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Research Report

STRUCTURAL PAVEMENT DESIGN ADVANCEMENT IN ALABAMA – PHASE I: SOFTWARE DEVELOPMENT AND DESIGN INPUT ASSESSMENT

Submitted to

The Alabama Department of Transportation

Prepared by

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Like many agencies, the Alabama Department of Transportation (ALDOT) uses the AASHTO 1993 Design Guide as the basis for pavement thickness design in Alabama. The design software, DARWin, is no longer supported by AASHTO, causing a need for an Alabama-specific version of the software that can be used by ALDOT and its consultants in modern Windows-based operating systems. Further, there is a need to (1) gather and assess datasets that will support the assessment of current AASHTO 1993 design inputs, (2) compare computed design inputs from those datasets to current default values used by ALDOT, and (3) extract from the datasets information that could be used for future implementation of the AASHTOWare© Pavement-ME pavement design software. The outcomes of this project include the development of the Alabama Design and Analysis of Pavement Thickness (ADAPT) software which can be deployed throughout ALDOT and amongst its consultants to design pavements in accordance with the AASHTO 1993 methodology. A sensitivity analysis of design comparing ADAPT to DARWin is provided. A Microsoft Access database of historical data for subgrade, aggregate base, stabilized base, asphalt concrete, and portland cement concrete was also created. This database was then used to statistically compare the current ALDOT default structural inputs with measured values. It is recommended that ALDOT not change its current structural design inputs for aggregate base and reassess the way it currently evaluates Full Depth Reclamation with cement and soil-cement mixtures. Subgrade moduli for 11 AASHTO classified materials are also provided.</td></tr>
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DISCLAIMERS

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NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES

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ABSTRACT

Like many agencies, the Alabama Department of Transportation (ALDOT) uses the American Association of State Highway Transportation Officials (AASHTO) 1993 Design Guide as the basis for pavement thickness design in Alabama. The design software, DARWin, is no longer supported by AASHTO, causing a need for an Alabama-specific version of the software that can be used by ALDOT and its consultants in modern Windows-based operating systems. Further, there is a need to (1) gather and assess datasets that will support the assessment of current AASHTO 1993 design inputs, (2) compare computed design inputs from those datasets to current default values used by ALDOT, and (3) extract from the datasets information that could be used for future implementation of the AASHTOWare© Pavement-ME pavement design software. The outcomes of this project include the development of the Alabama Design and Analysis of Pavement Thickness (ADAPT) software which can be deployed throughout ALDOT and amongst its consultants to design pavements in accordance with the AASHTO 1993 methodology. A sensitivity analysis of design comparing ADAPT to DARWin is provided. A Microsoft Access database of historical data for subgrade, aggregate base, stabilized base, asphalt concrete, and portland cement concrete was also created. This database was then used to statistically compare the current ALDOT default structural inputs with measured values. It is recommended that ALDOT not change its current structural design inputs for aggregate base and reassess the way it currently evaluates Full Depth Reclamation with cement and soil-cement mixtures. Subgrade moduli for 11 AASHTO classified materials are also provided.

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1 INTRODUCTION

1.1 OVERVIEW

The Alabama Department of Transportation (ALDOT) currently uses DARWin 3.1, a software based on the 1993 AASHTO Pavement Design Guide, for structural pavement design. This practice is similar to many other state agencies. However, AASHTO no longer supports DARWin 3.1 as they now consider the Mechanistic-Empirical Pavement Design Guide (MEPDG) and companion software, AASHTOWare© Pavement Mechanistic-Empirical (ME) Pavement Design, the standard for thickness design. Consequently, DARWin 3.1 is increasingly more difficult to distribute and operate in modern operating systems (e.g., Windows 11). ALDOT, like many owner agencies, has extensive experience with the 1993 design process and has not yet transitioned to the Pavement-ME program due to the considerable time and expense required in calibration and implementation of the new system, though adoption of the MEPDG is a long-term consideration. Therefore, there is a need to develop a Windows-based program that will support 1993 AASHTO thickness design by replacing DARWin 3.1 while evaluating the feasibility of a potential transition to the MEPDG and AASHTOWare software.

It is also necessary to gather data on materials to evaluate the default ALDOT inputs used in the 1993 AASHTO design methodology since many are unchanged since the 1990s. Evaluating these inputs will ensure that pavement designs reflect modern materials. In the future, knowledge of the modern inputs will provide for an accurate comparison between the AASHTO 1993 method and the MEPDG to better understand any differences in the final design recommendation between the two approaches. This new software, in conjunction with acquiring needed data to reassess 1993 AASHTO thickness design inputs and compile necessary inputs for MEPDG, is a key step toward the long-term modernization of pavement design.

1.2 BACKGROUND

The official AASHTO method of structural pavement design switched from empirical to mechanistic-empirical with the release of the MEPDG and design software AASHTOWare© Pavement ME in 2013. Though considered a significant advancement in pavement thickness design, it is currently not widely used as state agencies must first execute time- and cost-intensive evaluation, calibration and validation studies with the new software before full implementation. A survey published in 2014 showed that 28 states continued to use the older AASHTO empirical method with very few having begun the transition to the new M-E approach (Pierce and McGovern, 2014). Figure 1 provides the results of 2017 survey on the implementation status of the M-E pavement design methodology for asphalt and concrete pavements. Of the 21 survey respondents, 9 have implemented M-E design for asphalt pavements and overlays, and 7 have implemented for concrete pavements and overlays. The remaining respondents indicate that they will either implement in the coming year(s) or that they have no implementation plans. The status of the remaining states is unknown.

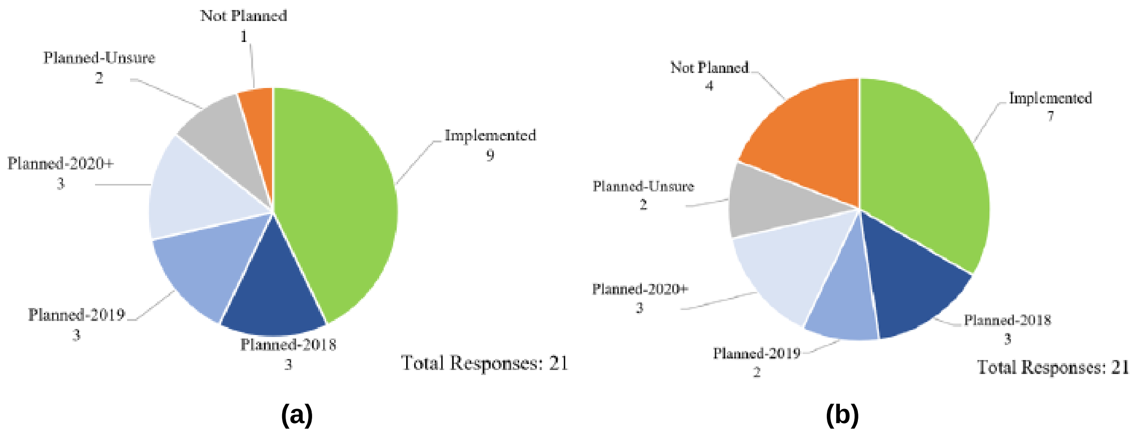


Figure 1. M-E implementation Status for (a) Asphalt Pavements and Overlays and (b) Concrete Pavements and Overlays (Applied Pavement Technology, 2018).

As indicated in the previous discussion, the Alabama Department of Transportation is certainly not alone in having continued with the AASHTO empirical design system. Specifically, ALDOT uses the 1993 AASHTO Design Guide and corresponding software, DARWin 3.1. However, while many states continue to design using input parameters set decades ago, ALDOT implemented a new asphalt concrete structural coefficient in 2009 that updated the empirical system to reflect modern flexible pavement performance (Peters-Davis and Timm 2009). It's notable that only two states (Alabama and Washington State) have updated their asphalt structural coefficients above the default value of 0.44 recommended by American Association of State Highway Officials (AASHO) in 1962 (Li et al. 2011). The remaining states continue to use 0.44 (or less) to represent modern asphalt mixtures (Pierce and McGovern, 2014). This likely leads to overdesigned flexible pavements in many cases.

The issue of updating empirical design inputs is certainly not limited to asphalt structural coefficients. Other design parameters, for both flexible and rigid pavements listed in Table 1, should also be reevaluated for the empirical design system to be effective in continued use.

Table 1. AASHTO Empirical Method Design Inputs.

Input	Symbol	Pavement Type
Equivalent Single Axle Loads	ESALs or W_{18}	Both
Reliability, %	R	
Input Standard Error	S_0	
Change in Serviceability	ΔPSI	
Effective Roadbed Soil Resilient Modulus, psi	M_r	Flexible
Structural Coefficients	a_i	
Drainage Coefficients	m_i	
Effective Modulus of Subgrade Reaction, pci	k	Rigid
Mean Concrete Modulus of Rupture, psi	S'_c	
Load Transfer Coefficient	J	
Drainage Coefficient	C_d	
Terminal Serviceability	p_t	

Table 2 provides an excerpt of the pavement component design coefficients as provided in ALDOT's Guidelines for Flexible Pavement Design in Alabama (ALDOT 1990). This table has been updated to reflect the 2009 adoption of 0.54 for the asphalt concrete wearing layer and binder layer structural coefficient, but the other coefficients have not changed since the 1990's. It should also be noted that Lime Stabilized Soil Aggregate, for example, does not have a modulus value associated with it, and thus a structural coefficient has been assumed. In the years since this table was assembled, a number of projects and subsequent data points have been generated around the state that may have input parameters that are different from those typically used in pavement design. There is a benefit to acquiring that data to assess whether the estimated modulus and subsequent structural coefficients are still accurate for pavement structures today. The same can be said for key components of rigid pavement, such as the modulus of rupture and related strength properties. Validating or updating these values may lead to cost savings through thinner pavements (e.g., 0.54 adjusted asphalt structural coefficient reduced thickness by as much as 18%) or by mitigating under design if the actual input is lower than that which is currently recommended. While collecting this data and incorporating the findings into the new pavement design software will solve a current problem for ALDOT, the data can also be used to populate an M-E material property database. This database can then be used in the future when ALDOT has had time to perform its due diligence in assessing the feasibility and potential implementation of ME design.

Table 2 Excerpt of pavement component design structural coefficients as provided in ALDOT's Guidelines for Flexible Pavement Design in Alabama (ALDOT 1990)

Pavement Component	Estimated Modulus (psi)	Structural Layer coefficient
Surface Course		
Plant Mix (High Stability)	950,000	0.54*
Sand Asphalt	370,000	0.40
Road mix (Low Stability)	110,000	0.20
L Treatment	130,000	0.23
Double Bituminous Surface Treatments	120,000	0.22
Single Bituminous Surface Treatments	110,000	0.20
Base Course		
Crushed Aggregate Base		
Limestone	30,000	0.14
Slag		0.14
Sandstone	28,000	0.13
Granite	25,000	0.12
Soil Aggregate Base		
Lime Stabilized Soil Aggregate	-	0.15
Soil + Limestone	19,000	0.09
Soil + Slag		0.09
Soil + Oyster Shells		0.09
Soil + Sandstone	18,000	0.08
Soil + Granite		0.08
Soil + Ocala Limestone		0.08
Soil + Gravel	16,000	0.07
Sand & Chert		0.07
Cement Treated (No Soil-Cement)		
650 psi or More Crushed Aggregate	850,000	0.23
400 to 650 psi Soil Aggregate	750,000	0.20
400 psi or Less Granular Soil	600,000	0.15

*Updated coefficient in 2009

1.3 RESEARCH OBJECTIVES

Given the needs described above, this project has two primary objectives:

1. Develop a modern, ALDOT-customized, pavement thickness design computer program that follows the AASHTO 1993 design procedure. The program will replace DARWin 3.1 which is currently used by ALDOT, but no longer supported by AASHTO.
2. Gather the appropriate design inputs from around the state for use in the new, DARWin replacement, thickness design computer program.
    a. In gathering this information, assess whether or not the inputs need to be updated and/or if new inputs need to be incorporated.
    b. Populate a database of Pavement-ME inputs for future use as Pavement-ME adoption is considered.

