAL DATA

Number of layers 4
Wheel load = 9000.0 lb.
Tire pressure = 120.00 psi.
Radius of loaded area (a) = 4.886 inches

LAYER TYPE

1 asphalt; 2 granular; 3 cohese
Layer number (from top) Type (1,2,or3)

Layer number (from top)	Type (1,2,or3)
1	1
2	1
3	1
4	1

MATERIAL PROPERTIES
Asphalt Material Properties

Layer	Name of Layer	Thickness (inches)	Modulus (psi)	Poisson's ratio	Density (lb/cu.ft)	Ko
1	HMA	7	500000.0	0.35	150	1.5
2	LeanMix	8	3500000.0	0.15	130	1
3	Subbase	9	20000.0	0.40	130	0.75
4	Subgrade	32	7500.0	0.40	120	0.6

Layer 4 actually semi-infinite", but thickness controls depth to which displacements/stresses are computed.

CROSS SECTIONS FOR CALCULATION OF RESULTS

Number of horizontal sections = 1 Number of vertical sections = 1

Depth for horizontal sections (inches) = 0

Radial distance for vertical sections (inches) = 0. 0

DIVISION OF FINITE ELEMENT MESH

Number of Elements in Vertical Direction

Layer	Thickness	Number of elements
1. HMA	7	20
2. RCC	8	15
3. Subbase	9	6
4. Subgrade	32	6

Number of Elements in Horizontal Direction

Range (a: contact radius)	Number of elements
1. R #NAME?	9
2. R = a - 3a	9
3. R = 3a - 6a	9
4. R = 6a - 40a	72

FINAL DISPLACEMENTS, STRESSES AND STRAINS

Horizontal Section 1 at Depth of 0.00 mm

R. Dist.	Displacements R. Disp.	Vert. Disp.	Stresses R. Strs.		Tang. Strs.		Vert. Strs.	Shear Strs.		Strains Rad. S.	Tang. Stn.		Vert. Stn.	Shear Stn.
0	0.0000E+00	-.6956E-02												
0.3	-.1383E-04	-.6952E-02	-107	3	-107.033	-120	0.484	-.5096E-	04	-.5096E-04	-1.02E-01	3	0.2614E-05	
0.8	-.4136E-04	-.6940E-02	-106.5	9	-106.717	-120	-0.037	-.5043E-	04	-.5078E-04	-1.02E-01	3	-.1993E-06	
1.4	-.6893E-04	-.6918E-02	-107.1	6	-107.022	-120	-0.138	-.5116E-	04	-.5079E-04	-1.02E-01	3	-.7479E-06	
1.9	-.9700E-04	-.6883E-02	-108.1	2	-107.673	-120	-0.206	-.5226E-	04	-.5105E-04	-1.02E-01	3	-.1113E-05	
2.4	-.1258E-03	-.6835E-02	-109.4	7	-108.642	-120	-0.243	-.5370E-	04	-.5148E-04	-1.02E-01	3	-.1312E-05	
3	-.1553E-03	-.6771E-02	-111.2	3	-110.047	-120	-0.298	-.5522E-	04	-.5202E-04	-1.03E-01	3	-.1610E-05	
3.5	-.1860E-03	-.6684E-02	-113.7	5	-111.935	-120	-0.022	-.5760E-	04	-.5270E-04	-1.04E-01	3	-.1175E-06	
4.1	-.2163E-03	-.6568E-02	-116.2	6	-115.798	-120	-0.46	-.5439E-	04	-.5313E-04	-1.15E-01	3	-.2481E-05	
4.6	-.2377E-03	-.6380E-02	-74	1	-84.115	-92.736	27.7	-.2422E-	04	-.5151E-04	-7.48E-01	4	0.1496E-03	

5.4	-.2423E-	03	-.6095E-02	-14.3	4	-32.207	-13.926	9.975	0.3623E-	05	-.4463E-04	4.73E-01	5	0.5387E-04
6.5	-.2356E-	03	-.5858E-02	2.1	9	-14.439	0	-2.835	0.8750E-	05	-.3616E-04	2.50E-01	4	-.1531E-04
7.6	-.2322E-	03	-.5738E-02	-7	6	-17.463	0	-0.399	-.2471E-	05	-.3055E-04	1.88E-01	4	-.2157E-05
8.7	-.2386E-	03	-.5657E-02	-10.4	8	-17.159	0	-0.405	-.9447E-	05	-.2747E-04	2.08E-01	4	-.2185E-05
9.8	-.2513E-	03	-.5596E-02	-12.9	4	-17.325	0	-0.23	-.1388E-	04	-.2572E-04	2.15E-01	4	-.1243E-05
10.9	-.2678E-	03	-.5545E-02	-14.3	6	-17.372	-0.039	-0.121	-.1653E-	04	-.2467E-04	2.21E-01	4	-.6524E-06
11.9	-.2865E-	03	-.5498E-02	-15	3	-17.312	-0.173	-0.034	-.1782E-	04	-.2398E-04	2.23E-01	4	-.1852E-06
13	-.3060E-	03	-.5453E-02	-15.1	4	-17.121	-0.232	0.03	-.1813E-	04	-.2348E-04	2.21E-01	4	0.1629E-06
14.1	-.3255E-	03	-.5408E-02	-14.9	4	-16.872	-0.325	0.044	-.1784E-	04	-.2306E-04	2.16E-01	4	0.2352E-06
15.5	-.3487E-	03	-.5349E-02	-14.1	4	-16.326	-0.305	0.112	-.1664E-	04	-.2254E-04	2.07E-01	4	0.6029E-06
17.1	-.3744E-	03	-.5277E-02	-13	2	-15.599	-0.273	0.126	-.1492E-	04	-.2190E-04	1.95E-01	4	0.6810E-06
18.7	-.3972E-	03	-.5202E-02	-11.8	1	-14.826	-0.257	0.134	-.1306E-	04	-.2121E-04	1.81E-01	4	0.7247E-06
20.4	-.4170E-	03	-.5124E-02	-10.6	1	-14.037	-0.232	0.129	-.1124E-	04	-.2048E-04	1.68E-01	4	0.6986E-06
22	-.4339E-	03	-.5045E-02	-9.5	0	-13.265	-0.211	0.122	-.9558E-	05	-.1974E-04	1.55E-01	4	0.6577E-06
23.6	-.4483E-	03	-.4963E-02	-8.4	7	-12.522	-0.192	0.114	-.8036E-	05	-.1898E-04	1.43E-01	4	0.6138E-06
25.2	-.4602E-	03	-.4880E-02	-7.5	3	-11.814	-0.175	0.105	-.6675E-	05	-.1823E-04	1.32E-01	4	0.5649E-06
26.9	-.4701E-	03	-.4796E-02	-6.6	9	-11.143	-0.155	0.097	-.5470E-	05	-.1749E-04	1.22E-01	4	0.5222E-06
28.5	-.4782E-	03	-.4712E-02	-5.9	5	-10.529	-0.17	0.081	-.4401E-	05	-.1678E-04	1.12E-01	4	0.4371E-06
30.5	-.4855E-	03	-.4609E-02	-5.1	0	-9.804	-0.146	0.084	-.3242E-	05	-.1593E-04	1.01E-01	4	0.4536E-06
32.8	-.4916E-	03	-.4488E-02	-4.2	4	-9.025	-0.112	0.073	-.2094E-	05	-.1500E-04	9.06E-01	5	0.3923E-06
35.1	-.4953E-	03	-.4366E-02	-3.5	0	-8.320	-0.102	0.065	-.1104E-	05	-.1412E-04	8.07E-01	5	0.3511E-06
37.4	-.4969E-	03	-.4245E-02	-2.8	5	-7.673	-0.092	0.058	-.2582E-	06	-.1329E-04	7.18E-01	5	0.3119E-06
39.7	-.4967E-	03	-.4125E-02	-2.2	7	-7.077	-0.082	0.053	0.4782E-	06	-.1251E-04	6.38E-01	5	0.2883E-06
42	-.4948E-	03	-.4006E-02	-1.7	5	-6.527	-0.072	0.048	0.1123E-	05	-.1178E-04	5.65E-01	5	0.2603E-06
44.3	-.4916E-	03	-.3888E-02	-1.2	9	-6.020	-0.063	0.043	0.1680E-	05	-.1109E-04	4.99E-01	5	0.2330E-06
46.6	-.4871E-	03	-.3771E-02	-0.8	8	-5.554	-0.057	0.039	0.2161E-	05	-.1045E-04	4.39E-01	5	0.2096E-06
48.9	-.4817E-	03	-.3656E-02	-0.5	2	-5.120	-0.048	0.037	0.2582E-	05	-.9845E-05	3.85E-01	5	0.1987E-06
51.2	-.4753E-	03	-.3543E-02	-0.2	0	-4.722	-0.041	0.031	0.2937E-	05	-.9277E-05	3.36E-01	5	0.1649E-06
53.5	-.4682E-	03	-.3432E-02	0	8	-4.356	-0.037	0.03	0.3244E-	05	-.8744E-05	2.92E-01	5	0.1603E-06
55.8	-.4604E-	03	-.3323E-02	0.3	4	-4.011	-0.03	0.028	0.3518E-	05	-.8243E-05	2.51E-01	5	0.1508E-06
58.2	-.4520E-	03	-.3216E-02	0.5	7	-3.696	-0.025	0.022	0.3740E-	05	-.7772E-05	2.14E-01	5	0.1193E-06
60.5	-.4432E-	03	-.3111E-02	0.7	6	-3.406	-0.022	0.023	0.3923E-	05	-.7329E-05	1.81E-01	5	0.1223E-06
62.8	-.4339E-	03	-.3009E-02	0.9	4	-3.135	-0.017	0.019	0.4079E-	05	-.6913E-05	1.51E-01	5	0.1026E-06
65.1	-.4244E-	03	-.2909E-02	1	9	-2.885	-0.013	0.018	0.4203E-	05	-.6521E-05	1.23E-01	5	0.9692E-07
67.4	-.4146E-	03	-.2812E-02	1.2	2	-2.653	-0.011	0.015	0.4303E-	05	-.6152E-05	9.83E-01	6	0.8273E-07
69.7	-.4045E-	03	-.2717E-02	1.3	3	-2.438	-0.009	0.015	0.4382E-	05	-.5805E-05	7.55E-01	6	0.8134E-07
72	-.3944E-	03	-.2625E-02	1.4	4	-2.236	-0.005	0.014	0.4447E-	05	-.5477E-05	5.49E-01	6	0.7337E-07
74.3	-.3840E-	03	-.2535E-02	1.5	3	-2.051	-0.002	0.011	0.4488E-	05	-.5168E-05	3.64E-01	6	0.6002E-07
76.6	-.3737E-	03	-.2447E-02	1.6	0	-1.880	-0.001	0.011	0.4509E-	05	-.4877E-05	1.97E-01	6	0.5771E-07
78.9	-.3633E-	03	-.2362E-02	1.6	6	-1.721	0	0.009	0.4520E-	05	-.4603E-05	4.52E-01	7	0.4991E-07
81.2	-.3528E-	03	-.2280E-02	1.7	2	-1.570	0	0.01	0.4527E-	05	-.4343E-05	-9.41E-01	7	0.5356E-07
83.5	-.3424E-	03	-.2200E-02	1.7	6	-1.430	0	0.007	0.4522E-	05	-.4098E-05	-2.21E-01	6	0.3886E-07
85.8	-.3320E-	03	-.2123E-02	1.8	0	-1.302	0	0.007	0.4500E-	05	-.3867E-05	-3.32E-01	6	0.3871E-07
88.2	-.3216E-	03	-.2048E-02	1.8	3	-1.183	0	0.006	0.4472E-	05	-.3648E-05	-4.33E-01	6	0.3271E-07
90.5	-.3113E-	03	-.1975E-02	1.8	5	-1.072	0	0.005	0.4435E-	05	-.3442E-05	-5.25E-01	6	0.2831E-07
92.8	-.3012E-	03	-.1905E-02	1.8	6	-0.968	0	0.006	0.4396E-	05	-.3246E-05	-6.07E-01	6	0.3064E-07
95.1	-.2911E-	03	-.1838E-02	1.8	8	-0.871	0	0.004	0.4352E-	05	-.3061E-05	-6.81E-01	6	0.2219E-07
97.4	-.2811E-	03	-.1772E-02	1.8	8	-0.781	0	0.004	0.4301E-	05	-.2886E-05	-7.47E-01	6	0.2224E-07
99.7	-.2712E-	03	-.1709E-02	1.8	8	-0.696	0	0.003	0.4246E-	05	-.2721E-05	-8.05E-01	6	0.1883E-07
102	-.2615E-	03	-.1648E-02	1.8	8	-0.619	0	0.003	0.4186E-	05	-.2564E-05	-8.57E-01	6	0.1569E-07
104.3	-.2519E-	03	-.1590E-02	1.8	7	-0.547	0	0.002	0.4120E-	05	-.2415E-05	-9.01E-01	6	0.1247E-07