2 LITERATURE REVIEW

2.1 AASHTO 1993

From 1958 to 1960 the AASHO Road Test was conducted in Ottawa, Illinois. The results from this test were used to develop the pavement design guides published from 1962 through 1993 by the American Association of State Highway and Transportation Officials (AASHTO). Since the 1960's, most U.S. pavement thickness design has been empirically-based (Highway Research Board (1962), AASHTO Guide (1993)). The results from the AASHO Road Test depended on the materials properties, cross-sections, construction practices, climate, and traffic applications representing the conditions and technology at the test location. The pavement design guide (AASHTO 1993) was updated several times and the latest edition was published in 1998. Despite the improvements, the pavement performance observed during the road test remains the foundation of the design guides (AASHTO Guide (1993)).

The four principal factors correlated from the observations during the AASHO Road Test for asphalt pavement were: the soil condition represented by the subgrade resilient modulus (M_R), traffic quantified by equivalent single axle loads (ESALs), the change in pavement condition quantified by the change in pavement serviceability index (ΔPSI), and pavement structure represented by a structural number (SN) (Highway Research Board 1962; AASHTO Guide 1993). This relationship is shown in Equation 1, which represents the principal equation for the AASHTO flexible pavement thickness design method:

$$logW_{18} = Z_R S_0 + 9.36\log(SN+1) - 0.20 + \frac{log\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.4+\frac{1094}{(SN+1)^{5.19}}} + 2.32logM_R - 8.07 \qquad (1)$$

where, W_{18} = design traffic loading (ESALs), Z_R = standard deviation associated with the reliability level, S_0 = standard error, ΔPSI = allowable change in present serviceability index (ΔPSI = P_i - P_t where, P_i = initial serviceability and P_t = terminal serviceability), M_R = subgrade resilient modulus, and SN = structural number of the pavement (SN = $\Sigma a_i d_i m_i$,a_i = structural layer coefficient, d_i = layer thickness, m_i = drainage coefficient).

The values in the equation are regression coefficients that helped obtain the best match between the independent variables (SN, ΔPSI, M_R) and the performance of the pavement section quantified by ESALs (AASHTO 1993). The outputs from the AASHTO design process are layer thicknesses. Solving for SN algebraically in Equation 1 is a difficult task, therefore there are different means that can be utilized to solve for SN such as the design nomograph published by AASHTO, spreadsheet tools, and the Design, Analysis, and Rehabilitation for Windows (DARWin) software developed for AASHTO (Timm et al. 2014b).

2.2 DARWIN

DARWin is a computerized pavement design tool based on the AASHTO Design Guide for pavement structures. The tool contains three main design modules along with the life cycle cost analysis module that are: (1) Flexible Pavement Structural Design Module used to design and analyze Asphalt Concrete (AC) pavements; (2) Rigid Pavement Structural Design Module used to design and analyze Portland Cement Concrete (PCC) pavements; and (3) Overlay Design Module used to design seven different types of overlays (Khasawneh 2013).

The most popular pavement design procedure in the U.S. is the empirically based AASHTO design guide with approximately 78% states as users (Timm et al. 2014, Pierce and McGovern 2013). Although the empirical AASHTO design procedure is still used and trusted, its fundamental equation is based on observations from a road test where one soil type, one climate, one type of asphalt mix, limited pavement cross-sections were used, and limited load applications were considered. These conditions were specific to the reality at the time and represent the design limitations of the AASHTO method currently. Thus, there is a need to implement a more modern method. In addition, the pavement engineering field (including design, materials, and construction) has experienced significant progress since the test, which leaves the AASHTO design guide increasingly outdated with time. Therefore, designers are forced to extrapolate beyond the original conditions of the road test (Timm et al. 2014b).

2.3 MEPDG

The National Cooperative Highway Research Program (NCHRP) identified the need to improve pavement design and account for modern conditions and technology, thus starting a project in 1998 called "Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase I." The project ended in 2004 with a product called the Mechanistic Empirical Pavement Design Guide (MEPDG) (Timm et al. 2014). In 2008, a series of transitions from the MEPDG to AASHTOWare© programs (later renamed DARWin-ME) was observed due the regular changes made by the developers to improve the program. The final commercially available product named AASHTOWare© Pavement ME Design was first released in 2013 and represented a major step forward from the AASHTO 1993 design guide and the DARWin software to a more all-encompassing pavement design system (AASHTO 2008; AASHTO Guide 1993).

Although the MEPDG is considered a tremendous technological advancement, it is challenging to implement it because of the time and costs associated with software licensing and training, development of multiple large data sets through field and laboratory testing required to run the software, and validation/calibration studies to completely implement the new procedure (Timm et al. 2014b). This is highlighted by the aforementioned 2018 survey of state agencies implementing MEPDG referenced in the introduction of this report. Of the 21 survey respondents, only 9 have implemented M-E design for asphalt pavements and overlays, and 7 have implemented for concrete pavements and overlays. Others expressed that they plan to implement or are in the early stages.

To determine the design inputs for materials in the MEPDG, a hierarchical approach with three design inputs levels where the level of engineering effort exerted in the design process is dependent on the importance, size and cost of the project. Input Level 1 is used when the designer possesses results from comprehensive laboratory tests. Input Level 2 requires the designer to estimate the input values through correlations with commonly measured material properties from Laboratory or field tests. Level 3 inputs are estimated based on experience with little or no testing. Most MEPDG analysis is performed using Levels 2 and 3 inputs because Level 1 requires testing of the pavement materials that are not yet constructed at the time of the design. The major material types used in the MEPDG are shown in Figure 2 and their design inputs classified by material type are shown in Tables 3 through 5 (AASHTO 2020).

Asphalt Materials

- Stone Matrix Asphalt (SMA)
- Asphalt Concrete (AC)
  - Dense-Graded
  - Open Graded Asphalt
  - Asphalt Stabilized Base Mixes
  - Sand Asphalt Mixtures
- Cold Mix Asphalt
  - Central Plant Processed
  - In-Place Recycled

PCC Materials

- Intact Slabs—PCC
  - High Strength Mixes
  - Lean Concrete Mixes
- Fractured Slabs
  - Crack/Seat
  - Break/Seat
  - Rubblized

Chemically Stabilized Materials

- Cement Stabilized Aggregate
- Soil Cement
- Lime Cement Fly Ash
- Lime Fly Ash
- Lime Stabilized Soils
- Open Graded Cement Stabilized Aggregate

Non-Stabilized Granular Base/Subbase

- Granular Base/Subbase
- Sandy Subbase
- Cold Recycled Asphalt (used as aggregate)
  - RAP (includes millings)
  - Pulverized In-Place
- Cold Recycled Asphalt Pavement (AC plus aggregate base/subbase)

Subgrade Soils

- Gravelly Soils (A-1, A-2)
- Sandy Soils
  - Loose Sands (A-3)
  - Dense Sands (A-3)
  - Silty Sands (A-2-4, A-2-5)
  - Clayey Sands (A-2-6, A-2-7)
- Silty Soils (A-4, A-5)
- Clayey Soils, Low Plasticity Clays (A-6)
  - Dry-Hard
  - Moist Stiff
  - Wet/Sat-Soft
- Clayey Soils, High Plasticity Clays (A-7)
  - Dry-Hard
  - Moist Stiff
  - Wet/Sat-Soft

Bedrock

- Solid, Massive, and Continuous
- Highly Fractured, Weathered

Figure 1. Major Material Types for the MEPDG (AASHTO 2020)

Table 3. Design Inputs for Asphalt Concrete (AC) Materials (adapted from AASHTO 2020)

Measured Property	Input Level
Dynamic modulus Tensile strength TS Creep compliance, D (t) Air voids Effective volumetric asphalt content Total unit weight	Level 2 or 3
Poisson's ratio Subsurface shortwave absorptivity Thermal conductivity Heat capacity Coefficient of thermal contraction	Level 3

Table 4. Design Inputs for Portland Cement Concrete (PCC) Materials (adapted from AASHTO 2020)

Measured Property	Input Level
Elastic modulus and flexural strength Poisson's ratio Unit weight Coefficient of thermal expansion Surface shortwave absorptivity Thermal conductivity Heat capacity PCC set temperature	Levels 2 and 3
Cement type Cementitious material content Water to cement ratio Aggregate type Curing method Ultimate shrinkage Reversible shrinkage Time to develop 50 percent of ultimate shrinkage	Level 3

Table 5. Design Inputs for Chemically Stabilized Materials (adapted from AASHTO 2020)

Measured Property	Input Level
Elastic / resilient modulus Flexural strength Poisson's ratio Unit weight Thermal conductivity Heat capacity	Levels 2 and 3

Table 6. Design Inputs for Unbound Aggregate Base, Subbase, Embankment, and Subgrade Soil Materials (adapted from AASHTO 2020)

Measured Property	Input Level
Resilient modulus Maximum dry density Optimum moisture content Specific gravity Saturated hydraulic conductivity Soil water characteristic curve parameters	Levels 2 and 3

2.4 RECALIBRATION OF STRUCTURAL LAYER COEFFICIENTS

Since there are numerous data sets such as material properties that both the empirical and mechanistic-empirical approaches share, it is logical to update the AASHTO 1993 design input values while MEPDG is being implemented, especially for states like Alabama that are considering MEPDG (Timm et al. 2014b).

For that, Timm et al. (2014b) recommended procedures to update the empirically-based design method to reflect the performance of modern pavement. The researchers focused on recalibrating the asphalt structural coefficient because it is the most influential variable in the design of pavement thickness. This is a response to the recommendation from AASHTO, which encourages states to develop agency-specific structural coefficients based on their experience. Structural coefficients are empirical values used to relate the load-carrying capacity of different materials. The three general approaches recommended by Timm et al. (2014b) to recalibrating the asphalt structural coefficient are: (1) Deflection-based method that relies on field testing of existing pavements to determine in-place modulus, which is used to obtain a structural coefficient through existing empirical equations; (2) Performance-based method that relies on the actual performance of the material; and (3) Mechanistic-empirical method that relies on the MEPDG locally calibrated with performance data.

In 1962, AASHO recommended a structural coefficient of 0.44 for the asphalt layer although a range of values was reported from the test loops as shown in Table 7. The 1962 report explains that 0.44 was obtained using a weighted average, however there is no clarification regarding how the values were weighted when inspecting the data.

Table 7. HMA Layer Coefficients from AASHO Road Test (Adapted from Highway Research Board 1962).