106.6	-.2425E-	03 -.1534E-02	1.8	6	-0.482	0	0.001	0.4046E-	05 -.2275E-05	-9.37E-01	6	0.7393E-08
108.9	-.2332E-	03 -.1480E-02	1.8	4	-0.420	0	0.002	0.3974E-	05 -.2141E-05	-9.69E-01	6	0.1334E-07
111.2	-.2242E-	03 -.1428E-02	1.8	3	-0.362	0	0.001	0.3903E-	05 -.2015E-05	-9.97E-01	6	0.6228E-08
113.5	-.2152E-	03 -.1378E-02	1.8	1	-0.309	0	0.001	0.3825E-	05 -.1896E-05	-1.02E-01	5	0.6170E-08
115.8	-.2065E-	03 -.1330E-02	1.7	9	-0.261	0	0	0.3745E-	05 -.1783E-05	-1.04E-01	5	0.1817E-08
118.1	-.1980E-	03 -.1284E-02	1.7	6	-0.216	0	0.001	0.3665E-	05 -.1676E-05	-1.05E-01	5	0.5571E-08
120.5	-.1896E-	03 -.1240E-02	1.7	4	-0.174	0	0	0.3582E-	05 -.1574E-05	-1.06E-01	5	-.2324E-08
122.8	-.1814E-	03 -.1199E-02	1.7	1	-0.136	0	0.001	0.3500E-	05 -.1478E-05	-1.07E-01	5	0.3557E-08
125.1	-.1734E-	03 -.1158E-02	1.6	8	-0.098	0	0	0.3424E-	05 -.1387E-05	-1.08E-01	5	0.1472E-08
127.4	-.1656E-	03 -.1120E-02	1.6	5	-0.065	0	-0.001	0.3344E-	05 -.1300E-05	-1.08E-01	5	-.2745E-08
129.7	-.1580E-	03 -.1084E-02	1.6	2	-0.035	0	0	0.3264E-	05 -.1218E-05	-1.08E-01	5	-.8245E-09
132	-.1506E-	03 -.1049E-02	1.6	0	-0.006	0	0	0.3186E-	05 -.1141E-05	-1.08E-01	5	-.2291E-08
134.3	-.1433E-	03 -.1016E-02	1.5	7	0.021	0	0	0.3111E-	05 -.1067E-05	-1.08E-01	5	-.6910E-09
136.6	-.1362E-	03 -.9842E-03	1.5	4	0.045	0	-0.001	0.3035E-	05 -.9971E-06	-1.08E-01	5	-.4977E-08
138.9	-.1293E-	03 -.9543E-03	1.5	1	0.069	0	0	0.2962E-	05 -.9307E-06	-1.08E-01	5	-.6744E-09
141.2	-.1225E-	03 -.9259E-03	1.4	8	0.090	0	-0.001	0.2892E-	05 -.8677E-06	-1.07E-01	5	-.3922E-08
143.5	-.1159E-	03 -.8991E-03	1.4	5	0.110	0	-0.001	0.2821E-	05 -.8078E-06	-1.07E-01	5	-.4458E-08
145.8	-.1095E-	03 -.8737E-03	1.4	3	0.129	0	0	0.2754E-	05 -.7509E-06	-1.06E-01	5	-.9933E-09
148.1	-.1032E-	03 -.8498E-03	1.4	0	0.147	0	-0.001	0.2690E-	05 -.6968E-06	-1.06E-01	5	-.4988E-08
150.4	-.9710E-	04 -.8273E-03	1.3	8	0.164	0	-0.001	0.2626E-	05 -.6454E-06	-1.05E-01	5	-.2725E-08
152.8	-.9111E-	04 -.8062E-03	1.3	5	0.180	0	-0.001	0.2566E-	05 -.5964E-06	-1.04E-01	5	-.3836E-08
155.1	-.8525E-	04 -.7864E-03	1.3	3	0.194	0	-0.001	0.2507E-	05 -.5498E-06	-1.04E-01	5	-.3022E-08
157.4	-.7954E-	04 -.7679E-03	1.3	0	0.208	0	-0.001	0.2450E-	05 -.5054E-06	-1.03E-01	5	-.3828E-08
159.7	-.7395E-	04 -.7507E-03	1.2	8	0.221	0	-0.001	0.2395E-	05 -.4631E-06	-1.02E-01	5	-.3640E-08
162	-.6848E-	04 -.7347E-03	1.2	6	0.234	0	0	0.2344E-	05 -.4227E-06	-1.02E-01	5	-.1862E-08
164.3	-.6313E-	04 -.7200E-03	1.2	4	0.247	0	-0.001	0.2295E-	05 -.3842E-06	-1.01E-01	5	-.3354E-08
166.6	-.5789E-	04 -.7064E-03	1.2	2	0.258	0	-0.001	0.2247E-	05 -.3475E-06	-1.01E-01	5	-.3608E-08
168.9	-.5276E-	04 -.6940E-03	1.2	0	0.268	0	-0.001	0.2200E-	05 -.3123E-06	-9.99E-01	6	-.2844E-08
171.2	-.4773E-	04 -.6828E-03	1.1	8	0.279	0	-0.001	0.2156E-	05 -.2788E-06	-9.93E-01	6	-.2869E-08
173.5	-.4281E-	04 -.6726E-03	1.1	6	0.288	0	0	0.2114E-	05 -.2467E-06	-9.89E-01	6	-.2090E-08
175.8	-.3797E-	04 -.6636E-03	1.1	5	0.298	0	0	0.2075E-	05 -.2160E-06	-9.84E-01	6	-.2508E-08
178.1	-.3323E-	04 -.6556E-03	1.1	3	0.307	0	0	0.2037E-	05 -.1865E-06	-9.80E-01	6	-.2466E-08
180.4	-.2857E-	04 -.6487E-03	1.1	2	0.316	0	0	0.2001E-	05 -.1583E-06	-9.76E-01	6	-.2161E-08
182.8	-.2399E-	04 -.6428E-03	1.1	0	0.325	0	0	0.1968E-	05 -.1313E-06	-9.72E-01	6	-.1205E-08
185.1	-.1948E-	04 -.6380E-03	1	9	0.333	0	0	0.1937E-	05 -.1053E-06	-9.69E-01	6	-.2042E-08
187.4	-.1505E-	04 -.6341E-03	1	8	0.342	0	0	0.1908E-	05 -.8032E-07	-9.67E-01	6	-.2132E-09
189.7	-.1068E-	04 -.6312E-03	1	7	0.350	0	0	0.1881E-	05 -.5630E-07	-9.66E-01	6	-.1828E-08
192	-.6367E-	05 -.6293E-03	1	6	0.359	0	0	0.1856E-	05 -.3317E-07	-9.64E-01	6	0.5659E-09
194.3	-.2113E-	05 -.6284E-03	1	5	0.366	0	-0.001	0.1832E-	05 -.1088E-07	-9.65E-01	6	-.3672E-08

Vertic al Section 1 at Radial D istance of 0.00 mm

Displac ements Str esses Strains

Depth	R. disp.	Vert. disp.	R. strs.		Tang. strs.		Vert. strs.	Shear strs.	R. stns.	Tang. stns.	Vert.
stns.	Shear stn.										
0	0.00E+00	-6.96E-03	-103.72	-103.72	-120	0	-5.10E-05	-5.10E-05	-9.44E-05	0.00E+00	
-0.2	0.00E+00	-6.94E-03	-98.69	-98.69	-120.09	0	-4.42E-05	-4.42E-05	-1.02E-04	0.00E+00	
-0.5	0.00E+00	-6.90E-03	-88.74	-88.74	-120.35	0	-3.11E-05	-3.11E-05	-1.17E-04	0.00E+00	
-0.9	0.00E+00	-6.86E-03	-79.13	-79.13	-120.18	0	-1.87E-05	-1.87E-05	-1.30E-04	0.00E+00	

-1.2	0.00E+00	-6.81E-03	-70.11	-70.11	-119.65	0	-7.26E-06	-7.26E-06	-1.41E-04	0.00E+00
-1.6	0.00E+00	-6.76E-03	-61.89	-61.89	-118.63	0	2.75E-06	2.75E-06	-1.51E-04	0.00E+00
-1.9	0.00E+00	-6.70E-03	-54.59	-54.59	-117.02	0	1.12E-05	1.12E-05	-1.58E-04	0.00E+00
-2.3	0.00E+00	-6.65E-03	-48.28	-48.28	-114.85	0	1.79E-05	1.79E-05	-1.62E-04	0.00E+00
-2.6	0.00E+00	-6.59E-03	-42.98	-42.98	-112.16	0	2.29E-05	2.29E-05	-1.64E-04	0.00E+00
-3	0.00E+00	-6.53E-03	-38.64	-38.64	-109.02	0	2.64E-05	2.64E-05	-1.64E-04	0.00E+00
-3.3	0.00E+00	-6.48E-03	-35.21	-35.21	-105.55	0	2.85E-05	2.85E-05	-1.62E-04	0.00E+00
-3.7	0.00E+00	-6.42E-03	-32.62	-32.62	-101.87	0	2.93E-05	2.93E-05	-1.58E-04	0.00E+00
-4	0.00E+00	-6.37E-03	-30.79	-30.79	-98.07	0	2.91E-05	2.91E-05	-1.53E-04	0.00E+00
-4.4	0.00E+00	-6.31E-03	-29.69	-29.69	-94.23	0	2.79E-05	2.79E-05	-1.47E-04	0.00E+00
-4.7	0.00E+00	-6.26E-03	-29.24	-29.24	-90.39	0	2.58E-05	2.58E-05	-1.40E-04	0.00E+00
-5.1	0.00E+00	-6.22E-03	-29.44	-29.44	-86.58	0	2.29E-05	2.29E-05	-1.32E-04	0.00E+00
-5.4	0.00E+00	-6.17E-03	-30.28	-30.28	-82.79	0	1.92E-05	1.92E-05	-1.23E-04	0.00E+00
-5.8	0.00E+00	-6.13E-03	-31.77	-31.77	-79.01	0	1.46E-05	1.46E-05	-1.14E-04	0.00E+00
-6.1	0.00E+00	-6.09E-03	-33.94	-33.94	-75.17	0	9.16E-06	9.16E-06	-1.03E-04	0.00E+00
-6.5	0.00E+00	-6.06E-03	-36.85	-36.85	-71.21	0	2.64E-06	2.64E-06	-9.09E-05	0.00E+00
-6.8	0.00E+00	-6.03E-03	-40.57	-40.57	-66.96	0	-5.14E-06	-5.14E-06	-7.72E-05	0.00E+00
-7	0.00E+00	-6.02E-03	-42.76	-42.76	-64.83	0	-9.37E-06	-9.37E-06	-6.95E-05	0.00E+00
-7	0.00E+00	-6.02E-03	-50.64	-50.64	-64.83	0	-9.37E-06	-9.37E-06	-1.40E-05	0.00E+00
-7.3	0.00E+00	-6.01E-03	-45.19	-45.19	-61.59	0	-8.21E-06	-8.21E-06	-1.36E-05	0.00E+00
-7.8	0.00E+00	-6.00E-03	-35.11	-35.11	-55.21	0	-6.03E-06	-6.03E-06	-1.26E-05	0.00E+00
-8.3	0.00E+00	-6.00E-03	-25.84	-25.84	-48.85	0	-4.04E-06	-4.04E-06	-1.16E-05	0.00E+00
-8.9	0.00E+00	-5.99E-03	-16.99	-16.99	-42.81	0	-2.14E-06	-2.14E-06	-1.06E-05	0.00E+00
-9.4	0.00E+00	-5.99E-03	-8.41	-8.41	-37.11	0	-2.96E-07	-2.96E-07	-9.72E-06	0.00E+00
-9.9	0.00E+00	-5.98E-03	0	0	-31.75	0	1.53E-06	1.53E-06	-8.90E-06	0.00E+00
-10.5	0.00E+00	-5.98E-03	8.35	8.35	-26.73	0	3.35E-06	3.35E-06	-8.18E-06	0.00E+00
-11	0.00E+00	-5.97E-03	16.75	16.75	-22.06	0	5.20E-06	5.20E-06	-7.56E-06	0.00E+00
-11.5	0.00E+00	-5.97E-03	25.28	25.28	-17.77	0	7.09E-06	7.09E-06	-7.06E-06	0.00E+00
-12.1	0.00E+00	-5.97E-03	34.04	34.04	-13.89	0	9.06E-06	9.06E-06	-6.69E-06	0.00E+00
-12.6	0.00E+00	-5.96E-03	43.11	43.11	-10.43	0	1.11E-05	1.11E-05	-6.47E-06	0.00E+00
-13.1	0.00E+00	-5.96E-03	52.62	52.62	-7.48	0	1.33E-05	1.33E-05	-6.43E-06	0.00E+00
-13.7	0.00E+00	-5.96E-03	62.67	62.67	-5.08	0	1.57E-05	1.57E-05	-6.60E-06	0.00E+00
-14.2	0.00E+00	-5.95E-03	73.43	73.43	-3.29	0	1.82E-05	1.82E-05	-7.01E-06	0.00E+00
-14.7	0.00E+00	-5.95E-03	85.26	85.26	-2.49	0	2.11E-05	2.11E-05	-7.78E-06	0.00E+00
-15	0.00E+00	-5.95E-03	91.69	91.69	-2.32	0	2.26E-05	2.26E-05	-8.35E-06	0.00E+00
-15	0.00E+00	-5.95E-03	-0.91	-0.91	-2.32	0	2.26E-05	2.26E-05	-5.69E-05	0.00E+00
-15.8	0.00E+00	-5.90E-03	-0.92	-0.92	-2.34	0	2.23E-05	2.23E-05	-5.48E-05	0.00E+00
-17.3	0.00E+00	-5.82E-03	-0.94	-0.94	-2.34	0	2.20E-05	2.20E-05	-5.18E-05	0.00E+00
-18.8	0.00E+00	-5.75E-03	-0.96	-0.96	-2.36	0	2.23E-05	2.23E-05	-5.01E-05	0.00E+00
-20.3	0.00E+00	-5.67E-03	-0.96	-0.96	-2.4	0	2.31E-05	2.31E-05	-4.93E-05	0.00E+00
-21.8	0.00E+00	-5.60E-03	-0.96	-0.96	-2.45	0	2.44E-05	2.44E-05	-4.96E-05	0.00E+00
-23.3	0.00E+00	-5.52E-03	-0.95	-0.95	-2.51	0	2.62E-05	2.62E-05	-5.10E-05	0.00E+00
-24	0.00E+00	-5.49E-03	-0.94	-0.94	-2.55	0	2.73E-05	2.73E-05	-5.21E-05	0.00E+00
-24	0.00E+00	-5.49E-03	-1.23	-1.23	-2.55	0	2.73E-05	2.73E-05	-7.80E-05	0.00E+00
-26.7	0.00E+00	-5.29E-03	-1.33	-1.33	-2.68	0	2.58E-05	2.58E-05	-7.25E-05	0.00E+00
-32	0.00E+00	-4.93E-03	-1.53	-1.53	-2.97	0	2.30E-05	2.30E-05	-6.37E-05	0.00E+00
-37.3	0.00E+00	-4.61E-03	-1.74	-1.74	-3.28	0	2.09E-05	2.09E-05	-5.69E-05	0.00E+00
-42.7	0.00E+00	-4.32E-03	-1.95	-1.95	-3.6	0	1.92E-05	1.92E-05	-5.14E-05	0.00E+00
-48	0.00E+00	-4.06E-03	-2.16	-2.16	-3.93	0	1.76E-05	1.76E-05	-4.70E-05	0.00E+00
-53.3	0.00E+00	-3.82E-03	-2.38	-2.38	-4.26	0	1.58E-05	1.58E-05	-4.21E-05	0.00E+00
-56	0.00E+00	-3.71E-03	-2.49	-2.49	-4.43	0	1.47E-05	1.47E-05	-3.97E-05	0.00E+00