Loop	Layer Coefficient (a_1)	Test Sections	R^2
2	0.83	44	0.8
3	0.44	60	0.83
4	0.44	60	0.9
5	0.47	60	0.92
6	0.33	60	0.81

In 2006, Timm and Priest, using the data and performance from the instrumentation of all structural sections in the 2003 research cycle of the National Center for Asphalt Technology's (NCAT) Pavement Test Track, determined a relationship between temperature and stiffness. The average HMA modulus of 811,115 psi was calculated using this relationship and the corresponding structural coefficient 0.54 was obtained. This was checked through extrapolation of the curve developed in 1972 relating the layer coefficient to the elastic modulus (E) of the HMA at 70°F, as shown in Figure 3. As a result, the Alabama HMA structural coefficient was changed to 0.54 (Peters-Davis and Timm 2009). Washington State also revised their HMA structural coefficient to 0.50 (Li et al. 2011). The revised structural coefficients reflect better the advances in material properties, field performance, and modern construction practices in these states. The increase in of the structural coefficient helps obtain optimum asphalt design and minimize costs (Peters-Davis and Timm 2009).

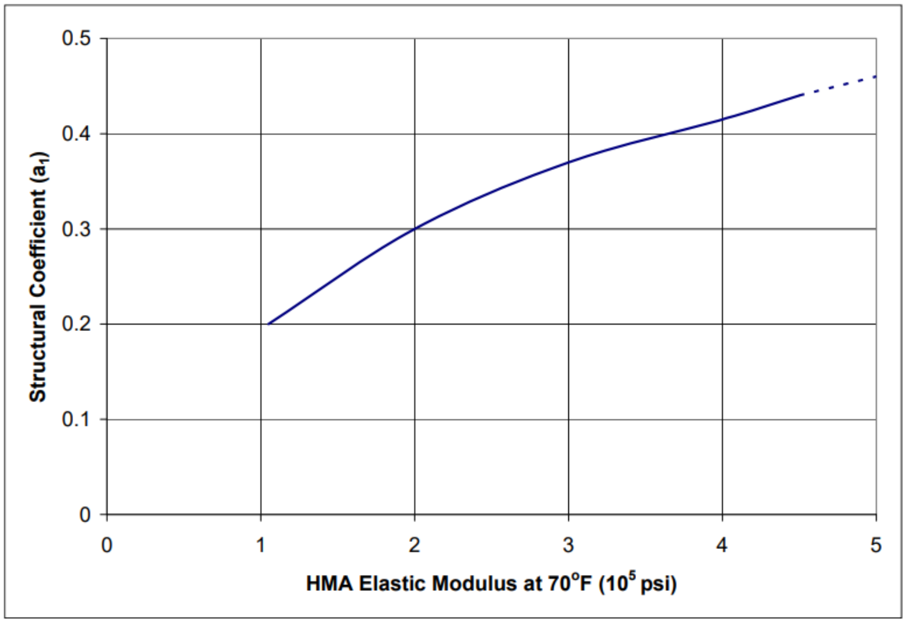


Figure 2. Relationship Between HMA a1 and Modulus (Peters-Davis and Timm 2009).

2.5 SUMMARY OF LITERATURE REVIEW

The predominant method of designing pavements throughout the United States remains the empirical AASHTO methodology. ALDOT continues to use the AASHTO 1993 methodology, with specific default inputs as laid out in ALDOT's 1990 Guidelines for Flexible Pavement Design in Alabama. The DARWin software used to design pavements with this methodology is no longer supported by AASHTO, and there has been some research, including in Alabama, to recalibrate the default inputs. Meanwhile, the mechanistic-empirical pavement design methodology, or MEPDG, has been introduced and has design software supported by AAHSTO, though most agencies have not yet implemented this method due to various challenges.

3 DEVELOPMENT OF MATERIALS DATABASE

To provide the most up-to-date material inputs for empirical-based AASHTO 1993 method and to ease future implementation AASHTOWare© Pavement-ME, a materials database was built in Microsoft Access. This database can be used by ALDOT to (1) easily search and access relevant, location specific materials data for design and (2) to continue to populate with future data collected by the Materials and Tests Bureau. The data collected is usable in either the empirical-based AASHTO 1993 design method or AASHTOWare© Pavement-ME, while some data may be useful to both pavement design tools. Further, the data was used for comparisons to current structural design inputs used in ALDOT's Pavement Design Manual (ALDOT 1990).

3.1 DATA COLLECTION METHODS

3.1.1 Subgrade

Hard copies of the data were provided by ALDOT for the subgrade materials. The data are results of laboratory tests on soils located in different counties of Alabama to determine the resilient modulus of subgrade. Approximately 1040 copies were received, and the data were transferred into a database in Access by hand. The information extracted from documents are provided in Table 8.

Table 8. Extracted subgrade information.

Project Information	• County • Division • Project Number • Laboratory Number • Report Date, Material • Producer	• CPMS project reference number • Identification marks • Source of material • Date sampled • Remarks
Soil Characterization	• % Passing ¾ • % Passing #4 • % Passing #10 • % Clay • % Silt • Total sand	• % Passing #40 • % Passing #200 • Liquid Limit (LL) • Plastic Limit (PL) • Plastic Index (PI) • Soil Class
Testing Information	• Date tested • Layer type • Material type • Approximate distance from top of subgrade to sample in feet	• Preconditioning – greater than 5% permanent strain • Testing - greater than 5% permanent strain? • Number of load sequences completed
Specimen Detail	• % Optimum moisture content • Maximum dry density in pcf • % Compaction moisture content • % Moisture content after resilient modulus testing	• Compaction dry density in pcf • Target dry density in pcf • % Target moisture content • % Compaction level achieved
Triaxial Shear Test	• Triaxial shear maximum strength in psi	• Specimen fail during triaxial shear? • Sequences 6 to 15
Resilient Modulus K-Coefficients	• K1 • K2	• K5 • R2
Resilient Modulus	• Resilient modulus (Mr) in psi	

The final design resilient modulus values were obtained following the procedure from ALDOT for conducting soil surveys and preparing materials reports. According to ALDOT (2012): *"The design MR for soils classified as A-1, A-3, A- 2-4, and A-2-5 shall be the average of the MR values generated at a confining pressure of 4 psi (0.03 MPa). For all other AASHTO soil classes, the design MR shall be the average of the MR values generated at a confining pressure of 2 psi (0.015 MPa). The MR values generated at both confining pressures shall be averaged to determine the design MR value. Upon computing the average MR value, if there are any values in the MR* *data set that exceed the mean value by ± 2 standard deviations, these values shall be discarded and the remaining values shall be re-averaged to determine the final average MR value to be used in the pavement structural design analysis."* Figure 4 summarizes the process.

Design Resilient Modulus by AASHTO Soil Classification

AASHTO Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7 A-7-5 A-7-6
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				
Confining Pressure for Design	4 psi	4 psi	4 psi	4 psi	4 psi	2 psi	2 psi	2 psi	2 psi	2 psi	2 psi
Sample Moisture Content	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Wet side of Optimum	Wet side of Optimum

Figure 4. Process To Obtain Design Resilient Modulus of Subgrade (ALDOT 2012)

Some of the data was provided in terms of CBR, therefore the subgrade resilient modulus (M_R) was calculated using Equation 2 from the AASHTO 1993 guidelines.

$$M_R(psi) = 1{,}500 \times CBR \quad (2)$$

Where, CBR = California Bearing Ratio.

3.1.2 Aggregate Base

The data were provided by ALDOT in MS Excel and PDF formats. The data are results of laboratory tests on aggregates, including resilient modulus, from different sources that provide materials to ALDOT. Twenty-one documents (PDFs) were received, and the data were transferred into a database in Access. The information extracted from documents are provided in Table 9.

Table 9. Extracted Aggregate Base Information.

Project Information	• Division • Project Number • County • Type of Material • Laboratory Number • Date received	• Date tested • CPMS project reference number • Identification marks • Report date • Source of material
Testing Information	• Layer type • Material type • Approximate distance from top of subgrade to sample in feet • Preconditioning – greater than 5% permanent strain?	• Testing – greater than 5% permanent strain? • Testing – number of load sequences completed
Specimen Detail	• % Optimum moisture content • Maximum dry density in pcf • % Compaction moisture content • % Moisture content after resilient modulus testing	• Compaction dry density in pcf • Target dry density in pcf • % Target moisture content • % Compaction level achieved
Triaxial Shear Test	• Triaxial shear maximum strength in psi • Specimen fail during triaxial shear?	• Sequences 1 to 15
Resilient Modulus K-Coefficients	• K1 • K2	• K5 • R2
Resilient Modulus	• Resilient modulus (Mr) in psi	

In their study, Hossain and Lane (2015) calculated resilient modulus values for aggregates base/subbase using a 5-psi confinement (S_3) and a 15-psi deviator stress (S_{cyclic}) as suggested in NCHRP (2004) Research Results Digest 285. Therefore, the resilient modulus of the aggregates from the data received was obtained at sequence 6 where S_3 = 5 psi and S_{cyclic} = 15 psi.

The CBR was backcalculated using Equation 3 from the 1990 Holman Report (ALDOT 1990).

$$logE_2 = 3.649084 + 0.421664\log(CBR) \quad (3)$$

Where, E_2 = modulus of aggregate base.

The structural layer coefficient (a_2) was backcalculated using Equation 4 from the 1990 Holman Report (ALDOT 1990).

$$a_2 = -0.05271 + 0.098133\log(CBR) \quad (4)$$

The classification data of the aggregates were provided in PDF formats. Eight (8) documents (PDFs) that represent the 8 quarries were received, and the data were transferred into a database in Access. The information extracted from documents are provided in Table 10.

Table 10. Extracted aggregate classification information.

Project Information	• County • Division • Producer • Source • Type • Sampled by	• LL • PL • PI • Maximum Dry Density (pcf)
Material Properties	• % Optimum moisture • % Passing 2” • % Passing 1 ½” • % Passing 1” • % Passing ¾” • % Passing ½” • % Passing #4 • % Passing #8 • % Passing #10 • % Passing #16 • % Passing #30 • % Passing #50 • % Passing #100 • % Passing #200	• Unit weight in pcf • Gravity bulk • Gravity bulk (SSD) • % Absorption • Uncompacted voids • Flat or elongated (3:1) • Flat or elongated (5:1) • % LA abrasion • Sodium Sulfate Soundness % Sound • AASHTO T-11

The volumetric properties data of the aggregates were also provided in PDF formats. Around 122 documents (PDFs) were received, and the data were transferred into a database in Access. The information extracted from documents are provided in Table 11.

Table 11. Extracted Aggregate Volumetric Information.

Project Information	• Source • County • Type	• Date tested • Sample ID • Sample card number
Material Properties	• Unit weight in pcf • Specific gravity bulk • Specific gravity bulk (SSD) • Specific gravity apparent • % Absorption • % Uncompacted voids • Percent deleterious materials • Flat or elongated (3:1) • Flat or elongated (5:1)	• Sand Equivalent number • % LA abrasion • Sodium sulfate soundness % sound • BPN number • Color test • Test-silica • AASHTO T-11 (%) • Micro deval

3.1.3 Stabilized Base (FDR and Soil Cement)

ALDOT provided hard copies of data for stabilized base materials. The data are results of laboratory tests on stabilized base with cement (FDR & soil cement) located in different counties of Alabama to determine the resilient modulus of stabilized base. Around 55 documents were received, and the data were transferred into a database in Access. The information extracted from documents are provided in Table 12.