TECHNI CAL INFORMA TION

Total number of e lements = 46 53 To tal number of nodes = 480 0
Number of equatio ns = 9504
Bandwi dth = 202
Number of iterati ons to reach convergenc e = 1
Elasti c modulus o f spring alon g bottom b oundary = 7500.0 psi P oisson's ra tio of spri ng = 0.40
Relati ve error of convergence = 0.00000E 0

EQUIVA LENT RESILI ENT MODULUS F OR EACH LA YER

Layer	Name	Modulus (Psi.)
1	HMA	500000
2	LeanMix	3500000
3	Subbase	20000
4	Subgrade	7500

FATIGU E LIFE & RU T DEPTH DATA

Averag e annual te mperature = 0.00 (Fah renheit)
Kinema tic viscosi ty = 0.00 centistoke
Allowa ble rut dep th = 0.00 in ches
Allowa ble fatigue damage = 0.00%

SUMMAR Y

Maximu m tensile (radial) strai n in the a sphalt layer 0.00000937

Compre ssive (vert ical) strain at the top of base = 1. 4.02E-03

Compre ssive (vert ical) strain at top of roadbed = 7.7 9.60E-04

Allowa ble ESAL ap plications ba sed on fat igue life = 0 0.00E+00

Allowa ble ESAL ap plications ba sed on rut depth = 0.00 0.00E+00

TITLE

FILENAMES

```
Data file used for this run: C:\Pavements\MFPDS\TH_PCC_2nd.med
Name of this output file   : TH_PCC_2nd.mpo
Unit                       : English
Route                      :
Region                     :
Control Section            :
Lane                       :
Job No.                    :
Trial No.                  :
Description                :
```

INITIAL DATA

```
Number of layers = 4
Wheel load =    9000.0 lb.
Tire pressure =  120.00 psi.
Radius of loaded area (a) =      4.886 inches
```

LAYER TYPE

1 asphalt; 2 granular; 3 cohese

Layer number (from top)	Type (1,2,or3)
1	1
2	1
3	1
4	1

MATERIAL PROPERTIES

Asphalt Material Properties

Layer	Name of Layer	Thickness (inches)	Modulus (psi)	Poisson's ratio	Density (lb/cu.ft)	Ko
1	HMA	7.0	500000.0	0.35	150.0	1.50
2	PCC	8.0	4000000.0	0.15	130.0	1.00
3	Subbase	9.0	20000.0	0.40	130.0	0.75
4	Subgrade	32.0	7500.0	0.40	120.0	0.60

Layer 4 actually semi-infinite, but thickness controls depth to which displacements/stresses are computed.

CROSS SECTIONS FOR CALCULATION OF RESULTS

Number of horizontal sections = 1   Number of vertical sections = 1

Depth for horizontal sections (inches) = 0.00

Radial distance for vertical sections (inches) = 0.00

DIVISION OF FINITE ELEMENT MESH

Number of Elements in Vertical Direction

Layer	Thickness	Number of elements
1. HMA	7.0	20
2. PCC	8.0	15
3. Subbase	9.0	6
4. Subgrade	32.0	6

Number of Elements in Horizontal Direction

Range (a: contact radius)	Number of elements
1. R = 0 - a	9
2. R = a - 3a	9
3. R = 3a - 6a	9
4. R = 6a - 40a	72

FINAL DISPLACEMENTS, STRESSES AND STRAINS

Horizontal Section 1 at Depth of 0.00 mm

	Displacements		Stresses				Strains			
R. Dist.	R. Disp.	Vert. Disp.	R. Strs.	Tang. Strs.	Vert. Strs.	Shear Strs.	Rad. S.	Tang. Stn.	Vert. Stn.	Shear Stn.
0.0	0.0000E+00	-.6770E-02								
0.3	-.1325E-04	-.6766E-02	-105.34	-105.343	-120.000	0.475	-.4881E-04	-.4881E-04	-.1043E-03	0.2567E-05
0.8	-.3962E-04	-.6755E-02	-104.92	-105.041	-120.000	-0.042	-.4832E-04	-.4865E-04	-.1044E-03	-.2271E-06
1.4	-.6605E-04	-.6732E-02	-105.51	-105.362	-120.000	-0.146	-.4907E-04	-.4867E-04	-.1044E-03	-.7894E-06
1.9	-.9300E-04	-.6698E-02	-106.50	-106.031	-120.000	-0.216	-.5022E-04	-.4895E-04	-.1043E-03	-.1168E-05
2.4	-.1207E-03	-.6651E-02	-107.88	-107.024	-120.000	-0.255	-.5171E-04	-.4939E-04	-.1042E-03	-.1378E-05
3.0	-.1492E-03	-.6587E-02	-109.69	-108.456	-120.000	-0.313	-.5329E-04	-.4996E-04	-.1049E-03	-.1689E-05
3.5	-.1788E-03	-.6501E-02	-112.26	-110.377	-120.000	-0.038	-.5575E-04	-.5066E-04	-.1056E-03	-.2056E-06
4.1	-.2082E-03	-.6386E-02	-114.83	-114.275	-120.000	-0.476	-.5262E-04	-.5113E-04	-.1169E-03	-.2573E-05
4.6	-.2286E-03	-.6199E-02	-72.62	-82.623	-92.674	27.687	-.2254E-04	-.4954E-04	-.7667E-04	0.1495E-03
5.4	-.2319E-03	-.5916E-02	-13.06	-30.789	-13.878	9.955	0.5142E-05	-.4272E-04	0.2940E-05	0.5376E-04
6.5	-.2237E-03	-.5681E-02	3.35	-13.107	0.000	-2.855	0.1009E-04	-.3433E-04	0.2333E-04	-.1542E-04

7.6	-.2189E-03	-.5564E-02	-6.03	-16.216	0.000	-0.419	-.1306E-05	-.2880E-04	0.1726E-04	-.2262E-05
8.7	-.2242E-03	-.5486E-02	-9.56	-15.994	0.000	-0.422	-.8441E-05	-.2581E-04	0.1936E-04	-.2281E-05
9.8	-.2358E-03	-.5428E-02	-12.12	-16.237	0.000	-0.246	-.1301E-04	-.2413E-04	0.2025E-04	-.1330E-05
10.9	-.2515E-03	-.5380E-02	-13.62	-16.354	-0.018	-0.135	-.1579E-04	-.2316E-04	0.2095E-04	-.7289E-06
11.9	-.2693E-03	-.5336E-02	-14.36	-16.356	-0.154	-0.047	-.1717E-04	-.2255E-04	0.2120E-04	-.2528E-06
13.0	-.2882E-03	-.5294E-02	-14.54	-16.223	-0.215	0.019	-.1757E-04	-.2212E-04	0.2110E-04	0.1034E-06
14.1	-.3072E-03	-.5252E-02	-14.39	-16.024	-0.307	0.034	-.1735E-04	-.2176E-04	0.2068E-04	0.1862E-06
15.5	-.3298E-03	-.5198E-02	-13.65	-15.538	-0.291	0.102	-.1623E-04	-.2131E-04	0.1985E-04	0.5528E-06
17.1	-.3549E-03	-.5130E-02	-12.59	-14.876	-0.262	0.119	-.1459E-04	-.2075E-04	0.1871E-04	0.6400E-06
18.7	-.3772E-03	-.5060E-02	-11.44	-14.160	-0.245	0.127	-.1280E-04	-.2014E-04	0.1743E-04	0.6856E-06
20.4	-.3966E-03	-.4987E-02	-10.30	-13.424	-0.222	0.123	-.1105E-04	-.1948E-04	0.1616E-04	0.6642E-06
22.0	-.4133E-03	-.4912E-02	-9.23	-12.700	-0.202	0.116	-.9429E-05	-.1880E-04	0.1495E-04	0.6250E-06
23.6	-.4275E-03	-.4835E-02	-8.25	-12.001	-0.186	0.108	-.7962E-05	-.1810E-04	0.1380E-04	0.5837E-06
25.2	-.4394E-03	-.4756E-02	-7.35	-11.334	-0.168	0.100	-.6651E-05	-.1740E-04	0.1274E-04	0.5379E-06
26.9	-.4492E-03	-.4677E-02	-6.54	-10.700	-0.148	0.092	-.5490E-05	-.1672E-04	0.1177E-04	0.4967E-06
28.5	-.4573E-03	-.4597E-02	-5.83	-10.121	-0.164	0.077	-.4460E-05	-.1605E-04	0.1084E-04	0.4157E-06
30.5	-.4648E-03	-.4500E-02	-5.02	-9.434	-0.140	0.080	-.3339E-05	-.1526E-04	0.9838E-05	0.4305E-06
32.8	-.4713E-03	-.4385E-02	-4.20	-8.695	-0.108	0.070	-.2229E-05	-.1438E-04	0.8807E-05	0.3762E-06
35.1	-.4753E-03	-.4270E-02	-3.48	-8.026	-0.099	0.062	-.1272E-05	-.1355E-04	0.7856E-05	0.3355E-06
37.4	-.4773E-03	-.4155E-02	-2.85	-7.412	-0.089	0.055	-.4542E-06	-.1276E-04	0.7007E-05	0.2985E-06
39.7	-.4775E-03	-.4040E-02	-2.29	-6.845	-0.079	0.051	0.2577E-06	-.1203E-04	0.6239E-05	0.2757E-06
42.0	-.4762E-03	-.3927E-02	-1.80	-6.321	-0.070	0.046	0.8821E-06	-.1134E-04	0.5542E-05	0.2488E-06
44.3	-.4735E-03	-.3814E-02	-1.35	-5.838	-0.062	0.041	0.1423E-05	-.1069E-04	0.4911E-05	0.2238E-06
46.6	-.4697E-03	-.3703E-02	-0.96	-5.394	-0.055	0.037	0.1889E-05	-.1008E-04	0.4339E-05	0.2006E-06
48.9	-.4649E-03	-.3593E-02	-0.61	-4.981	-0.047	0.035	0.2296E-05	-.9501E-05	0.3821E-05	0.1896E-06
51.2	-.4592E-03	-.3485E-02	-0.31	-4.602	-0.040	0.029	0.2638E-05	-.8962E-05	0.3355E-05	0.1570E-06
53.5	-.4528E-03	-.3378E-02	-0.04	-4.253	-0.037	0.028	0.2932E-05	-.8456E-05	0.2929E-05	0.1520E-06
55.8	-.4457E-03	-.3274E-02	0.21	-3.927	-0.030	0.027	0.3194E-05	-.7980E-05	0.2539E-05	0.1441E-06
58.2	-.4381E-03	-.3171E-02	0.42	-3.627	-0.027	0.021	0.3406E-05	-.7533E-05	0.2189E-05	0.1127E-06
60.5	-.4300E-03	-.3071E-02	0.61	-3.351	-0.023	0.022	0.3582E-05	-.7112E-05	0.1872E-05	0.1175E-06
62.8	-.4216E-03	-.2973E-02	0.78	-3.092	-0.018	0.018	0.3734E-05	-.6716E-05	0.1583E-05	0.9836E-07
65.1	-.4128E-03	-.2876E-02	0.92	-2.853	-0.014	0.017	0.3856E-05	-.6344E-05	0.1322E-05	0.9325E-07
67.4	-.4038E-03	-.2782E-02	1.05	-2.633	-0.013	0.015	0.3955E-05	-.5993E-05	0.1081E-05	0.7935E-07
69.7	-.3946E-03	-.2691E-02	1.16	-2.427	-0.011	0.015	0.4035E-05	-.5662E-05	0.8630E-06	0.7855E-07
72.0	-.3852E-03	-.2601E-02	1.27	-2.234	-0.006	0.013	0.4101E-05	-.5350E-05	0.6646E-06	0.7101E-07
74.3	-.3757E-03	-.2514E-02	1.35	-2.056	-0.004	0.011	0.4145E-05	-.5056E-05	0.4852E-06	0.5806E-07
76.6	-.3661E-03	-.2430E-02	1.42	-1.893	-0.003	0.010	0.4172E-05	-.4779E-05	0.3225E-06	0.5636E-07
78.9	-.3565E-03	-.2347E-02	1.49	-1.739	-0.002	0.009	0.4190E-05	-.4517E-05	0.1737E-06	0.4963E-07
81.2	-.3468E-03	-.2267E-02	1.55	-1.593	0.000	0.010	0.4207E-05	-.4269E-05	0.3561E-07	0.5329E-07
83.5	-.3371E-03	-.2189E-02	1.60	-1.457	0.000	0.007	0.4213E-05	-.4035E-05	-.9145E-07	0.3968E-07
85.8	-.3274E-03	-.2113E-02	1.64	-1.332	0.000	0.007	0.4204E-05	-.3813E-05	-.2048E-06	0.3941E-07
88.2	-.3177E-03	-.2040E-02	1.67	-1.215	0.000	0.006	0.4190E-05	-.3604E-05	-.3082E-06	0.3468E-07
90.5	-.3080E-03	-.1969E-02	1.70	-1.106	0.000	0.006	0.4167E-05	-.3405E-05	-.4028E-06	0.2986E-07
92.8	-.2984E-03	-.1900E-02	1.72	-1.002	0.000	0.006	0.4143E-05	-.3217E-05	-.4883E-06	0.3237E-07
95.1	-.2889E-03	-.1834E-02	1.74	-0.906	0.000	0.004	0.4113E-05	-.3039E-05	-.5668E-06	0.2423E-07
97.4	-.2795E-03	-.1769E-02	1.76	-0.817	0.000	0.004	0.4076E-05	-.2870E-05	-.6373E-06	0.2392E-07
99.7	-.2701E-03	-.1707E-02	1.76	-0.733	0.000	0.004	0.4034E-05	-.2710E-05	-.6987E-06	0.2077E-07
102.0	-.2609E-03	-.1647E-02	1.77	-0.656	0.000	0.003	0.3987E-05	-.2558E-05	-.7546E-06	0.1740E-07
104.3	-.2517E-03	-.1589E-02	1.77	-0.584	0.000	0.003	0.3934E-05	-.2413E-05	-.8034E-06	0.1494E-07
106.6	-.2427E-03	-.1533E-02	1.76	-0.518	0.000	0.002	0.3875E-05	-.2277E-05	-.8455E-06	0.9907E-08
108.9	-.2338E-03	-.1480E-02	1.75	-0.455	0.000	0.003	0.3818E-05	-.2147E-05	-.8845E-06	0.1596E-07

111.2	-.2251E-03	-.1428E-02	1.75	-0.395	0.000	0.002	0.3764E-05	-.2024E-05	-.9195E-06	0.9692E-08
113.5	-.2165E-03	-.1378E-02	1.74	-0.340	0.000	0.002	0.3703E-05	-.1907E-05	-.9500E-06	0.9041E-08
115.8	-.2080E-03	-.1330E-02	1.72	-0.290	0.000	0.001	0.3639E-05	-.1796E-05	-.9758E-06	0.5252E-08
118.1	-.1997E-03	-.1284E-02	1.71	-0.242	0.000	0.002	0.3576E-05	-.1690E-05	-.9972E-06	0.8717E-08
120.5	-.1915E-03	-.1240E-02	1.69	-0.199	0.000	0.000	0.3509E-05	-.1590E-05	-.1016E-05	0.5286E-09
122.8	-.1835E-03	-.1198E-02	1.67	-0.158	0.000	0.001	0.3441E-05	-.1495E-05	-.1031E-05	0.6518E-08
125.1	-.1756E-03	-.1158E-02	1.65	-0.118	0.000	0.001	0.3378E-05	-.1404E-05	-.1043E-05	0.4104E-08
127.4	-.1679E-03	-.1119E-02	1.63	-0.083	0.000	0.000	0.3311E-05	-.1318E-05	-.1054E-05	-.4065E-09
129.7	-.1603E-03	-.1083E-02	1.61	-0.050	0.000	0.000	0.3241E-05	-.1236E-05	-.1061E-05	0.1331E-08
132.0	-.1529E-03	-.1048E-02	1.59	-0.019	0.000	0.000	0.3173E-05	-.1159E-05	-.1065E-05	-.4899E-09
134.3	-.1457E-03	-.1014E-02	1.56	0.009	0.000	0.000	0.3106E-05	-.1085E-05	-.1069E-05	0.7072E-09
136.6	-.1386E-03	-.9824E-03	1.54	0.035	0.000	-0.001	0.3037E-05	-.1015E-05	-.1070E-05	-.3411E-08
138.9	-.1317E-03	-.9521E-03	1.51	0.060	0.000	0.000	0.2969E-05	-.9480E-06	-.1070E-05	0.4206E-09
141.2	-.1249E-03	-.9235E-03	1.49	0.083	0.000	-0.001	0.2904E-05	-.8845E-06	-.1069E-05	-.2883E-08
143.5	-.1183E-03	-.8963E-03	1.46	0.104	0.000	-0.001	0.2837E-05	-.8242E-06	-.1065E-05	-.3552E-08
145.8	-.1118E-03	-.8706E-03	1.44	0.124	0.000	0.000	0.2774E-05	-.7668E-06	-.1063E-05	-.2473E-09
148.1	-.1055E-03	-.8463E-03	1.41	0.143	0.000	-0.001	0.2713E-05	-.7121E-06	-.1059E-05	-.4128E-08
150.4	-.9930E-04	-.8235E-03	1.39	0.161	0.000	0.000	0.2653E-05	-.6600E-06	-.1055E-05	-.1917E-08
152.8	-.9324E-04	-.8020E-03	1.36	0.178	0.000	-0.001	0.2596E-05	-.6104E-06	-.1051E-05	-.3035E-08
155.1	-.8732E-04	-.7819E-03	1.34	0.193	0.000	0.000	0.2540E-05	-.5631E-06	-.1046E-05	-.2236E-08
157.4	-.8152E-04	-.7631E-03	1.32	0.209	0.000	-0.001	0.2486E-05	-.5180E-06	-.1041E-05	-.2879E-08
159.7	-.7585E-04	-.7455E-03	1.30	0.223	0.000	-0.001	0.2434E-05	-.4750E-06	-.1037E-05	-.2929E-08
162.0	-.7029E-04	-.7293E-03	1.28	0.236	0.000	0.000	0.2386E-05	-.4339E-06	-.1033E-05	-.1209E-08
164.3	-.6483E-04	-.7142E-03	1.26	0.250	0.000	0.000	0.2340E-05	-.3946E-06	-.1029E-05	-.2650E-08
166.6	-.5949E-04	-.7004E-03	1.24	0.261	0.000	-0.001	0.2293E-05	-.3571E-06	-.1025E-05	-.3170E-08
168.9	-.5425E-04	-.6877E-03	1.22	0.273	0.000	0.000	0.2248E-05	-.3212E-06	-.1020E-05	-.2184E-08
171.2	-.4911E-04	-.6762E-03	1.21	0.284	0.000	0.000	0.2206E-05	-.2868E-06	-.1016E-05	-.2271E-08
173.5	-.4407E-04	-.6659E-03	1.19	0.295	0.000	0.000	0.2167E-05	-.2540E-06	-.1013E-05	-.1497E-08
175.8	-.3911E-04	-.6566E-03	1.18	0.305	0.000	0.000	0.2129E-05	-.2224E-06	-.1009E-05	-.1956E-08
178.1	-.3424E-04	-.6485E-03	1.16	0.315	0.000	0.000	0.2093E-05	-.1922E-06	-.1006E-05	-.2077E-08
180.4	-.2945E-04	-.6414E-03	1.15	0.325	0.000	0.000	0.2058E-05	-.1632E-06	-.1003E-05	-.1789E-08
182.8	-.2474E-04	-.6354E-03	1.13	0.334	0.000	0.000	0.2026E-05	-.1354E-06	-.1001E-05	-.8700E-09
185.1	-.2010E-04	-.6304E-03	1.12	0.343	0.000	0.000	0.1995E-05	-.1086E-06	-.9990E-06	-.1738E-08
187.4	-.1553E-04	-.6264E-03	1.11	0.352	0.000	0.000	0.1967E-05	-.8288E-07	-.9975E-06	0.2553E-10
189.7	-.1102E-04	-.6235E-03	1.10	0.361	0.000	0.000	0.1941E-05	-.5810E-07	-.9966E-06	-.1706E-08
192.0	-.6572E-05	-.6215E-03	1.09	0.370	0.000	0.000	0.1915E-05	-.3423E-07	-.9953E-06	0.6214E-09
194.3	-.2181E-05	-.6205E-03	1.08	0.377	0.000	-0.001	0.1891E-05	-.1123E-07	-.9963E-06	-.3693E-08

Vertical Section 1 at Radial Distance of 0.00 mm

	Displacements		Stresses				Strains			
Depth	R. disp.	Vert. disp.	R. strs.	Tang. strs.	Vert. strs.	Shear strs.	R. stns.	Tang. stns.	Vert. stns.	Shear stn.
0.0	0.0000E+00	-.6770E-02	-102.07	-102.07	-120.00	0.00	-.4881E-04	-.4881E-04	-.9668E-04	0.0000E+00
-0.2	0.0000E+00	-.6752E-02	-97.11	-97.11	-120.09	0.00	-.4216E-04	-.4216E-04	-.1042E-03	0.0000E+00
-0.5	0.0000E+00	-.6713E-02	-87.28	-87.28	-120.36	0.00	-.2916E-04	-.2916E-04	-.1185E-03	0.0000E+00
-0.9	0.0000E+00	-.6669E-02	-77.79	-77.79	-120.20	0.00	-.1689E-04	-.1689E-04	-.1315E-03	0.0000E+00
-1.2	0.0000E+00	-.6621E-02	-68.88	-68.88	-119.70	0.00	-.5623E-05	-.5623E-05	-.1430E-03	0.0000E+00
-1.6	0.0000E+00	-.6569E-02	-60.76	-60.76	-118.71	0.00	0.4277E-05	0.4277E-05	-.1524E-03	0.0000E+00
-1.9	0.0000E+00	-.6515E-02	-53.55	-53.55	-117.14	0.00	0.1258E-04	0.1258E-04	-.1593E-03	0.0000E+00

-2.3	0.0000E+00	-.6458E-02	-47.34	-47.34	-115.00	0.00	0.1920E-04	0.1920E-04	-.1637E-03	0.0000E+00
-2.6	0.0000E+00	-.6400E-02	-42.13	-42.13	-112.35	0.00	0.2416E-04	0.2416E-04	-.1657E-03	0.0000E+00
-3.0	0.0000E+00	-.6342E-02	-37.87	-37.87	-109.26	0.00	0.2757E-04	0.2757E-04	-.1655E-03	0.0000E+00
-3.3	0.0000E+00	-.6285E-02	-34.53	-34.53	-105.84	0.00	0.2956E-04	0.2956E-04	-.1634E-03	0.0000E+00
-3.7	0.0000E+00	-.6228E-02	-32.02	-32.02	-102.21	0.00	0.3032E-04	0.3032E-04	-.1596E-03	0.0000E+00
-4.0	0.0000E+00	-.6173E-02	-30.28	-30.28	-98.46	0.00	0.2999E-04	0.2999E-04	-.1546E-03	0.0000E+00
-4.4	0.0000E+00	-.6120E-02	-29.26	-29.26	-94.68	0.00	0.2871E-04	0.2871E-04	-.1484E-03	0.0000E+00
-4.7	0.0000E+00	-.6070E-02	-28.91	-28.91	-90.89	0.00	0.2655E-04	0.2655E-04	-.1413E-03	0.0000E+00
-5.1	0.0000E+00	-.6022E-02	-29.20	-29.20	-87.13	0.00	0.2357E-04	0.2357E-04	-.1334E-03	0.0000E+00
-5.4	0.0000E+00	-.5976E-02	-30.14	-30.14	-83.39	0.00	0.1978E-04	0.1978E-04	-.1246E-03	0.0000E+00
-5.8	0.0000E+00	-.5934E-02	-31.74	-31.74	-79.66	0.00	0.1512E-04	0.1512E-04	-.1149E-03	0.0000E+00
-6.1	0.0000E+00	-.5896E-02	-34.03	-34.03	-75.87	0.00	0.9532E-05	0.9532E-05	-.1041E-03	0.0000E+00
-6.5	0.0000E+00	-.5862E-02	-37.07	-37.07	-71.95	0.00	0.2874E-05	0.2874E-05	-.9205E-04	0.0000E+00
-6.8	0.0000E+00	-.5832E-02	-40.93	-40.93	-67.73	0.00	-.5061E-05	-.5061E-05	-.7821E-04	0.0000E+00
-7.0	0.0000E+00	-.5818E-02	-43.20	-43.20	-65.61	0.00	-.9381E-05	-.9381E-05	-.7051E-04	0.0000E+00
-7.0	0.0000E+00	-.5818E-02	-56.35	-56.35	-65.61	0.00	-.9381E-05	-.9381E-05	-.1202E-04	0.0000E+00
-7.3	0.0000E+00	-.5815E-02	-50.46	-50.46	-62.38	0.00	-.8275E-05	-.8275E-05	-.1170E-04	0.0000E+00
-7.8	0.0000E+00	-.5809E-02	-39.58	-39.58	-56.02	0.00	-.6193E-05	-.6193E-05	-.1092E-04	0.0000E+00
-8.3	0.0000E+00	-.5804E-02	-29.56	-29.56	-49.62	0.00	-.4297E-05	-.4297E-05	-.1006E-04	0.0000E+00
-8.9	0.0000E+00	-.5798E-02	-20.01	-20.01	-43.56	0.00	-.2488E-05	-.2488E-05	-.9258E-05	0.0000E+00
-9.4	0.0000E+00	-.5794E-02	-10.76	-10.76	-37.78	0.00	-.7323E-06	-.7323E-06	-.8499E-05	0.0000E+00
-9.9	0.0000E+00	-.5789E-02	-1.70	-1.70	-32.33	0.00	0.9967E-06	0.9967E-06	-.7810E-05	0.0000E+00
-10.5	0.0000E+00	-.5785E-02	7.30	7.30	-27.19	0.00	0.2724E-05	0.2724E-05	-.7193E-05	0.0000E+00
-11.0	0.0000E+00	-.5782E-02	16.33	16.33	-22.46	0.00	0.4470E-05	0.4470E-05	-.6681E-05	0.0000E+00
-11.5	0.0000E+00	-.5778E-02	25.48	25.48	-18.07	0.00	0.6258E-05	0.6258E-05	-.6262E-05	0.0000E+00
-12.1	0.0000E+00	-.5775E-02	34.86	34.86	-14.10	0.00	0.8109E-05	0.8109E-05	-.5966E-05	0.0000E+00
-12.6	0.0000E+00	-.5772E-02	44.56	44.56	-10.56	0.00	0.1005E-04	0.1005E-04	-.5802E-05	0.0000E+00
-13.1	0.0000E+00	-.5769E-02	54.70	54.70	-7.53	0.00	0.1209E-04	0.1209E-04	-.5799E-05	0.0000E+00
-13.7	0.0000E+00	-.5766E-02	65.40	65.40	-5.07	0.00	0.1428E-04	0.1428E-04	-.5979E-05	0.0000E+00
-14.2	0.0000E+00	-.5762E-02	76.83	76.83	-3.23	0.00	0.1665E-04	0.1665E-04	-.6368E-05	0.0000E+00
-14.7	0.0000E+00	-.5759E-02	89.36	89.36	-2.45	0.00	0.1929E-04	0.1929E-04	-.7105E-05	0.0000E+00
-15.0	0.0000E+00	-.5757E-02	96.16	96.16	-2.27	0.00	0.2070E-04	0.2070E-04	-.7649E-05	0.0000E+00
-15.0	0.0000E+00	-.5757E-02	-0.93	-0.93	-2.27	0.00	0.2070E-04	0.2070E-04	-.5269E-04	0.0000E+00
-15.8	0.0000E+00	-.5719E-02	-0.94	-0.94	-2.28	0.00	0.2047E-04	0.2047E-04	-.5088E-04	0.0000E+00
-17.3	0.0000E+00	-.5644E-02	-0.96	-0.96	-2.29	0.00	0.2033E-04	0.2033E-04	-.4828E-04	0.0000E+00
-18.8	0.0000E+00	-.5573E-02	-0.98	-0.98	-2.32	0.00	0.2071E-04	0.2071E-04	-.4683E-04	0.0000E+00
-20.3	0.0000E+00	-.5503E-02	-0.99	-0.99	-2.36	0.00	0.2152E-04	0.2152E-04	-.4626E-04	0.0000E+00
-21.8	0.0000E+00	-.5433E-02	-0.99	-0.99	-2.41	0.00	0.2278E-04	0.2278E-04	-.4660E-04	0.0000E+00
-23.3	0.0000E+00	-.5363E-02	-0.99	-0.99	-2.48	0.00	0.2457E-04	0.2457E-04	-.4794E-04	0.0000E+00
-24.0	0.0000E+00	-.5327E-02	-0.98	-0.98	-2.52	0.00	0.2560E-04	0.2560E-04	-.4901E-04	0.0000E+00
-24.0	0.0000E+00	-.5327E-02	-1.23	-1.23	-2.52	0.00	0.2560E-04	0.2560E-04	-.7365E-04	0.0000E+00
-26.7	0.0000E+00	-.5143E-02	-1.33	-1.33	-2.66	0.00	0.2421E-04	0.2421E-04	-.6868E-04	0.0000E+00
-32.0	0.0000E+00	-.4799E-02	-1.53	-1.53	-2.95	0.00	0.2176E-04	0.2176E-04	-.6058E-04	0.0000E+00
-37.3	0.0000E+00	-.4492E-02	-1.74	-1.74	-3.26	0.00	0.1985E-04	0.1985E-04	-.5435E-04	0.0000E+00
-42.7	0.0000E+00	-.4216E-02	-1.95	-1.95	-3.58	0.00	0.1826E-04	0.1826E-04	-.4926E-04	0.0000E+00
-48.0	0.0000E+00	-.3964E-02	-2.16	-2.16	-3.92	0.00	0.1684E-04	0.1684E-04	-.4508E-04	0.0000E+00
-53.3	0.0000E+00	-.3736E-02	-2.38	-2.38	-4.25	0.00	0.1511E-04	0.1511E-04	-.4052E-04	0.0000E+00
-56.0	0.0000E+00	-.3628E-02	-2.49	-2.49	-4.42	0.00	0.1407E-04	0.1407E-04	-.3824E-04	0.0000E+00