Table 12. Extracted Stabilized Base information.

Project Information	• Division • Project number • County • Sample ID • Material code • Type of stabilization • Sample by source	• Date sampled • Sample type • Submitted by: • CPMS project reference number • Represented quantity • Report date
Material Properties	• Recommended percent cement • Remarks • Source of material • Description of material • Recommended maximum dry density in pcf • % Recommended optimum moisture • Recommended cement application rate in lbs./yd2 • Percent aggregate of composite sample • Actual required percent cement • Average design compressive strength at 7 days in psi • 3% Cement optimum moisture (%) • 5% Cement optimum moisture (%) • 7% Cement optimum moisture (%)	• 3% Cement maximum dry density in pcf • 5% Cement maximum dry density in pcf • 7% Cement maximum dry density in pcf • 3% Cement compressive strength in psi • 5% Cement compressive strength in psi • 7% Cement compressive strength in psi • Percent stabilized lime • Recommended lime application rate in lbs./yd2 • % Gravel • % Sand • % Fines • LL • PL • PI • Soil class • Producer • Design compressive strength in psi • Resilient modulus in psi

The resilient modulus was back calculated using Equation 5 from the 1990 Holman Report (ALDOT 1990).

$$logE_2 = 5.609477 + 0.000362\ (COMSTR) \quad (5)$$

Where, E_2 = modulus of stabilized aggregate base, COMSTR = compressive strength (psi) at 7 days.

The structural coefficient (a_2) was back calculated using Equation 6 from the 1990 Holman Report (ALDOT 1990).

$$a_2 = 0.073237 + 0.000178\ (COMSTR) \quad (6)$$

3.1.4 Concrete

There was limited data available for concrete pavements. Therefore, data from Alabama's Long-Term Pavement Performance (LTPP) test sections using concrete pavements were extracted. The data are general information and field-testing results on concrete pavements (JPCP, JRCP, CRCP) located in different counties of Alabama to determine the modulus of rupture and elastic modulus of concrete pavements. Only 8 concrete sections were listed in the report. The data for these sections were transferred into a database in Access. The information extracted from documents are provided in Table 13.

Table 13. Extracted Concrete Information.

Project Information	• Section • Experiment number • County, Route (direction) • GPS – Latitudes – Longitudes (degrees) • Surface type • Date of construction • Thickness of unbound (granular) base/subbase layer in inches	• Thickness of bound (treated) base/subbase layer in inches • Thickness of asphalt concrete layer in inches • Thickness of Portland cement concrete layer in inches
Material Properties	• Compressive strength in psi	• Modulus of Rupture in psi

The modulus of rupture (E_c) was calculated for only one section using Equation 7. The remaining sections had their modulus of rupture provided.

$$S_C = 9 \times \sqrt{f_c} \quad (7)$$

Where, f_c = compressive strength (psi).

The modulus of rupture was calculated for only one section using Equation 8.

$$E_C = 57{,}000 \times \sqrt{f_c} \quad (8)$$

Where, f_c = compressive strength (psi).

3.1.5 Asphalt

The data were taken from Microsoft Excel results sheets provided by the National Center for Asphalt Technology (NCAT). The data are laboratory and field-testing results on HMA pavements located in different counties of Alabama to determine the dynamic modulus of HMA pavements.

Around 600 mixtures were tested. The results of those tests were transferred into a database in Access. The information extracted from documents are provided in Table 14.

Table 14. Extracted Asphalt Information.

Project Information	• County • Location	• Project ID • Mixture (Mix) ID
Material Properties	• Temperature in degrees Celsius • Temperature in degrees Fahrenheit • Frequency in Hertz	• Shift factor • Reduced frequency • Dynamic modulus in ksi • Dynamic modulus in MPa

Additional asphalt data were recorded from three reports on the National Center for Asphalt Technology (NCAT) website. The data are laboratory testing results on HMA mixtures to determine the aggregate gradation. Fourteen mixtures were tested. The results of those tests were transferred into a database in Access. The information extracted from documents are provided in Table 15.

Table 15. Extracted Asphalt Information From NCAT Test Track.

Project Information	• County, Location • Project ID	• Type of mixtures • NMAS in millimeters
Material Properties	• % Passing 1” • % Passing ¾” • % Passing ½” • % Passing 3/8” • % Passing #4 • % Passing #8 • % Passing #16 • % Passing #30 • % Passing #50 • % Passing #100 • % Passing #200	• % ½ in crushed gravel • % Shot gravel • % Number 78s limestone • % Limestone screenings • % Sand, % Baghouse fines • % M-10 granite • % #87 Limestone • % ¼” Limestone • % #69 gravel • % #67 limestone • % #8910 limestone • % Coarse sand

Asphalt mixture data were also recorded from three reports on the National Center for Asphalt Technology (NCAT) website (Willis et al. 2014; West et al. 2018; and Leiva-Villacorta and Julian 2020). The data are laboratory testing results on HMA mixtures to determine the volumetrics as built. Around 14 mixtures were tested. The results of those tests were transferred into a database in Access. The information extracted from documents are provided in Table 16.

Table 16. Extracted asphalt mixture information from NCAT reports.

Project Information	• County • Location	• Project ID • Type of mixture
Material Properties	• %Pb • %Va • %VMA • %Vbe • D/A ratio	• Gmm • %VFA • Gse • %Pba • %Pbe

Asphalt binder property data was also collected from the same three reports. Around 14 binder samples from the 14 mixtures were tested. The results of those tests were transferred into a database in Access. The information extracted from documents are provided in Table 17.

Table 17. Extracted asphalt binder information from NCAT reports.

Project Information	• County • Location	• Project ID • Type of mixture
Material Properties	• Asphalt binder • Tcrit high • Tcrit int • Tcrit low s-value • Tcrit low m-value • True-grade • PG, • ΔTc • Average % recovery (100 Pa)	• Average % recovery (3200 Pa) • Average Jnr (k/Pa) 100 Pa • Average Jnr (k/Pa) 3200 Pa • Difference (% recovery) • Difference (% Jnr) • MP 19 Grade • Nf at applied strain 5/2% • Nf at Applied Strain 5%

3.2 COMPARISON OF ESTIMATED AND MEASURED PAVEMENT DESIGN INPUTS

3.2.1 Method of Analysis

Using data collected as described in Section 3.1, resilient modulus and/or structural layer coefficients of base materials, stabilized base materials, and subgrade were calculated. These were then statistically compared to the existing layer coefficients using single t-tests, multiple t-tests, or analysis of variance (ANOVA) tests as appropriate. Confidence intervals were also calculated.

The limestone and sandstone aggregate base materials were assessed separately and each had sample sizes below 100. A single hypothesis t-test was conducted with a 95% confidence level to determine whether the average resilient modulus and structural layer coefficient are statistically different than the default ALDOT values. Ninety-five percent confidence intervals were used to obtain ranges within which the structural coefficient values exist and were used to recommend new structural inputs as appropriate for the aggregate base materials. The hypothesis tests for analysis of materials structural properties is provided in Table 18.

The stabilized aggregate base was grouped as two different materials, Full Depth Reclamation with Cement (FDR-C) and soil cement (S-C), both with sample sizes less than 100. It is worth noting that while FDR-C and S-C data were gathered, ALDOT does not have default values for these two products. However, as referenced in Table 2, there are cement treated (no soil-cement) products that have default values. Because all FDR-C and S-C data had 7-day unconfined compaction strength (UCS) below 400 psi, the default ALDOT values for "Cement Treated (No Soil-Cement) 400 psi or Less Granular Soil" was used for comparison. Single hypothesis t-tests were conducted with a 95% confidence level to determine whether the average resilient modulus and structural layer coefficient are statistically different than the assumed default values. The hypothesis tests for analysis of materials structural properties is provided in Table 18. Furthermore, 95% confidence intervals were calculated, allowing for ranges within which the resilient modulus and structural layer coefficient values exist. These confidence intervals were then used to recommend new default structural inputs for the stabilized aggregate base materials.

There are 11 different subgrade categories or groups of samples, each reflecting the AASHTO soil classification A-1-a through A-7-6. Sample sizes for each classification varied from 1 to 42, while others were between 172 to 199. Because there are not ALDOT default values for the resilient modulus for each of the materials, 95% confidence intervals were calculated for each soil class and used to recommend new structural resilient modulus inputs for the different subgrade materials encountered in Alabama.

Further, both laboratory and field collected data was collected for soil types A-2-6 and A-6, both with sample sixes greater than 100. An ANOVA was conducted with a 95% confidence level to understand whether the resilient modulus values from laboratory testing were statistically different than those of the field testing. Then, multiple hypothesis t-tests were conducted at a 95% confidence level to determine whether the laboratory resilient modulus was *greater* than those values measured in the field. Each of the soil classes was grouped separately for the analysis. The hypothesis test assumptions along with what statistical test was conducted for each of the materials is shown below in Table 18.

Table 18. Hypothesis Tests for Analysis of Materials Structural Properties

Material's Type	Statistical Test	Hypothesis	ALDOT default inputs
Limestone	Single t-test	H_1: $U > 30{,}000$; H_0: $U \leq 30{,}000$ H_1: $U > 0.14$; H_0: $U \leq 0.14$	resilient modulus = 30,000 psi structural coefficient = 0.14
Sandstone	Single t-test	H_1: $U < 28{,}000$; H_0: $U \geq 28{,}000$ H_1: $U < 0.13$; H_0: $U \geq 0.13$	resilient modulus = 28,000 psi structural coefficient = 0.13
FDR-C	Single t-test	H_1: $U \neq 600{,}000$; H_0: $U = 600{,}000$ H_1: $U \neq 0.15$; H_0: $U = 0.15$	resilient modulus = 600,000 psi structural coefficient = 0.15
S-C	Single t-test	H_1: $U \neq 600{,}000$; H_0: $U = 600{,}000$ H_1: $U \neq 0.15$; H_0: $U = 0.15$	resilient modulus = 600,000 psi structural coefficient = 0.15
A-6 A-2-6	ANOVA	H_1: $U_{lab} \neq U_{field}$; H_0: $U_{lab} = U_{field}$	U_{lab} = mean value of resilient modulus from Lab Testing U_{field} = mean value of resilient modulus from Field Testing
	Multiple t-test	H_1: $U_{lab} > U_{field}$; H_0: $U_{lab} \leq U_{field}$	

3.2.2 Results of Analysis

3.2.1.1 Aggregate Base

The limestone aggregate base had a total of 15 samples. Examining the t-test results, it was concluded with a 95% confidence that the structural layer coefficient of limestone is not statistically greater than the ALDOT default value, with a 95% confidence intervale of 0.13 to 0.15. The resilient modulus, however, did have a statistically higher value of 31,700 psi compared to the ALDOT default value of 30,000 psi. This value was calculated by taking the average of the 95% confidence range of 29,700 to 33,600, rounded to the nearest 100 psi. Given the low practical difference in resilient modulus and the fact that the structural layer coefficient was equivalent, it is recommended that ALDOT *not* change their default values.