TECHNICAL INFORMATION

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Total number of elements =  4653      Total number of nodes =  4800
Number of equations =  9504
Bandwidth =   202
Number of iterations to reach convergence =  1
Elastic modulus of spring along bottom boundary =    7500.0 psi  Poisson's ratio of spring = 0.40
Relative error of convergence = 0.00000E+00
```

EQUIVALENT RESILIENT MODULUS FOR EACH LAYER

Layer	Name	Modulus (Psi.)
1	HMA	500000.
2	PCC	4000000.
3	Subbase	20000.
4	Subgrade	7500.

FATIGUE LIFE & RUT DEPTH DATA

```
Average annual temperature =   0.00 (Fahrenheit)
Kinematic viscosity =    0.00 centistoke
Allowable rut depth =  0.00 inches
Allowable fatigue damage =    0. %
```

SUMMARY

Maximum tensile (radial) strain in the asphalt layer = 9.381E-06

Compressive (vertical) strain at the top of base = 1.202E-05

Compressive (vertical) strain at top of roadbed = 7.365E-05

Allowable ESAL applications based on fatigue life = 0.000E+00

Allowable ESAL applications based on rut depth = 0.000E+00

APPENDIX C - HMA RUTTING DISTRESS SPREADSHEET

			Granular		SC		CTB		Lean Mix		RCC		PCC	
			Calcs	APS	Calcs	APS	Calcs	APS	Calcs	APS	Calcs	APS	Calcs	APS
Depth	0.25	ε_r	-3.28E-05	0.0163	6.56E-05	-0.0326	8.16E-05	-0.0405	9.47E-05	-0.0470	1.04E-04	-0.0516	1.06E-04	-0.0527
		k1	-0.75		-0.75		-0.75		-0.75		-0.75		-0.75	
	0.75	ε_r	1.17E-05	0.0238	9.06E-05	0.1841	1.04E-04	0.2109	1.15E-04	0.2337	1.23E-04	0.2506	1.25E-04	0.2544
		k1	3.07		3.07		3.07		3.07		3.07		3.07	
	1.5	ε_r	6.38E-05	0.1523	1.20E-04	0.2873	1.31E-04	0.3116	1.40E-04	0.3338	1.47E-04	0.3513	1.49E-04	0.3553
		k1	3.61		3.61		3.61		3.61		3.61		3.61	
	2.5	ε_r	1.06E-04	0.1531	1.20E-04	0.1736	1.48E-04	0.2130	1.55E-04	0.2242	1.62E-04	0.2336	1.64E-04	0.2359
		k1	2.18		2.18		2.18		2.18		2.18		2.18	
	3.5	ε_r	1.25E-04	0.0865	1.39E-04	0.0962	1.46E-04	0.1004	1.53E-04	0.1052	1.59E-04	0.1094	1.60E-04	0.1104
		k1	1.04		1.04		1.04		1.04		1.04		1.04	
	5.5	ε_r	1.56E-04	0.0188	1.11E-04	0.0134	1.11E-04	0.0134	1.15E-04	0.0139	1.20E-04	0.0146	1.22E-04	0.0147
		k1	0.18		0.18		0.18		0.18		0.18		0.18	
sub layer thickness		0.5		0.0081		-0.0163		-0.0202		-0.0235		-0.0258		-0.0263
		0.5		0.0119		0.0921		0.1055		0.1168		0.1253		0.1272
		1		0.1523		0.2873		0.3116		0.3338		0.3513		0.3553
		1		0.1531		0.1736		0.2130		0.2242		0.2336		0.2359
		1		0.0865		0.0962		0.1004		0.1052		0.1094		0.1104
		2		0.0377		0.0269		0.0269		0.0278		0.0291		0.0294
			Rut Depth	0.45	Rut Depth	0.66	Rut Depth	0.74	Rut Depth	0.78	Rut Depth	0.82	Rut Depth	0.83

Granular	SC	CTB	Lean Mix	RCC	PCC
0.5 in.	0.5 in.	0.5 in.	0.5 in.	0.5 in.	0.5 in.

N =	5.00E+07	
T =	45 F	Average Annual Pavement Temperature
hac =	7	

Allowable rut depth = 0.5 in.

Accum. plastic strain = 0.07143 in.

Interpolation	
x1 =	5.8
x2 =	6.1
y1 =	-1.15E-04
y2 =	-1.04E-04
x3 =	6
y3 =	**-1.077E-04**

This table was performed with a constant traffic (ESALs) of 50,000,000

	Rut Depth (in.)					
Temp (F)	**Granular**	**SC**	**CTB**	**Lean**	**RCC**	**PCC**
10	*0.04*	*0.06*	*0.07*	*0.08*	*0.08*	*0.08*
15	*0.08*	*0.12*	*0.13*	*0.14*	*0.15*	*0.15*
20	*0.13*	*0.19*	*0.21*	*0.22*	*0.23*	*0.23*
25	*0.18*	*0.26*	*0.29*	*0.31*	*0.33*	*0.33*
30	*0.24*	*0.35*	*0.39*	*0.42*	*0.44*	*0.44*
35	*0.30*	*0.45*	*0.50*	*0.53*	*0.56*	*0.56*
40	*0.37*	*0.55*	*0.61*	*0.65*	*0.68*	*0.69*
45	*0.45*	*0.66*	*0.74*	*0.78*	*0.82*	*0.83*
50	*0.53*	*0.78*	*0.87*	*0.92*	*0.97*	*0.98*
60	*0.70*	*1.03*	*1.15*	*1.23*	*1.29*	*1.30*
70	*0.90*	*1.31*	*1.47*	*1.56*	*1.64*	*1.66*
80	*1.10*	*1.62*	*1.81*	*1.93*	*2.02*	*2.04*
90	*1.33*	*1.95*	*2.17*	*2.31*	*2.43*	*2.45*

This table was performed with a constant temperature of 45 F

	Rut Depth (in.)					
ESALs	**Granular**	**SC**	**CTB**	**Lean**	**RCC**	**PCC**
100,000	*0.02*	*0.03*	*0.04*	*0.04*	*0.04*	*0.04*
1,000,000	*0.07*	*0.10*	*0.11*	*0.12*	*0.13*	*0.13*
5,000,000	*0.15*	*0.22*	*0.24*	*0.26*	*0.27*	*0.28*
10,000,000	*0.21*	*0.31*	*0.34*	*0.36*	*0.38*	*0.38*
20,000,000	*0.29*	*0.43*	*0.48*	*0.51*	*0.53*	*0.54*
50,000,000	*0.45*	*0.66*	*0.74*	*0.78*	*0.82*	*0.83*
70,000,000	*0.53*	*0.78*	*0.87*	*0.92*	*0.97*	*0.98*

This table should be performed from 100,000 to 70,000,000 ESALs in increments of 5,000,000 to see the trend of rut depth

APPENDIX D - RIGID LAYER FATIGUE SPREADSHEETS

Material	P.R	E-mod (min-max)	E-mod (psi)	E-mod (MPa)	Cement Content	Comp. Strength @ 7	Comp. Strength @ 28
SC	0.2	50,000 - 1,000,000	500,000	3,447			
CTB	0.2	700,000 - 1,500,000	1,000,000	6,895			
Lean	0.15	1,500,000 - 2,500,000	2,000,000	13,790			
RCC	0.15	3,480,000 - 4,500,000	3,500,000	24,132			4,630
PCC	0.15	3,000,000 - 6,000,000	4,000,000	27,579			

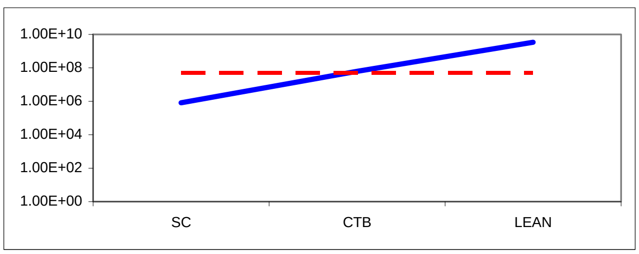
SC, CTB, and Lean = Chemically Stabilized Materials according to the MEPDG guide.
RCC data obtained from the "simplified rcc composite pave design" article from TRR 2004
PCC data obtained from Huang Book

RIGID LAYER FATIGUE ANALYSIS

Layer	AC	SC	CTB	LEAN	RCC	PCC	SUBBASE	SUBGRADE
Thickness	4	8	8	8	8	8	6	n/a
E-mod	500,000	500,000	1,000,000	2,000,000	3,500,000	4,000,000	20,000	12,000
PR	0.35	0.20	0.20	0.15	0.15	0.15	0.40	0.40
Stress	n/a	48.387	65.756	83.445	102.07	106.68	n/a	n/a
MR	n/a	100	200	450	600	650	n/a	n/a
Repetitions	n/a	8.26E+05	6.26E+07	3.42E+09	unlimited	unlimited	n/a	n/a

2 Loads => Each load is 4,500 lbs; contact area 37.5; first load @ 0,0; second load @ 0,12
The fatigue repetitions for SC, CTB, and LEAN were calculated using the fatigue equation in the MEPDG 0.170116667

50000000 50000000 50000000



SENSITIVITY OF RIGID LAYER THICKNESS ON REPETITIONS TO FAILURE

Layer		Stress (psi) at bottom of each Rigid Layer: SC	CTB	LEAN	RCC	PCC	σ / S_c	Z
Thickness	4 in.	74.505	106.18	140.23	181.88	193.52	0.30	7.999
	5 in.	64.313	90.559	118.55	152.36	161.62	0.25	8.999
	6 in.	55.949	78.016	101.23	128.84	136.25	0.21	9.999
	7 in.	49.044	67.823	87.254	109.98	115.97	0.18	10.999
	8 in.	42.01	57.96	73.71	96.69	96.16	0.15	11.999
	9 in.	38.484	52.491	66.465	82.307	86.344	0.13	12.999
	10 in.	34.414	46.661	58.655	72.064	75.433	0.12	13.999
MR		100	200	450	600	650		
		Repetitions to Failure for each Rigid Layer at each Thickness						
Thickness	4 in.	564	222,160	1.01E+08	unlimited	unlimited		
	5 in.	9,690	1,965,142	3.88E+08	unlimited	unlimited		
	6 in.	100,028	11,312,947	1.14E+09	unlimited	unlimited		
	7 in.	687,212	46,917,335	2.70E+09	unlimited	unlimited		
	8 in.	4,894,372	185,819,338	6.26E+09	unlimited	unlimited		
	9 in.	13,094,560	398,607,490	9.81E+09	unlimited	unlimited		
	10 in.	40,777,842	899,246,566	1.59E+10	unlimited	unlimited		
		Stress Ratio (flexural stress/mod. of rupture) for each Rigid Layer at each Thickness						
Thickness	4 in.	0.75	0.53	0.31	0.30	0.30		
	5 in.	0.64	0.45	0.26	0.25	0.25		
	6 in.	0.56	0.39	0.22	0.21	0.21		
	7 in.	0.49	0.34	0.19	0.18	0.18		
	8 in.	0.42	0.29	0.16	0.16	0.15		
	9 in.	0.38	0.26	0.15	0.14	0.13		
	10 in.	0.34	0.23	0.13	0.12	0.12		

It is assumed that the fatigue behavior of PCC and RCC are similar to one another.

If stress ratio is less than or equal to 0.45 in the PCC or RCC case, the repetitions to failure of the rigid layer are *unlimited*.

	Repetitions to Fatigue		
	HMA layer	RIGID layer	1M line (dotted)
AC on Granular Base	12,808,767		1000000
AC on Soil Cement	4.45E+10	4.89.E+06	1000000
AC on CTB		1.86.E+08	1000000
AC on Lean Mix		6.26E+09	1000000
AC on RCC			1000000
AC on PCC			1000000

Layer	AC	SC	CTB	LEAN	RCC	PCC	SUBBASE	SUBGRADE
Thickness	4	8	8	8	8	8	6	n/a
E-mod	500,000	500,000	1,000,000	2,000,000	3,500,000	4,000,000	20,000	12,000
PR	0.35	0.20	0.20	0.15	0.15	0.15	0.40	0.40
WinJULEA	n/a	48.387	65.756	83.445	102.07	106.68	n/a	n/a
KENSLAB		68.086	81.623	103.929	120.654	123.159		
MICHPAVE		59.19	79.61	98.52	124.37	123.31		
KENSLAB		125.762	162.8	210.03	250.408	267.879		
MR	n/a	100	200	450	600	650	n/a	n/a
Repetitions	n/a	8.26E+05	6.26E+07	3.42E+09	unlimited	unlimited	n/a	n/a

APPENDIX E - TOP-DOWN HMA SURFACE FATIGUE MECHANISTIC ANALYSIS TABLE

Strain X					
Granular	SC	CTB	LEAN	RCC	PCC
-1.91E-05	-5.88E-06	-4.49E-06	-3.10E-06	-4.41E-06	-5.62E-06
-1.21E-05	-5.88E-06	-4.49E-06	-3.10E-06	-1.91E-06	-1.63E-06
-1.23E-05	-5.73E-06	-4.30E-06	-2.88E-06	-1.69E-06	-1.41E-06
-1.27E-05	-5.63E-06	-4.15E-06	-2.71E-06	-1.53E-06	-1.25E-06
-1.30E-05	-5.49E-06	-3.97E-06	-2.51E-06	-1.32E-06	-1.05E-06
-1.33E-05	-5.33E-06	-3.76E-06	-2.28E-06	-1.10E-06	-8.29E-07
-1.36E-05	-5.12E-06	-3.51E-06	-2.02E-06	-8.38E-07	-5.71E-07
-1.40E-05	-4.97E-06	-3.31E-06	-1.80E-06	-6.27E-07	-3.65E-07
-1.44E-05	-4.76E-06	-3.07E-06	-1.54E-06	-3.72E-07	-1.15E-07
-1.47E-05	-4.53E-06	-2.79E-06	-1.24E-06	-8.97E-08	1.62E-07
-1.51E-05	-4.30E-06	-2.52E-06	-9.58E-07	1.82E-07	4.28E-07
-1.54E-05	-4.00E-06	-2.17E-06	-6.05E-07	5.19E-07	7.58E-07
-1.58E-05	-3.71E-06	-1.83E-06	-2.56E-07	8.50E-07	1.08E-06
-1.61E-05	-3.40E-06	-1.48E-06	1.03E-07	1.19E-06	1.41E-06
-1.65E-05	-3.08E-06	-1.12E-06	4.74E-07	1.54E-06	1.75E-06
-1.68E-05	-2.69E-06	-6.84E-07	9.12E-07	1.95E-06	2.15E-06
-1.72E-05	-2.31E-06	-2.62E-07	1.33E-06	2.34E-06	2.53E-06
-1.75E-05	-1.87E-06	2.16E-07	1.81E-06	2.78E-06	2.96E-06
-1.78E-05	-1.42E-06	7.14E-07	2.31E-06	3.24E-06	3.40E-06
-1.82E-05	-9.44E-07	1.23E-06	2.81E-06	3.70E-06	3.85E-06
-1.84E-05	-3.71E-07	1.85E-06	3.42E-06	4.26E-06	4.39E-06
-1.87E-05	1.45E-07	2.40E-06	3.96E-06	4.75E-06	4.86E-06
-1.88E-05	9.26E-07	3.23E-06	4.77E-06	5.49E-06	5.59E-06
-1.90E-05	1.51E-06	3.86E-06	5.38E-06	6.04E-06	6.12E-06
-1.91E-05	2.27E-06	4.66E-06	6.16E-06	6.75E-06	6.80E-06
-1.91E-05	3.04E-06	5.48E-06	6.94E-06	7.46E-06	7.49E-06
-1.91E-05	3.91E-06	6.40E-06	7.83E-06	8.26E-06	8.26E-06
-1.89E-05	4.83E-06	7.36E-06	8.77E-06	9.10E-06	9.08E-06
-1.86E-05	5.78E-06	8.37E-06	9.73E-06	9.97E-06	9.92E-06
-1.80E-05	6.94E-06	9.59E-06	1.09E-05	1.11E-05	1.10E-05
-1.75E-05	7.96E-06	1.07E-05	1.20E-05	1.20E-05	1.19E-05
-1.65E-05	9.15E-06	1.19E-05	1.32E-05	1.31E-05	1.29E-05
-1.54E-05	1.04E-05	1.32E-05	1.44E-05	1.42E-05	1.40E-05
-1.38E-05	1.17E-05	1.46E-05	1.58E-05	1.54E-05	1.52E-05
-1.18E-05	1.31E-05	1.61E-05	1.72E-05	1.66E-05	1.64E-05
-9.47E-06	1.43E-05	1.73E-05	1.83E-05	1.76E-05	1.73E-05
-6.42E-06	1.56E-05	1.86E-05	1.95E-05	1.86E-05	1.82E-05
-2.61E-06	1.69E-05	1.98E-05	2.05E-05	1.93E-05	1.89E-05
2.03E-06	1.80E-05	2.06E-05	2.11E-05	1.97E-05	1.92E-05
7.39E-06	1.87E-05	2.09E-05	2.09E-05	1.92E-05	1.86E-05
1.41E-05	1.94E-05	2.08E-05	2.04E-05	1.83E-05	1.76E-05
2.17E-05	1.93E-05	1.98E-05	1.86E-05	1.60E-05	1.52E-05
2.90E-05	1.73E-05	1.65E-05	1.44E-05	1.12E-05	1.03E-05
3.56E-05	1.31E-05	1.07E-05	7.33E-06	3.44E-06	2.38E-06
4.42E-05	9.40E-06	5.03E-06	2.80E-07	-4.41E-06	-5.62E-06
7.72E-05	2.93E-05	2.27E-05	1.64E-05	1.08E-05	9.43E-06
1.56E-04	9.45E-05	8.56E-05	7.76E-05	7.11E-05	6.96E-05
1.12E-04	3.83E-05	2.71E-05	1.74E-05	1.01E-05	8.40E-06
1.75E-04	8.96E-05	7.63E-05	6.52E-05	5.71E-05	5.52E-05
1.89E-04	9.52E-05	8.02E-05	6.79E-05	5.92E-05	5.72E-05
1.93E-04	9.30E-05	7.70E-05	6.39E-05	5.49E-05	5.28E-05
1.95E-04	9.26E-05	7.62E-05	6.29E-05	5.37E-05	5.17E-05
1.93E-04	9.30E-05	7.70E-05	6.39E-05	5.49E-05	5.28E-05
1.89E-04	9.52E-05	8.02E-05	6.79E-05	5.92E-05	5.72E-05
1.75E-04	8.96E-05	7.63E-05	6.52E-05	5.71E-05	5.52E-05
1.12E-04	3.83E-05	2.71E-05	1.74E-05	1.01E-05	8.40E-06
1.56E-04	9.45E-05	8.56E-05	7.76E-05	7.11E-05	6.96E-05
7.72E-05	2.93E-05	2.27E-05	1.64E-05	1.08E-05	9.43E-06
4.42E-05	9.40E-06	5.03E-06	2.80E-07	-4.41E-06	-5.62E-06
3.56E-05	1.31E-05	1.07E-05	7.33E-06	3.44E-06	2.38E-06
2.90E-05	1.73E-05	1.65E-05	1.44E-05	1.12E-05	1.03E-05
2.17E-05	1.93E-05	1.98E-05	1.86E-05	1.60E-05	1.52E-05
1.41E-05	1.94E-05	2.08E-05	2.04E-05	1.83E-05	1.76E-05
7.39E-06	1.87E-05	2.09E-05	2.09E-05	1.92E-05	1.86E-05
2.03E-06	1.80E-05	2.06E-05	2.11E-05	1.97E-05	1.92E-05
-2.61E-06	1.69E-05	1.98E-05	2.05E-05	1.93E-05	1.89E-05
-6.42E-06	1.56E-05	1.86E-05	1.95E-05	1.86E-05	1.82E-05
-9.47E-06	1.43E-05	1.73E-05	1.83E-05	1.76E-05	1.73E-05
-1.18E-05	1.31E-05	1.61E-05	1.72E-05	1.66E-05	1.64E-05
-1.38E-05	1.17E-05	1.46E-05	1.58E-05	1.54E-05	1.52E-05
-1.54E-05	1.04E-05	1.32E-05	1.44E-05	1.42E-05	1.40E-05
-1.65E-05	9.15E-06	1.19E-05	1.32E-05	1.31E-05	1.29E-05
-1.75E-05	7.96E-06	1.07E-05	1.20E-05	1.20E-05	1.19E-05
-1.80E-05	6.94E-06	9.59E-06	1.09E-05	1.11E-05	1.10E-05
-1.86E-05	5.78E-06	8.37E-06	9.73E-06	9.97E-06	9.92E-06
-1.89E-05	4.83E-06	7.36E-06	8.77E-06	9.10E-06	9.08E-06
-1.91E-05	3.91E-06	6.40E-06	7.83E-06	8.26E-06	8.26E-06
-1.91E-05	3.04E-06	5.48E-06	6.94E-06	7.46E-06	7.49E-06
-1.91E-05	2.27E-06	4.66E-06	6.16E-06	6.75E-06	6.80E-06
-1.90E-05	1.51E-06	3.86E-06	5.38E-06	6.04E-06	6.12E-06
-1.88E-05	9.26E-07	3.23E-06	4.77E-06	5.49E-06	5.59E-06
-1.87E-05	1.45E-07	2.40E-06	3.96E-06	4.75E-06	4.86E-06
-1.84E-05	-3.71E-07	1.85E-06	3.42E-06	4.26E-06	4.39E-06
-1.82E-05	-9.44E-07	1.23E-06	2.81E-06	3.70E-06	3.85E-06
-1.78E-05	-1.42E-06	7.14E-07	2.31E-06	3.24E-06	3.40E-06
-1.75E-05	-1.87E-06	2.16E-07	1.81E-06	2.78E-06	2.96E-06
-1.72E-05	-2.31E-06	-2.62E-07	1.33E-06	2.34E-06	2.53E-06
-1.68E-05	-2.69E-06	-6.84E-07	9.12E-07	1.95E-06	2.15E-06
-1.65E-05	-3.08E-06	-1.12E-06	4.74E-07	1.54E-06	1.75E-06
-1.61E-05	-3.40E-06	-1.48E-06	1.03E-07	1.19E-06	1.41E-06
-1.58E-05	-3.71E-06	-1.83E-06	-2.56E-07	8.50E-07	1.08E-06
-1.54E-05	-4.00E-06	-2.17E-06	-6.05E-07	5.19E-07	7.58E-07
-1.51E-05	-4.30E-06	-2.52E-06	-9.58E-07	1.82E-07	4.28E-07
-1.47E-05	-4.53E-06	-2.79E-06	-1.24E-06	-8.97E-08	1.62E-07
-1.44E-05	-4.76E-06	-3.07E-06	-1.54E-06	-3.72E-07	-1.15E-07
-1.40E-05	-4.97E-06	-3.31E-06	-1.80E-06	-6.27E-07	-3.65E-07
-1.36E-05	-5.12E-06	-3.51E-06	-2.02E-06	-8.38E-07	-5.71E-07
-1.33E-05	-5.33E-06	-3.76E-06	-2.28E-06	-1.10E-06	-8.29E-07
-1.30E-05	-5.49E-06	-3.97E-06	-2.51E-06	-1.32E-06	-1.05E-06
-1.27E-05	-5.63E-06	-4.15E-06	-2.71E-06	-1.53E-06	-1.25E-06
-1.23E-05	-5.73E-06	-4.30E-06	-2.88E-06	-1.69E-06	-1.41E-06

APPENDIX F - TEMPERATURE GRADIENT REDUCTION ANALYSIS SPREADSHEET

h_{ac} (cm)	h_{ac} (in.)	Dense AC Reduction Factor	Porous AC Reduction Factor
4.0	1.6	1.02	0.99
4.2	1.7	1.01	0.97
4.4	1.7	0.99	0.96
4.6	1.8	0.97	0.94
4.8	1.9	0.96	0.92
5.0	2.0	**0.94**	**0.90**
5.2	2.0	0.92	0.89
5.4	2.1	0.91	0.87
5.6	2.2	0.89	0.86
5.8	2.3	0.88	0.84
6.0	2.4	**0.86**	**0.82**
6.2	2.4	0.84	0.81
6.4	2.5	0.83	0.79
6.6	2.6	0.82	0.78
6.8	2.7	0.80	0.76
7.0	2.8	**0.79**	**0.75**
7.2	2.8	0.77	0.74
7.4	2.9	0.76	0.72
7.6	3.0	0.75	0.71
7.8	3.1	0.73	0.70
8.0	3.1	**0.72**	**0.68**
8.2	3.2	0.71	0.67
8.4	3.3	0.70	0.66
8.6	3.4	0.68	0.65
8.8	3.5	0.67	0.63
9.0	3.5	**0.66**	**0.62**
9.2	3.6	0.65	0.61
9.4	3.7	0.64	0.60
9.6	3.8	0.63	0.59
9.8	3.9	0.62	0.58
10.0	3.9	**0.61**	**0.57**