The sandstone aggregate base only had a sample size of 6. When assessing the statistically difference using the t-test results with a 95% confidence level, it was found that the resilient modulus and layer coefficient were statistically *less* than the ALDOT default value. The structural layer coefficient was 0.12 with a 95% confidence interval of 0.11 to 0.13, whilst the resilient modulus was 23,800 psi with a 95% confidence interval of 21,600 to 26,000 psi. Considering the low sample size, it is *not* recommended that ALDOT make any changes. However, it is recommended to continue collecting data to assess potential need to change the layer coefficient and/or design modulus. Figure 5 shows a comparison of the structural properties for both limestone and sandstone.

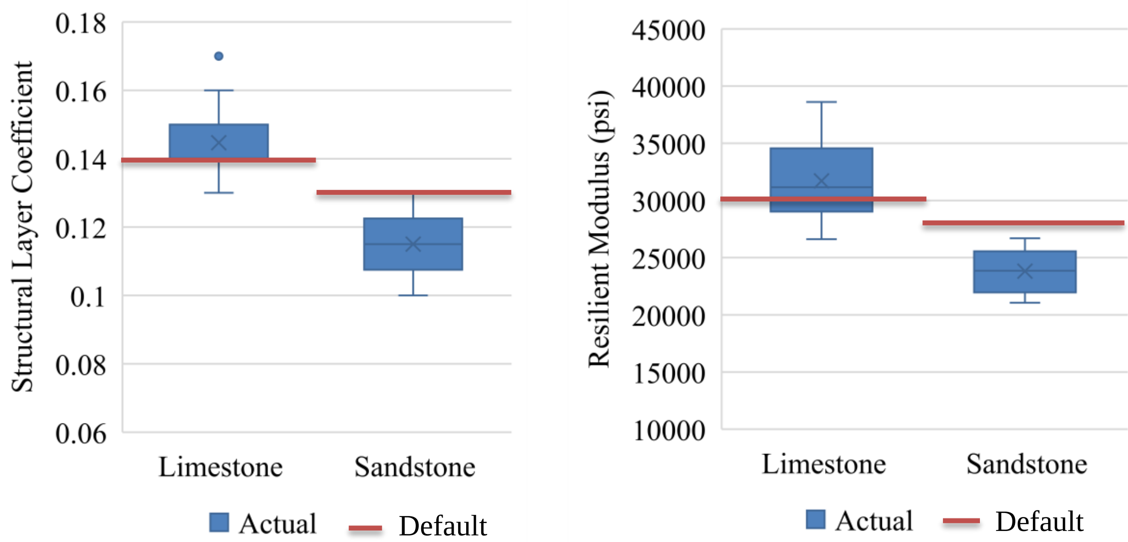


Figure 5. Comparison of structural properties for Aggregate Base Materials.

3.2.1.2 FDR with Cement and Soil-Cement

The conclusions from the conducted single t-tests showed that there is a 95% confidence that the FDR-C resilient modulus and structural coefficient are statistically different from ALDOT default values 600,000 psi and 0.15, respectively. Using 7-days UCS, the average resilient modulus of 553,200 psi and structural layer coefficient 0.14 obtained were slightly lower than the ALDOT default values. In addition, these values are significantly different from the recommended values from previous studies (Reeder et al. 2019; Diefenderfer and Apeagyei 2011) where the minimum recommended structural coefficient is 0.20. For comparison, 28-days UCS were also used to obtain average resilient modulus of 985,300 psi and structural coefficient of 0.26. It was noticed that these values were falling within the range recommended by other researchers for FDR-C (Scullion et al. 2008; Reeder et al. 2019; Diefenderfer and Apeagyei 2011). Consequently, instead of 7-days, the use of 28-days UCS is recommended to estimate the resilient modulus and structural coefficient of FDR-C. As a result, the new recommended structural coefficient for FDR with 4% cement is 0.26 and the 95% confidence interval is 0.22 to 0.30. The recommendations for the resilient modulus are 985,300 psi as the new value and 786,400 to 1,184,200 psi as the 95% confidence interval. The sample size was 43 for 7-days UCS and 10 for 28-days UCS. The summary of the results is shown in Figure 6 and Table 19.

Based on the single t-tests' results, there is a 95% confidence that the S-C resilient modulus and structural layer coefficient are statistically different from ALDOT default inputs 600,000 psi and 0.15, respectively. The average resilient modulus and structural layer coefficient obtained using 7-days UCS were 544,600 psi and 0.14, respectively. These values were slightly lower than the ALDOT default values and significantly lower than the recommended values from previous studies as well where the minimum recommended structural layer coefficient from the literature of 0.20 (Reeder et al. 2019). However, the average resilient modulus of 775,700 psi and structural layer coefficient of 0.21 obtained using 28-days UCS were found to be within the range recommended by Reeder et al. 2019. As a result, the use of 28-days UCS in lieu of 7-days is recommended to estimate the resilient modulus and structural coefficient of S-C. Therefore, this led to a recommendation of 775,700 psi and 0.21 as for consideration as resilient modulus and structural layer coefficient of S-C with 3% cement. The 95% confidence intervals are 637,400 to 914,100 psi and 0.17 to 0.25, respectively. The sample size was 17 for 7-days UCS and 9 for 28-days UCS. The summary of the results is shown in Figure 6 and Table 19.

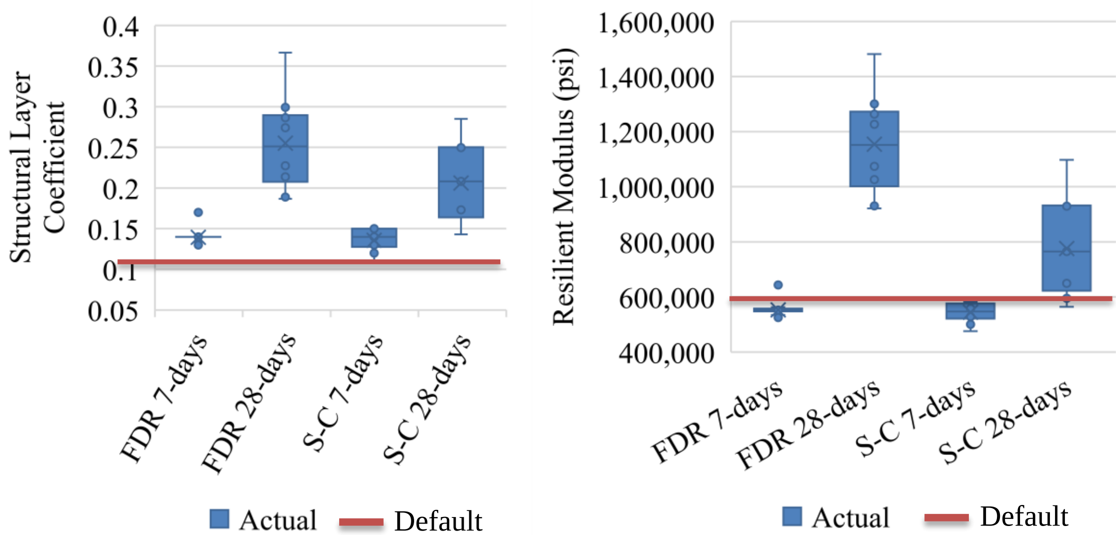


Figure 6. Comparison of structural properties for Stabilized Aggregate Base Materials.

3.2.1.3 Subgrade

As previously mentioned, the subgrade resilient modulus does not have default values. However, Table 19 provides a summary for AASHTO soil classifications of A1-a through A-7-6 using a 95% confidence interval.

Table 19. Calculated Inputs For Pavement Materials' Structural Properties.

Material Type	Resilient Modulus (psi)		Structural Coefficient	
	Average 95% CI Value	95% CI	Average 95% CI Value	95% CI
Limestone	31,700	29,700 - 33,600	0.14	0.13 – 0.15
Sandstone	23,800	21,600 - 26,000	0.12	0.11 - 0.13
FDR 7-days	553,200	548,600 - 557,800	0.14	0.138 - 0.142
FDR 28-days	985,300	786,400 – 1,184,200	0.26	0.22 – 0.30
S-C 7-days	544,600	525,400 - 563,700	0.14	0.13 - 0.15
S-C 28-days	775,700	637,400 – 914,100	0.21	0.17 – 0.25
A-1-a	12,800	9,500 – 16,100	-	-
A-1-b	10,000	9,300 - 10,800	-	-
A-2-4	9,400	9,100 - 9,800	-	-
A-2-6	9,000	8,200 - 9,800	-	-
A-2-7	8,600	6,500 - 10,600	-	-
A-3	8,900	7,200 - 10,700	-	-
A-4	7,800	7,600 - 8,100	-	-
A-5	8,200	8,200*	-	-
A-6	8,000	7,600 - 8,300	-	-
A-7-5	7,000	5,400 - 8,700	-	-
A-7-6	8,500	8,000 - 9,000	-	-

*There is only one data point

A comparison was performed between the laboratory and field collected results using falling weight deflectometer (FWD) data for A-2-6 and A-6 soil classifications. First, an ANOVA test was conducted with a 95% confidence level, finding that there is a significant difference tween the resilient modulus measured in the laboratory versus that measured in the field. The Multiple t-test was performed at a 95% confidence level for each soil type, finding that in both cases the field-measured resilient modulus was higher than the laboratory-measured resilient modulus. The higher values may be caused by a number of factors, including increased compaction due to trafficking or the method of measurement. No changes are recommended to ALDOT standard procedures, but this is considered useful information for future design decisions. The final results can be seen in Table 20.

Table 20. Comparison of Subgrade Resilient Modulus From Laboratory and Field Testing

Soil Class	Resilient Modulus (psi)	
	Laboratory	Field
A-2-6	9,000	11,000
A-6	8,000	8,800

4 SOFTWARE DEVELOPMENT

4.1 DEVELOPMENT OF ADAPT

New software titled Alabama Design and Analysis of Pavement Thickness (ADAPT) was developed for this project to replace the DARWin 3.1 software previously employed by ALDOT to execute structural pavement design using the 1993 AASHTO Design Guide. The software was created in Microsoft Visual C++ and is a Windows-based program.

ADAPT facilitates both new and overlay design according the 1993 AASHTO Design Guide following guidance provided by ALDOT pavement design procedures for both flexible and rigid pavements. Specifically, ADAPT is capable of the following design scenarios:

- New flexible pavement design
- New rigid pavement design
- Asphalt overlay of existing asphalt pavement
- Asphalt overlay of existing asphalt on concrete pavement
- Unbonded concrete overlay of existing concrete pavement

Each scenario listed above has a specific design module in ADAPT corresponding to that pavement type. There is a separate traffic module that performs equivalent single axle load (ESAL) computations that are subsequently used in the various new and overlay design modules. There are also sub-modules that allow the designer to work directly with falling weight deflectometer (FWD) files to establish in situ properties for asphalt overlays of existing asphalt on concrete pavements and unbonded concrete overlays. When designs are complete, ADAPT can generate a formatted output file that includes all the relevant design inputs, computations, and outputs.

A core feature of ADAPT is short training videos that are accessible from each module described above. These videos work through examples and discuss the inputs and outputs of each module and ALDOT-specific recommended values. The videos are also accessible from an ADAPT web page that explains the program in greater detail.