APPENDIX G - ECONOMIC EVALUATION SPREADSHEETS

FLEXIBLE PAVEMENT ALTERNATIVE

Total Travel Lanes Width =	24	Ft
Inside Shoulder Width =	10	Ft
Outside Shoulder Width =	12	Ft
Length of Road =	5,280	Ft
Mainline Area =	126,720	Square Ft
Inside Shoulder Area =	52,800	Square Ft
Outside Shoulder Area =	63,360	Square Ft

Inside Shoulder

Paved Road (Mainline Area)

Outside Shoulder

Typical from VDOT

AC SM + IM + BM	11.5"		
Drainage Layer	0		
Granular Base	8"	$	239,996
Subbase	9"	$	1,136,729

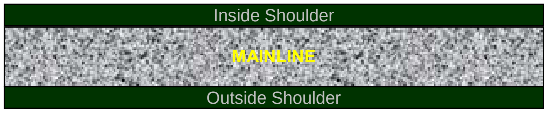
Analysis Year	Calendar Year	Activity		Thickness (in.)	Quantity	Units	Unit Cost	Total	PWC
0	2007	Mainline - AC Surface		2	1,541.76	Tons	$ 76.00	$ 117,174	$ 117,174
		Mainline - AC Intermediate		4	3,083.52	Tons	$ 65.00	$ 200,429	$ 200,429
		Mainline - AC Base		5.5	4,443.12	Tons	$ 62.00	$ 275,473	$ 275,473
		Mainline and Shoulder - Stabilized Drainage Layer		1.5	2,216.28	Tons	$ 25.00	$ 55,407	$ 55,407
		Mainline - CTA		0	0.00	Tons	$ 21.00	$ -	$ -
		Mainline - 21A		0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - 21B	(granular base)	8	6,420.48	Tons	$ 18.00	$ 115,569	$ 115,569
		Mainline - Type 1 Aggregate	(subbase)	9	7,128.00	Tons	$ 15.00	$ 106,920	$ 106,920
		Shoulder - AC Surface		2	1,413.28	Tons	$ 76.00	$ 107,409	$ 107,409
		Shoulder - AC Intermediate		4	2,826.56	Tons	$ 65.00	$ 183,726	$ 183,726
		Shoulder - AC Base		5.5	4,072.86	Tons	$ 62.00	$ 252,517	$ 252,517
		Shoulder - CTA		0	0.00	Tons	$ 21.00	$ -	$ -
		Shoulder - 21A		0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - 21B		8	5,808.00	Tons	$ 18.00	$ 104,544	$ 104,544
		Shoulder - Type 1 Aggregate		9	6,534.00	Tons	$ 15.00	$ 98,010	$ 98,010
							Cost Estimate	*$ 1,617,179*	*$ 1,617,179*
12	2019	Mainline - Pre-Overlay Full-Depth Patching 1%		11.5	88.65	Tons	$ 90.00	$ 7,979	$ 4,983
		Mainline - Mill		2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 8,794
		Mainline and Shoulders - Replace AC Wearing Course		2	2,955.04	Tons	$ 76.00	$ 224,583	$ 140,274
		Shoulders - Surface Treatment			12,906.67	SY	$ 1.50	$ 19,360	$ 12,092
							Cost Estimate	*$ 266,002*	*$ 166,144*
22	2029	Mainline - Pre-Overlay Full-Depth Patching 1%		11.5	88.65	Tons	$ 90.00	$ 7,979	$ 3,367
		Mainline - Mill		2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 5,941
		Mainline - Replace AC Intermediate		2	1,541.76	Tons	$ 65.00	$ 100,214	$ 42,286
		Mainline and Shoulders - Overlay AC Wearing Course		2	2,955.04	Tons	$ 76.00	$ 224,583	$ 94,764
							Cost Estimate	*$ 346,856*	*$ 146,358*
32	2039	Mainline - Pre-Overlay Full-Depth Patch 5%		5.5	211.99	Tons	$ 90.00	$ 19,079	$ 5,439
		Mainline - Mill All SM and IM Layers		8	112,640.00	SY-in	$ 0.50	$ 56,320	$ 16,054
		Mainline - Replace AC Base		1.5	1,211.76	Tons	$ 62.00	$ 75,129	$ 21,416
		Mainline - Replace AC Intermediate		4	3,083.52	Tons	$ 65.00	$ 200,429	$ 57,134
		Mainline and Shoulders - Overlay AC Wearing Course		2	2,955.04	Tons	$ 76.00	$ 224,583	$ 64,019
							Cost Estimate	*$ 575,540*	*$ 164,062*
44	2051	Mainline - Pre-Overlay Full-Depth Patching 1%		13	100.21		$ 90.00	$ 9,019	$ 1,606
		Mainline - Mill		2	28,160.00		$ 0.50	$ 14,080	$ 2,507
		Mainline - Replace AC Wearing Course		2	1,541.76		$ 76.00	$ 117,174	$ 20,862
		Shoulders - Surface Treatment			12,906.67		$ 1.50	$ 19,360	$ 3,447
							Cost Estimate	*$ 159,633*	*$ 28,422*
50	2057	Salvage Value			0.40	Lump Sum	$ (159,633.06)	$ (63,853)	$ (8,985)
							Cost Estimate	*$ (63,853)*	*$ (8,985)*

Initial Const.	**$**	**1,617,179**
Total PW	**$**	**2,113,180**

RIGID PAVEMENT ALTERNATIVE (CRCP Construction with Tied PCC Shoulders)

Total Travel Lanes Width =	24	Ft
Inside Shoulder Width =	10	Ft
Outside Shoulder Width =	12	Ft
Length of Road =	5,280	Ft
Mainline Area =	126,720	Square Ft
Inside Shoulder Area =	52,800	Square Ft
Outside Shoulder Area =	63,360	Square Ft

In BLUE are the items considered for the Flexible Alternative



Typical from VD("

CRCP
Drainage Layer
CTA Layer

Analysis Year	Calendar Year	Activity	Thickness (in.)	Quantity	Units	Unit Cost	Total	PWC
0	2007	Mainline - CRCP	14	14,080.00	SY	$ 85.00	$ 1,196,800.00	$ 1,196,800.00
		Mainline and Shoulders - Stabilized Drainage Layer	1.5	2,216.28	Tons	$ 34.00	$ 75,353.52	$ 75,353.52
		Mainline - CTA	6	4,752.00	Tons	$ 21.00	$ 99,792.00	$ 99,792.00
		Mainline - 21A	0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - 21B	0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - Type 1 Aggregate	0	0.00	Tons	$ 15.00	$ -	$ -
		Shoulder - CRCP	14	12,906.67	SY	$ 85.00	$ 1,097,066.67	$ 1,097,066.67
		Shoulder - CTA	6	4,356.00	Tons	$ 21.00	$ 91,476.00	$ 91,476.00
		Shoulder - 21A	0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - 21B	0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - Type 1 Aggregate	0	0.00	Tons	$ 15.00	$ -	$ -
						Cost Estimate	*$ 2,560,488.19*	*$ 2,560,488.19*
10	2017	Mainline - Crack/Punchout Repair 2%	2	281.60	SY	$ 200.00	$ 56,320.00	$ 38,047.77
		Mainline and Shoulders - Clean and Seal Longitudinal Joints	100	15,840.00	Lin Ft	$ 1.00	$ 15,840.00	$ 10,700.94
						Cost Estimate	*$ 72,160.00*	*$ 48,748.71*
20	2027	Mainline - Crack/Punchout Repair 5%	5	704.00	SY	$ 200.00	$ 140,800.00	$ 64,259.28
		Mainline and Shoulders - Overlay AC Intermediate	2	2,955.04	Tons	$ 65.00	$ 192,077.60	$ 87,661.71
		Mainline and Shoulders - Overlay AC Wearing Course	1.5	2,216.28	Tons	$ 76.00	$ 168,437.28	$ 76,872.58
						Cost Estimate	*$ 501,314.88*	*$ 228,793.57*
30	2037	Mainline - Crack/Punchout Repair 5%	5	704.00	SY	$ 200.00	$ 140,800.00	$ 43,411.27
		Mainline - Pre-Overlay Full-Depth Patching of AC Layers 5%	3.5	134.90	Tons	$ 90.00	$ 12,141.00	$ 3,743.30
		Mainline - Mill	2	28,160.00	SY-in	$ 0.50	$ 14,080.00	$ 4,341.13
		Mainline - Replace AC Wearing Course	2	1,541.76	Tons	$ 76.00	$ 117,173.76	$ 36,126.86
		Shoulders - Surface Treatment		12,906.67	SY	$ 1.50	$ 19,360.01	$ 5,969.05
						Cost Estimate	*$ 303,554.77*	*$ 93,591.60*
40	2047	Mainline - Crack/Punchout Repair 10%	10	1,408.00	SY	$ 200.00	$ 281,600.00	$ 58,654.19
		Mainline - Mill	3.5	49,280.00	SY-in	$ 0.50	$ 24,640.00	$ 5,132.24
		Mainline - Replace AC Intermediate Course	2	1,541.76	Tons	$ 65.00	$ 100,214.40	$ 20,873.56
		Mainline - Replace AC Wearing Course	1.5	1,156.32	Tons	$ 76.00	$ 87,880.32	$ 18,304.51
		Shoulders - Surface Treatment		12,906.67	SY	$ 1.50	$ 19,360.01	$ 4,032.48
						Cost Estimate	*$ 513,694.73*	*$ 106,996.98*
40	2047	Salvage Value		0.00	Lump Sum	$ (513,694.73)	$ -	$ -
						Cost Estimate	*$ -*	*$ -*

Initial Const.	**$ 2,560,488.19**
Total PW	**$ 3,038,619.05**

COMPOSITE PAVEMENT ALTERNATIVE (HMA over CTB)

Total Travel Lanes Width =	24	Ft
Inside Shoulder Width =	10	Ft
Outside Shoulder Width =	12	Ft
Length of Road =	5,280	Ft
Mainline Area =	126,720	Square Ft
Inside Shoulder Area =	52,800	Square Ft
Outside Shoulder Area =	63,360	Square Ft

Inside Shoulder

Paved Road (Mainline Area)

Outside Shoulder

Typical CTB Composite (UK Design)

AC SM + IM + BM

Drainage Layer

CTA (Base Layer)

Subbase

Analysis Year	Calendar Year	Activity	Thickness (in.)	Quantity	Units	Unit Cost	Total	PWC
0	2007	Mainline - AC Surface	2	1,541.76	Tons	$ 76.00	$ 117,174	$ 117,174
		Mainline - AC Intermediate	4	3,083.52	Tons	$ 65.00	$ 200,429	$ 200,429