4.2 SENSITIVITY ANALYSIS

4.2.1 Overview

The sensitivity analysis was performed to compare the design results of the newly developed ADAPT software with those of the previously used DARWin 3.1 software and ensure their equivalence. The analysis consisted of conducting six different types of design in the ADAPT and DARWin 3.1 software while varying some design inputs and comparing the results to verify their equivalence. The 6 types of design considered are:

- NDFP - New Design Flexible Pavement
- NDJPCP - New Design Jointed Plain Concrete Pavement
- NDJRCP - New Design Jointed Reinforced Concrete Pavement
- NDCRCP - New Design Continuously Reinforced Concrete Pavement
- ODFP - Overlay Design Flexible Pavement
- ODRP - Overlay Design Rigid Pavement

4.2.2 Methods and Results

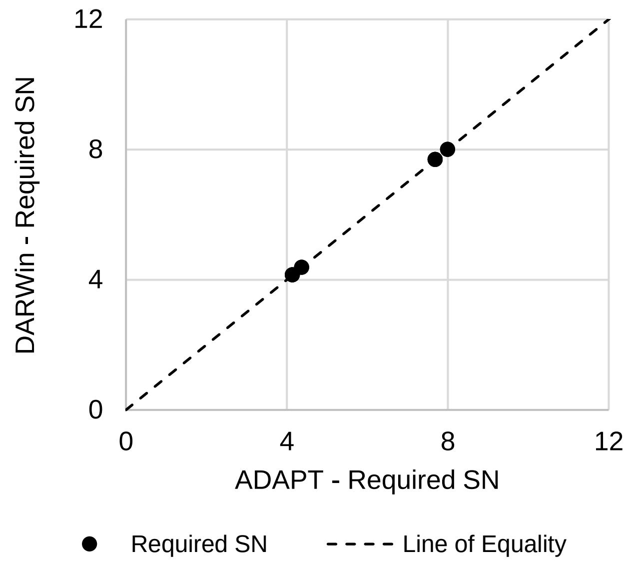
4.2.2.1 NDFP - New Design Flexible Pavement

The purpose of the “new design flexible pavement” design was to determine the required thicknesses of the layers that compose a new flexible pavement. Ten design scenarios were simulated in both ADAPT and DARWin to compare their results. An excerpt of the inputs used for the design is shown in Table 21 where the project setting was either an interstate or non-interstate with different annual average daily traffic (AADT), number of lanes, %growth rate, %trucks, and %trucks in design lane. The subgrade modulus was varied between 7,000 psi and 8,000 psi. The number of pavement layers was varied from 1 to 3 layers, which are an AC layer with a modulus of 800,000 psi, a granular base of 40,000 psi, and a stabilized subbase of 15,000 psi.

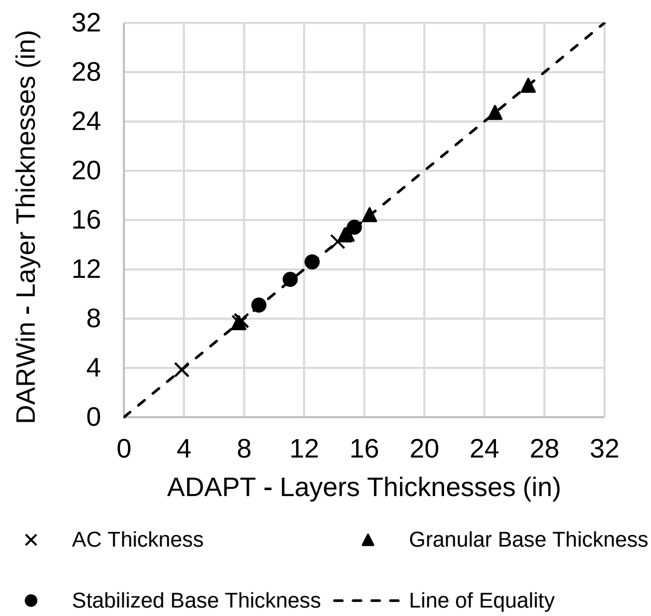
The results obtained were the required structural number (SN) and required layers' thicknesses. Figure 1 presents the summary of the comparisons which were done using linear inequality graphs where the results from ADAPT are on the x-axis and DARWin results are on the y-axis. The dashed boundary line called the line of equality represents the linear equation x = y, which means that the results match. The regions on the right and left of the line represent the entire set of solutions for the inequalities x > y and y > x, respectively. Examining Figure 7, it can be said that all the design results are located on the line of equality, which means that the values are matching. The average percent difference between the result values rounded to 2 decimal places was 0.2%, with the median being equal to 0.1%. The average difference between the thickness values was 0 in for the AC layer and 0.02 in for the base and stabilized base layers. The detailed list of design inputs and the results are presented in Appendix A.1.

Table 21. NDFP - Design Inputs

Trial	Project Setting	AADT	Number of Lanes	Growth Rate	Truck Percentage	%Truck in Design Lane	Subgrade Modulus (psi)	Layers
1	Interstate	45000	2	4	22	85	8000	1
2	Interstate	45000	2	4	22	85	8000	2
3	Interstate	45000	2	4	22	85	8000	3
4	Interstate	45000	2	4	22	85	7000	2
5	Interstate	45000	2	4	22	85	7000	3
6	Non-Interstate	15000	1	3	5	90	8000	1
7	Non-Interstate	15000	1	3	5	90	8000	2
8	Non-Interstate	15000	1	3	5	90	8000	3
9	Non-Interstate	15000	1	3	5	90	7000	2
10	Non-Interstate	15000	1	3	5	90	7000	3



(a)



(b)

Figure 7. NDFP - Comparison of Design Results For (a) Required SN and (b) Thickness.

4.2.1.2 NDJPCP - New Design Jointed Plain Concrete Pavement

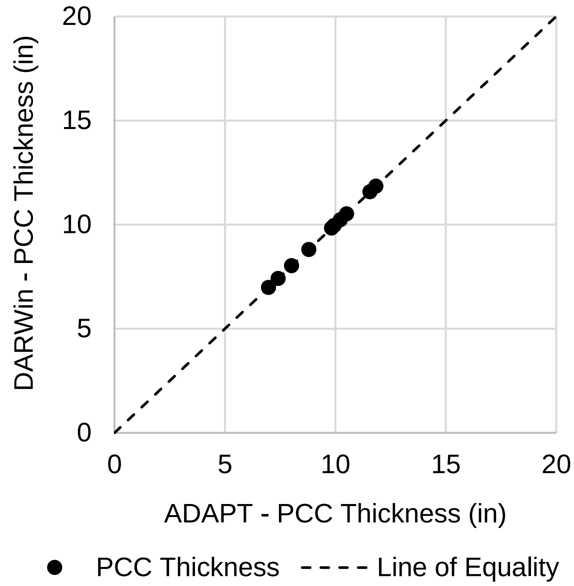
The "New Design Jointed Plain Concrete Pavement" design objective was to determine the required thickness of the Portland Cement Concrete (PCC) layer in a new JPCP. Ten (10) design scenarios were simulated in both ADAPT and DARWin to compare their results. An excerpt of the inputs used for the design is shown in Table 22 where the project setting was an interstate with an

AADT of 15,000, one lane, 3% growth rate, 5% truck, and 100% truck in design lane. The subgrade modulus was kept at 8,000 psi. The type of shoulder was varied between asphalt and tied PCC, with tie bars of 0.75 in. diameter, allowable steel working stress of 30,000 psi, and a distance to nearest free edge of 12 ft. The use of tie bars, dowels, drains, and/or bedrock (120 in deep) was also considered. The number of pavement layers was varied from 1 to 2 layers, which are the PCC with an elastic modulus of 4,200,000 psi and a cement treated aggregate subbase with a modulus of 1,500,000 psi.

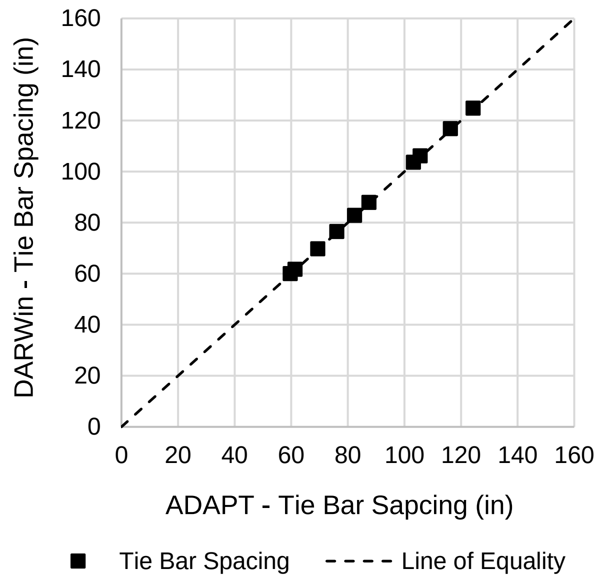
The results obtained were the required PCC thickness and tie bar spacing. Figure 8 presents the summary of the comparison. It is important to note that the tie bar spacing values being compared are the computed values, although ALDOT recommends a maximum spacing of 48 in, which is reported in ADAPT. It can be seen in Figure 8 that all the design results are located on the line of equality regardless of the varied design inputs. The average percent difference between the result values rounded to 2 decimal places was 0.2%, with the median being equal to 0.2%. The average difference between the thickness values was 0 in for the PCC layer. The tie bar length obtained was 35 in for ADAPT and 35.1 in for DARWin. The detailed list of design inputs and the results are presented in Appendix A.2.

Table 21. NDJPCP - Design Inputs

Trial	AADT	Shoulder Type	Tie Bars	Dowels	Drains	Bedrock	Depth to Bedrock (in)	Layers
1	15000	Asphalt	Yes	No	No	No	-	1
2	15000	Asphalt	Yes	No	No	No	-	2
3	15000	Asphalt	Yes	Yes	No	No	-	1
4	15000	Asphalt	Yes	Yes	No	No	-	2
5	15000	Tied PCC	Yes	No	No	No	-	1
6	15000	Tied PCC	Yes	No	No	No	-	2
7	15000	Tied PCC	Yes	Yes	No	No	-	1
8	15000	Tied PCC	Yes	Yes	No	No	-	2
9	15000	Tied PCC	Yes	Yes	Yes	No	-	2
10	15000	Tied PCC	Yes	Yes	No	Yes	120	2



(a)



(b)

Figure 8. NDJPCP - Comparison of Design Results For (a) Thickness and (b) Tie Bar Spacing