		Mainline - AC Base	3	2,423.52	Tons	$ 62.00	$ 150,258	$ 150,258
		Mainline - CTA	8	6,336.00	Tons	$ 21.00	$ 133,056	$ 133,056
		Mainline - 21A	0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - 21B (granular base)	0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - Type 1 Aggregate (subbase)	9	7,128.00	Tons	$ 15.00	$ 106,920	$ 106,920
		Mainline and Shoulder - Stabilized Drainage Layer	1.5	2,216.28	Tons	$ 25.00	$ 55,407	$ 55,407
		Shoulder - AC Surface	2	1,413.28	Tons	$ 76.00	$ 107,409	$ 107,409
		Shoulder - AC Intermediate	4	2,826.56	Tons	$ 65.00	$ 183,726	$ 183,726
		Shoulder - AC Base	3	2,221.56	Tons	$ 62.00	$ 137,737	$ 137,737
		Shoulder - CTA	8	5,808.00	Tons	$ 21.00	$ 121,968	$ 121,968
		Shoulder - 21A	0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - 21B	0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - Type 1 Aggregate	9	6,534.00	Tons	$ 15.00	$ 98,010	$ 98,010
						Cost Estimate	*$ 1,412,094*	*$ 1,412,094*
12	2019	Mainline - Pre-Overlay Full-Depth Patching 1%	9	69.38	Tons	$ 90.00	$ 6,244	$ 3,900
		Mainline - Mill	2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 8,794
		Mainline - Replace AC Wearing Course	2	1,541.76	Tons	$ 76.00	$ 117,174	$ 73,186
		Shoulders - Surface Treatment		12,906.67	SY	$ 1.50	$ 19,360	$ 12,092
						Cost Estimate	*$ 156,858*	*$ 97,973*
22	2029	Mainline - Pre-Overlay Full-Depth Patching 1%	9	69.38	Tons	$ 90.00	$ 6,244	$ 2,635
		Mainline - Mill	2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 5,941
		Mainline - Replace AC Intermediate	2	1,541.76	Tons	$ 65.00	$ 100,214	$ 42,286
		Mainline and Shoulders - Overlay AC Wearing Course	2	2,955.04	Tons	$ 76.00	$ 224,583	$ 94,764
						Cost Estimate	*$ 345,122*	*$ 145,626*
32	2039	Mainline - Pre-Overlay Full-Depth Patch 5%	3	115.63	Tons	$ 90.00	$ 10,407	$ 2,967
		Mainline - Mill All SM and IM Layers	8	112,640.00	SY-in	$ 0.50	$ 56,320	$ 16,054
		Mainline - Replace AC Base	3.5	2,827.44	Tons	$ 62.00	$ 175,301	$ 49,971
		Mainline - Replace AC Intermediate	2	1,541.76	Tons	$ 65.00	$ 100,214	$ 28,567
		Mainline and Shoulders - Overlay AC Wearing Course	2	2,955.04	Tons	$ 76.00	$ 224,583	$ 64,019
						Cost Estimate	*$ 566,826*	*$ 161,578*
44	2051	Mainline - Pre-Overlay Full-Depth Patching 1%	10.5	80.94		$ 90.00	$ 7,285	$ 1,297
		Mainline - Mill	2	28,160.00		$ 0.50	$ 14,080	$ 2,507
		Mainline - Replace AC Wearing Course	2	1,541.76		$ 76.00	$ 117,174	$ 20,862
		Shoulders - Surface Treatment		12,906.67		$ 1.50	$ 19,360	$ 3,447
						Cost Estimate	*$ 157,899*	*$ 28,113*
50	2057	Salvage Value		0.40	Lump Sum	$ (157,898.58)	$ (63,159)	$ (8,887)
						Cost Estimate	*$ (63,159)*	*$ (8,887)*

Initial Const.	**$ 1,412,094**
Total PW	**$ 1,836,497**

COMPOSITE PAVEMENT ALTERNATIVE (HMA over CRCP)

Total Travel Lanes Width =	24	Ft
Inside Shoulder Width =	10	Ft
Outside Shoulder Width =	12	Ft
Length of Road =	5,280	Ft
Mainline Area =	126,720	Square Ft
Inside Shoulder Area =	52,800	Square Ft
Outside Shoulder Area =	63,360	Square Ft

Inside Shoulder
Paved Road (Mainline Area)
Outside Shoulder

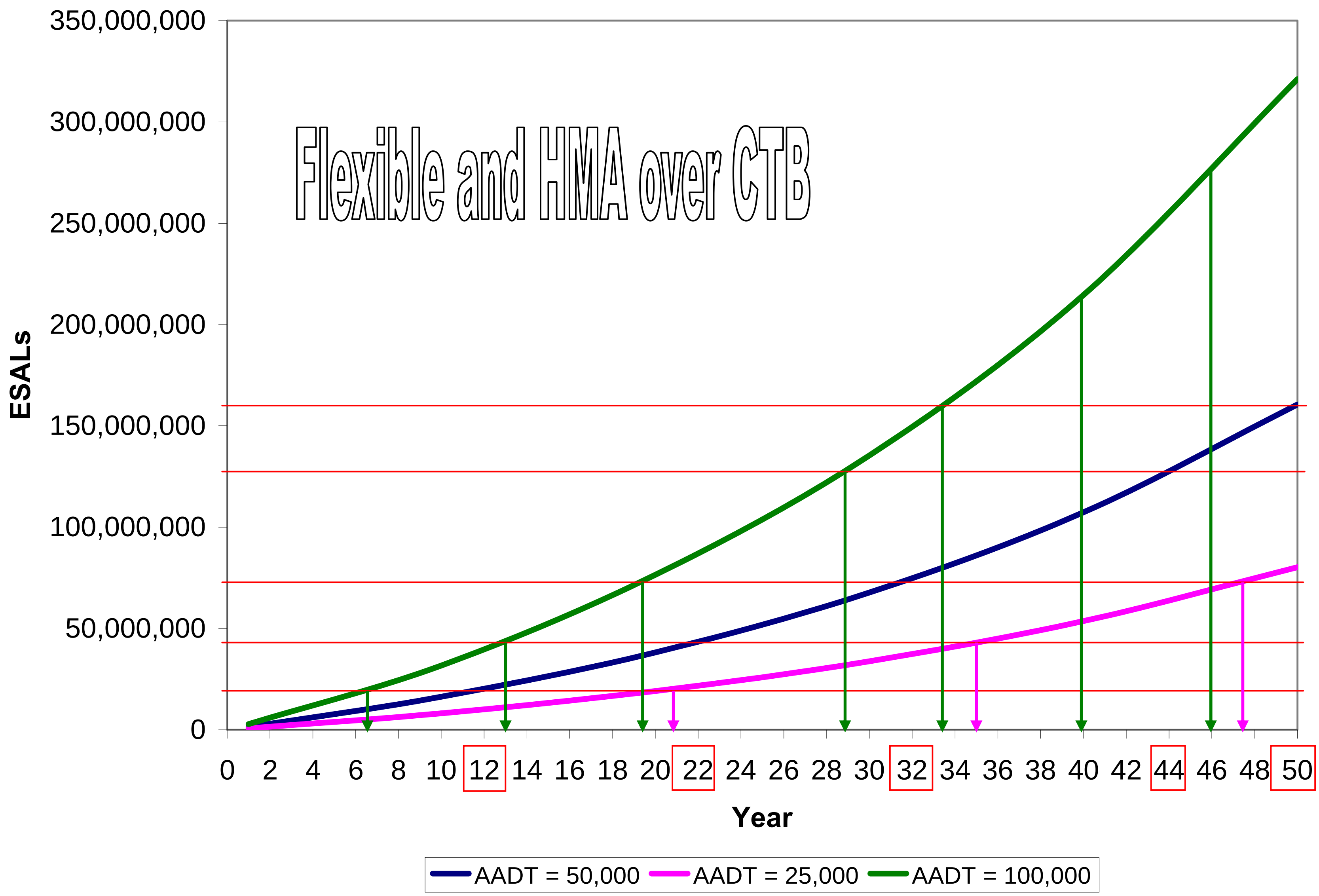
Typical CRCP Composite
Paved Road

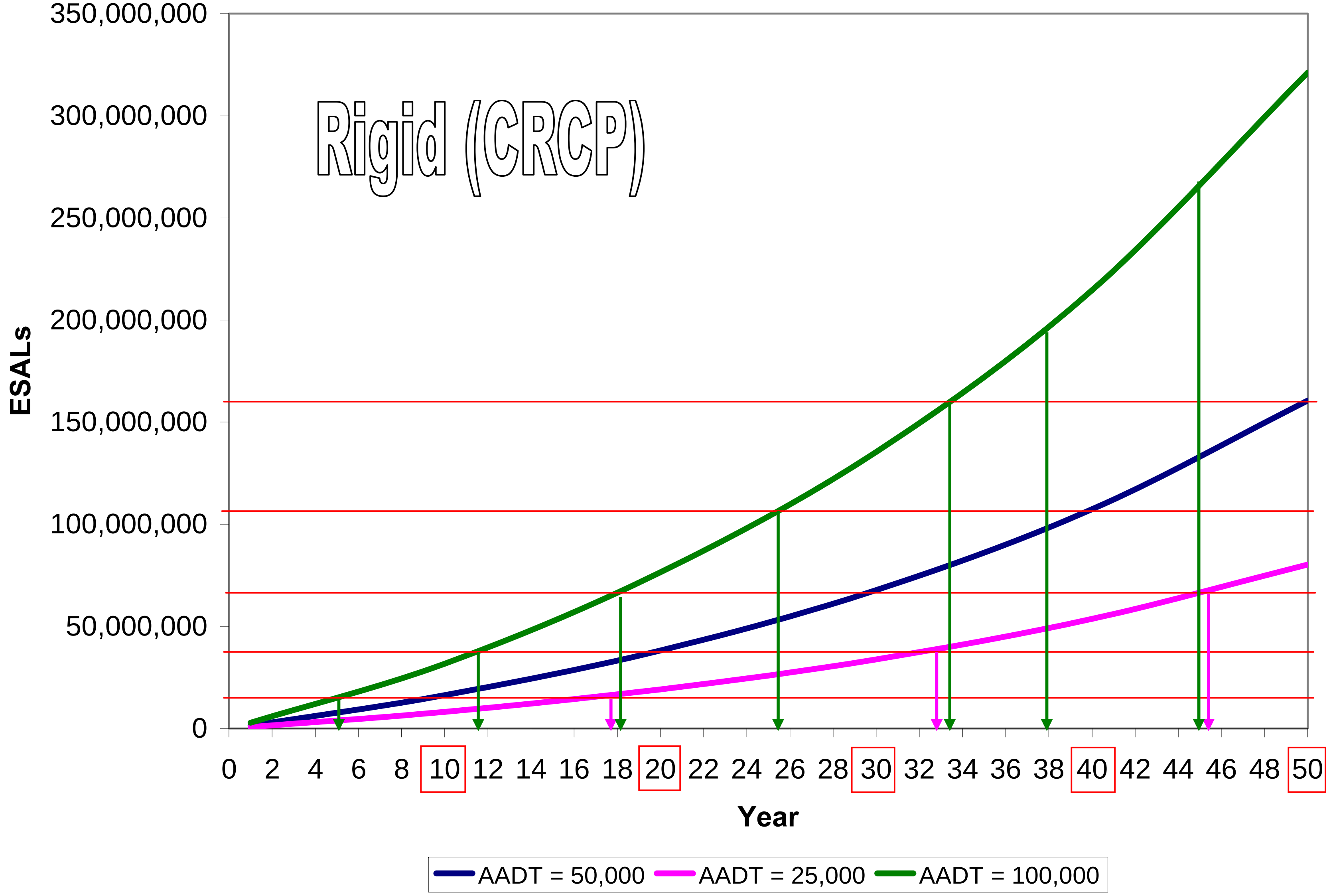
AC SM + IM + BM
Drainage Layer
CRCP Base
Subbase

Analysis Year	Calendar Year	Activity		Thickness (in.)	Quantity	Units	Unit Cost	Total	PWC
0	2007	Mainline - AC Surface		2	1,541.76	Tons	$ 40.00	$ 61,670	$ 61,670
		Mainline - AC Intermediate		2	1,541.76	Tons	$ 34.00	$ 52,420	$ 52,420
		Mainline - AC Base		3	2,423.52	Tons	$ 31.00	$ 75,129	$ 75,129
		Mainline - CRCP		8	14,080.00	SY	$ 66.00	$ 929,280	$ 929,280
		Mainline - 21A		0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - 21B	(granular base)	0	0.00	Tons	$ 18.00	$ -	$ -
		Mainline - Type 1 Aggregate	(subbase)	9	7,128.00	Tons	$ 15.00	$ 106,920	$ 106,920
		Mainline and Shoulder - Stabilized Drainage Layer		1.5	2,216.28	Tons	$ 25.00	$ 55,407	$ 55,407
		Shoulder - AC Surface		2	1,413.28	Tons	$ 40.00	$ 56,531	$ 56,531
		Shoulder - AC Intermediate		2	1,413.28	Tons	$ 34.00	$ 48,052	$ 48,052
		Shoulder - AC Base		3	2,221.56	Tons	$ 31.00	$ 68,868	$ 68,868
		Shoulder - CRCP		8	12,906.67	Tons	$ 66.00	$ 851,840	$ 851,840
		Shoulder - 21A		0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - 21B		0	0.00	Tons	$ 18.00	$ -	$ -
		Shoulder - Type 1 Aggregate		9	6,534.00	Tons	$ 15.00	$ 98,010	$ 98,010
							Cost Estimate	*$ 2,404,127*	*$ 2,404,127*
10	2017	Mainline - Pre-Overlay Full-Depth Patching 1%		7	53.96	Tons	$ 90.00	$ 4,857	$ 3,281
		Mainline - Mill		2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 9,512
		Mainline - Overlay AC Wearing Course		2	1,541.76	Tons	$ 76.00	$ 117,174	$ 79,158
		Shoulders - Surface Treatment			12,906.67	SY	$ 1.50	$ 19,360	$ 13,079
							Cost Estimate	*$ 155,470*	*$ 105,030*
20	2027	Mainline - Pre-Overlay Full-Depth Patching 1%		7	53.96	Tons	$ 90.00	$ 4,857	$ 2,216
		Mainline - Mill		2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 6,426
		Mainline - Overlay AC Wearing Course		2	1,541.76	Tons	$ 76.00	$ 117,174	$ 53,477
							Cost Estimate	*$ 136,110*	*$ 62,119*
30	2037	Mainline - Pre-Overlay Full-Depth Patching 1%		7	53.96	Tons	$ 90.00	$ 4,857	$ 1,497
		Mainline - Mill		2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 4,341
		Mainline - Overlay AC Wearing Course		2	1,541.76	Tons	$ 76.00	$ 117,174	$ 36,127
							Cost Estimate	*$ 136,110*	*$ 41,965*
40	2047	Mainline - Pre-Overlay Full-Depth Patching 1%		7	53.96	Tons	$ 90.00	$ 4,857	$ 1,012
		Mainline - Mill		2	28,160.00	SY-in	$ 0.50	$ 14,080	$ 2,933
		Mainline - Overlay AC Wearing Course		2	1,541.76	Tons	$ 76.00	$ 117,174	$ 24,406
		Shoulders - Surface Treatment			12,906.67	SY	$ 1.50	$ 19,360	$ 4,032
							Cost Estimate	*$ 155,470*	*$ 32,383*
50	2057	Salvage Value			0.40	Lump Sum	$ (155,470.30)	$ (62,188)	$ (8,751)
						Cost Estimate		*$ (62,188)*	*$ (8,751)*

Initial Const.	**$ 2,404,127**
Total PW	**$ 2,636,874**

Discount Rate	PW
2%	$2,399,747
	$3,357,286
	$2,102,390
	$2,745,714
3%	$2,237,186
	$3,174,285
	$1,950,947
	$2,684,723
4%	$2,113,180
	$3,038,619
	$1,836,497
	$2,636,874
5%	$2,017,744
	$2,936,932
	$1,749,320
	$2,599,025
6%	$1,943,639
	$2,859,889
	$1,682,385
	$2,568,818


Flexible and HMA over CTB
350,000,000
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
ESALs
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Year
AADT = 50,000
AADT = 25,000
AADT = 100,000


Rigid (CRCP)
ESALs
350,000,000
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Year
AADT = 50,000
AADT = 25,000
AADT = 100,000

~33M		~67M		~135M		
M&R Year	PW	M&R Year	PW	M&R Year	PW	
21		12		7		
35		22		13		
47	1,903,921	32	2,113,180	19	2,907,754	Flexible
		44		29		
		50		33		
21		12		7		
35		22		13		
47	1,649,219	32	1,836,497	19	2,534,765	Composite with CTB
		44		29		
		50		33		
18		10		5		
33		20		12		
45	2,785,483	30	3,038,619	18	4,079,351	Rigid
		40		25		
		50		33		
10		10		10		
20		20		20		
30	2,636,874	30	2,636,874	30	2,636,874	Composite with CRCP
40		40		40		
50		50		50		

FLEXIBLE		*reconstruction*			
Year	0-29	33	40	46	
	2,351,993	443,259	55,405	57,097	**2,907,754**
CTB					
Year	0-29	33	40	46	
	2,058,234	387,047	32,672	56,812	**2,534,765**
RIGID					
Year	0-25	33	38	45	
	3,275,456	701,814	16,257	85,824	**4,079,351**