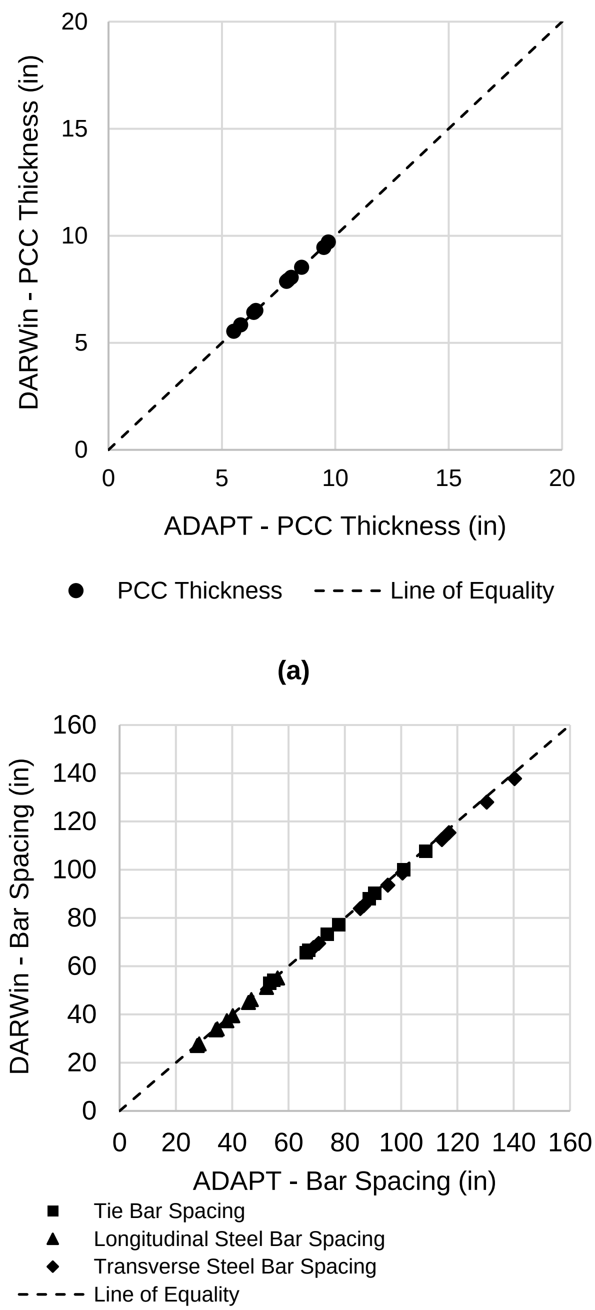
4.2.2.3 NDJRCP - New Design Jointed Reinforced Concrete Pavement

The "New Design Jointed Reinforced Concrete Pavement" design's purpose was the determination of the required thickness of the Portland Cement Concrete (PCC) layer in a new JRCP. Ten (10) design scenarios were simulated in both ADAPT and DARWin to compare their results. An excerpt of the inputs used for the design is shown in Table 23 where the project setting was an interstate with an AADT of 15,000, one lane, 3% growth rate, 5% truck, and 100% truck in design lane. The subgrade modulus was kept at 8,000 psi. The type of shoulder was varied between asphalt and tied PCC. Tie bars, dowels, drains, and/or bedrock (60 in deep) were also considered. The tie bars had a diameter of 0.625 in., an allowable steel working stress of 30,000 psi, and a distance to nearest free edge of 12 ft. The slab length was 30 ft and the steel mesh had an allowable steel stress of 30,000 psi. The number of pavement layers was varied from 1 to 2 layers, which are the PCC with an elastic modulus of 4,200,000 psi and a cement treated aggregate subbase with a modulus of 1,500,000 psi.

The results obtained were the required PCC thickness, tie bar spacing, longitudinal steel bar spacing, and transverse steel bar spacing. Figure 9 presents the summary of the comparison. It can be seen in Figure 9 that all the design results for PCC thickness are located on the line of equality despite the variation of design inputs. The average difference between the thickness values was 0.01 in for the PCC layer. From Figure 9, it can also be seen that the ADAPT spacing values for tie bars, longitudinal bars, and transverse bars are slightly greater than those of DARWin. Since the input values are the same, this difference could be due to the fact that the calculated PCC thicknesses are slightly greater in ADAPT than in DARWin due to rounding to the nearest 0.5 inch in ADAPT, thus the percent steel required per concrete area is also slightly greater. The average percent difference between the results was 1.1% with the median being equal to 1.2%. The detailed list of design inputs and the results are presented in Appendix A.3.

Table 22. NDJRCP - Design Inputs

Trial	AADT	Shoulder Type	Tie Bars	Dowels	Drains	Bedrock	Depth to Bedrock (in)	Layers
1	15000	Asphalt	Yes	No	No	No	-	1
2	15000	Asphalt	Yes	No	No	No	-	2
3	15000	Asphalt	Yes	Yes	No	No	-	1
4	15000	Asphalt	Yes	Yes	No	No	-	2
5	15000	Tied PCC	Yes	No	No	No	-	1
6	15000	Tied PCC	Yes	No	No	No	-	2
7	15000	Tied PCC	Yes	Yes	No	No	-	1
8	15000	Tied PCC	Yes	Yes	No	No	-	2
9	15000	Tied PCC	Yes	Yes	Yes	No	-	2
10	15000	Tied PCC	Yes	Yes	No	Yes	60	2



(b)

Figure 9. NDJRCP - Comparison of Design Results For (a) PCC Thickness and (b) Bar Spacing

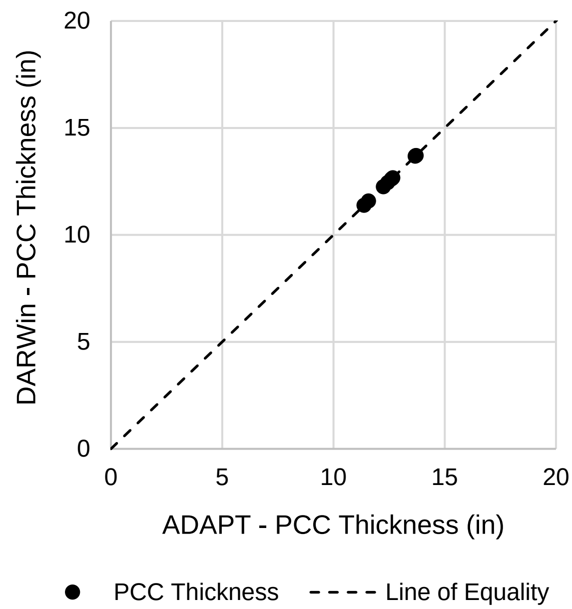
4.2.2.4 NDCRCP - New Design Continuously Reinforced Concrete Pavement

The objective of the “New Design Continuously Reinforced Concrete Pavement” design was to determine the required thickness of the Portland Cement Concrete (PCC) layer in a new CRCP. Ten (10) design scenarios were simulated in both ADAPT and DARWin to compare their results. An excerpt of the inputs used for the design is shown in Table 24 where the project setting was an interstate with an AADT of 45,000, two lanes, 4% growth rate, 10% truck, and 85% truck in design lane. The subgrade modulus and the type of shoulder were kept at 6,000 psi and tied PCC, respectively. The use of tie bars, drains, and/or bedrock was also considered. The tie bars had a diameter of 0.75 in., an allowable steel working stress of 30,000 psi, and a distance to nearest free edge of 12 ft. The slab width was 12 ft, the concrete shrinkage at 28 days was 0.00036 in/in, the coarse aggregate was gravel, the concrete thermal coefficient was 0.000006 in/in/F, and the tensile stress in slab due to wheel load was 190 psi. The longitudinal steel had a thermal coefficient of 0.000005 in/in/F, an allowable steel stress of 62,180 psi, and a temperature drop of 50 F. The transverse steel had an allowable steel stress of 30,000 psi. The bedrock, when included, had a depth that varied between 30 and 108 in. The number of pavement layers was varied from 1 to 2 layers, which are the PCC with an elastic modulus of 4,200,000 psi and a cement treated aggregate subbase with a modulus of 1,500,000 psi.

The results obtained were the required PCC thickness, tie bar spacing, longitudinal steel number of bars, and transverse steel bar spacing. Figure 10 presents the summary of the comparison. It is seen in Figure 10 that all the design results for PCC thickness, tie bar spacing, and transverse bar spacing are located on the line of equality even though the design inputs were varied. However, the number longitudinal steel bars were slightly higher in ADAPT than in DARWin and is believed to be caused by the slight difference due to rounding as reported for NDJRCP. The average percent difference between the results was 1.8% with the median being equal to 0.4%. The detailed list of design inputs and the results are presented in Appendix A.4.

Table 23. NDCRCP - Design Inputs

Trial	**AADT**	**Shoulder Type**	**Tie Bars**	**Drains**	**Bedrock**	**Depth to Bedrock (in)**	**Layers**
1	45000	Tied PCC	Yes	No	No	-	1
2	45000	Tied PCC	Yes	No	No	-	2
3	45000	Tied PCC	Yes	Yes	No	-	1
4	45000	Tied PCC	Yes	Yes	No	-	2
5	45000	Tied PCC	Yes	Yes	Yes	60	1
6	45000	Tied PCC	Yes	Yes	Yes	108	2
7	45000	Tied PCC	Yes	No	Yes	96	1
8	45000	Tied PCC	Yes	No	Yes	84	2
9	45000	Tied PCC	Yes	No	Yes	40	1
10	45000	Tied PCC	Yes	No	Yes	30	2



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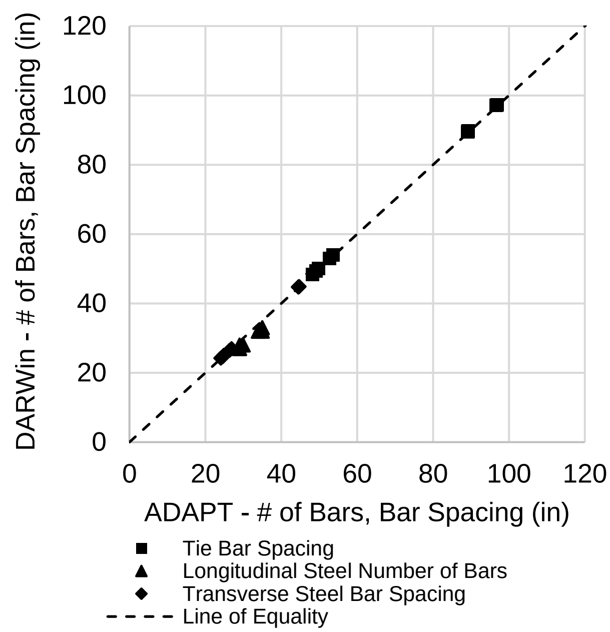


(b)

Figure 10. NDCRCP - Comparison of Design Results For (a) PCC Thickness and (b) Bar Spacing

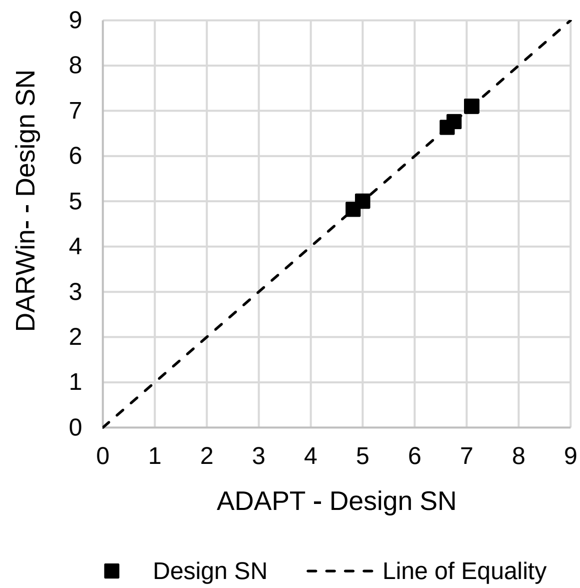
4.2.2.5 ODFP - Overlay Design Flexible Pavement

The purpose of the “Overlay Design Flexible Pavement” design was to determine the required thickness of the asphalt concrete (AC) overlay layer for an existing flexible pavement. Ten design scenarios were simulated in both ADAPT and DARWin to compare their results. An excerpt of the inputs used for the design is shown in Table 25 where the project setting was an interstate with different annual average daily traffic (AADT), number of lanes, %growth rate, %truck, and %truck in design lane. The subgrade modulus was varied between 5,500 psi and 7,000 psi. The total thickness of existing pavement layers was varied between 11 in. and 24 in. The back-calculated effective pavement modulus and the milling thickness were varied from 200,000 psi to 400,000 psi and 0 in. to 6 in., respectively. The AC overlay structural coefficient was kept at 0.54.

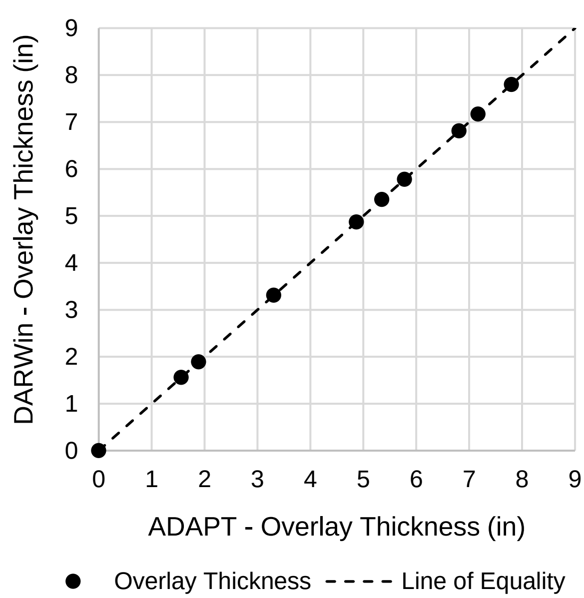
The results obtained were the required overlay thickness and the design SN. Figure 11 presents the summary of the comparison. It is seen in Figure 11 that all the design results are located on the line of equality. The average percent difference between the results was 0% with the median being equal to 0%. The average difference between the overlay thickness values was 0 in. The detailed list of design inputs and the results are presented in Appendix A.5.

Table 24. ODFP - Design Inputs

Trial	AADT	N° of Lanes	Growth Rate	%Truck	%Truck in Design Lane	Subgrade Modulus (psi)	Total Thickness of Existing Pavement Layers (in)	Back-calculated Effective Pavement Modulus (psi)	Milling Thickness (in)
1	45000	2	4	10	85	7000	11	200000	0
2	45000	2	4	10	85	6000	11	200000	0
3	45000	2	4	10	85	6000	16	200000	0
4	45000	2	4	10	85	6000	16	400000	0
5	45000	2	4	10	85	6000	16	400000	4
6	15000	1	3	2	100	6000	16	400000	4
7	15000	1	3	2	100	5500	16	400000	4
8	15000	1	3	2	100	5500	24	400000	4
9	15000	1	3	2	100	5500	11	200000	2
10	15000	1	3	2	100	5500	11	200000	6



(a)



(b)

Figure 11. ODFP - Comparison of Design Results For (a) Design SN and (b) Design Thickness

4.2.2.6 ODRP - Overlay Design Rigid Pavement

The purpose of the "Overlay Design Rigid Pavement" design was to determine the required thickness of the PCC or AC overlay layer for an existing rigid pavement. Ten design scenarios were simulated in both ADAPT and DARWin to compare their results. The inputs used for the design are shown in Tables 26 and 27 where the project setting was an interstate with different annual average daily traffic (AADT), number of lanes, %growth rate, %truck, and %truck in design lane. Two types of overlay were considered: (1) AC over AC/PCC and (2) PCC over PCC. For AC over AC/PCC, the existing AC layer thickness was varied from 3 in. to 6 in., the AC milling thickness was varied from 0 in. to 2 in., and the AC/PCC interface condition (bonded or unbonded) was considered. Additionally, the adjustment factors for PCC durability, AC quality, and joints and cracks were also varied, as listed in Table 27. The existing PCC thickness and the static modulus of subgrade reaction were varied from 4 in. to 12 in. and from 15 pci to 700 pci, respectively.

The result obtained was the required overlay thickness and Figure 12 presents the summary of the comparison. It is seen in Figure 12 that all the design results are located on the line of equality. The average percent difference between the results was 0.5% with the median being equal to 0.5%. The average difference between the overlay thickness values was 0.01 in. The detailed list of design inputs and the results are presented in Appendix A.6.

Table 25. ODRP - Design Inputs

Trial	Type of Overlay	AADT	Number of Lanes	Growth Rate	Truck Percentage	%Truck in Design Lane	Existing PCC Thickness (in)	Static Modulus of Subgrade Reaction (pci)
1	AC Over AC/PCC	45000	2	4	10	85	12	300
2		45000	2	4	10	85	10	100
3		45000	2	4	10	85	12	20
4		45000	2	4	10	85	10	20
5		45000	2	4	10	85	12	100
6	PCC Over PCC	15000	1	3	2	90	4	700
7		15000	1	3	2	90	6	400
8		15000	1	3	2	90	8	200
9		15000	1	3	2	90	5	50
10		15000	1	3	2	90	7	15

Table 26. ODRP - Design Inputs Continued

Trial	Existing AC Thickness (in)	AC Milling Thickness (in)	AC/PCC Interface Condition	Joints and Cracks Adjustment Factor (Fjc)	PCC Durability Adjustment Factor (Fdur)	AC Quality Adjustment Factor (Fac)
1	3	0	Unbonded	0.8	0.9	1
2	3	0	Bonded	0.9	0.9	0.8
3	3	0	Bonded	0.89	0.9	0.8
4	6	2	Unbonded	0.8	1	0.9
5	6	2	Bonded	0.8	1	1
6	-	-	-	0.95	-	-
7	-	-	-	0.9	-	-
8	-	-	-	0.95	-	-
9	-	-	-	0.91	-	-
10	-	-	-	0.95	-	-

Figure 12. ODRP - Comparison of Design Results

4.2.3 Summary

In the sensitivity analysis of the new software ADAPT, the design results from the software were compared to results from the previous DARWin software. The average percent differences between the design results were 0.2%, 0.2%, 1.1%, 1.8%, 0%, and 0.5% for NDFP, NDJPCP, NDJRCP, NDCRCP, ODFP, and ODRP, respectively. The overall average percent difference for all these design types was 0.8% with a median of 0.3%. The maximum difference between the design thicknesses obtained throughout this analysis for AC and PCC layers was 0.02 in. Based on the extremely low percent difference between the results, it can be concluded that the design results from ADAPT and DARWin are practically equivalent.

5 FINDINGS, CONCLUSIONS, RECOMMENDATIONS, AND IMPLEMENTATION

5.1 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The following findings resulted from this study:

- The structural layer coefficient of the collected limestone data is not statistically different than the ALDOT default value.
- The resilient modulus of collected limestone data was found to be slightly higher than that of the ALDOT default value.
- The structural layer coefficient and resilient modulus of the collected sandstone data was statistically equivalent to that of the ALDOT default value.
- Structural layer coefficients and resilient modulus values for both FDR-C and S-C are lower than both that of the ALDOT Default and significantly lower than those found in the literature when using the 7-day UCS.
- Structural layer coefficients and resilient modulus values for both FDR-C and S-C are higher than both that of the ALDOT Default and similar to those found in the literature when using the 28-day UCS.
- The ADAPT software computes similar results to the DARWin software for new design flexible pavement, new design jointed plain concrete pavement, new design jointed reinforced concrete pavement, new design continuously reinforced concrete pavement, overlay design flexible pavement, and overlay design rigid pavement sections.

The following conclusions were formed based on the findings of this study:

- The default structural layer coefficient values and resilient modulus values for limestone and sandstone base materials remained practically the same as the default values.
- The use of the 28-day UCS strength resulted in FDR-C and S-C material inputs similar to that of those found in the literature. At 28-days the FDR-C average resilient modulus was 985,300 psi with a structural layer coefficient of 0.26, and the S-C average resilient modulus was 775,700 psi with a structural layer coefficient of 0.21.
- Resilient modulus data for subgrade soils around Alabama have been collected and can be used in the design of pavements when FWD data is not available. However, FWD data provides statistically higher resilient modulus values in the two cases investigated by the research team, so in this way the resilient modulus from the laboratory could be viewed as conservative in design.
- The ADAPT software computes results that are equivalent or practically equivalent to that of DARWin for various material types and locations.

The project team makes the following recommendations to ALDOT for implementation consideration:

- Continue using the default structural layer coefficient values and resilient modulus values for limestone and sandstone base materials.
- Consider the use of 28-day UCS strength for FDR-C and S-C materials. This may increase the use of these techniques and save ALDOT money due to their relatively inexpensive application and their increased structural contribution.
- Implement the use of ADAPT for all ALDOT pavement designs.
- Use and continue to build upon the Microsoft Access database developed as a part of this research project. This database can be used to extract and compute materials information for locations throughout Alabama.

5.2 IMPLEMENTATION PLAN

The research team will work with Scott George and other ALDOT staff to launch the ADAPT software, which is already partially in use at the time of this report, for pavement design on ALDOT routes. ALDOT will maintain and manage the software use, and has an option to work with the investigators at Auburn University's Highway Research Center to update the software at ALDOT's discretion through future contracts.

ALDOT will continue to update the Microsoft Access database for use in the ADAPT software, along with the ability to assess and consider changes to their default structural design inputs. ALDOT will also consider the impacts, benefits, and drawbacks of adjusting the default structural layer coefficient and default resilient modulus default values for FDR-C and S-C.

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Appendix A.1

New Design Flexible Pavement

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Desig

Project Name:

NDFP1

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

New Design

Pavement Type(s):

Flexible

n Trials\NDFP - New Design Flexible Pavement\NDFP1.xlsx

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	22.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	12
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	8,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	7.69
Design Structural Number, Rounded:	8
Total Trucks (Classes 5-13):	23,091,498
Total Other Vehicles (Classes 1-4):	81,869,857
Truck Damage Factor:	0.9745
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	3,526,332
Flexible Pavement Total Design ESALs (W18):	22,519,039

Flexible Pavement Design Option 1

Trial 1

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	7.69	14.24	14.24	7.69
2	Soil	8,000						

Flexible Pavement Design Option 2

Trial 2

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	4.23	7.83	7.83	4.23
2	Granular Base	40,000	0.14	1	7.69	24.71	24.71	7.69
3	Soil	8,000						

Flexible Pavement Design Option 3

Trial 3

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	4.23	7.83	7.83	4.23
2	Granular Base	40,000	0.14	1	6.31	14.86	14.86	6.31
3	Improved Roadbed (stabilized w/ agg)	15,000	0.11	1	7.69	12.55	12.55	7.69
4	Soil	8,000						

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

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Project Name:

NDFP2

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Non-Interstate

Project Type:

New Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	22.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	12
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	7,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	8
Design Structural Number, Rounded:	8
Total Trucks (Classes 5-13):	23,091,498
Total Other Vehicles (Classes 1-4):	81,869,857
Truck Damage Factor:	0.9745
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	3,526,332
Flexible Pavement Total Design ESALs (W18):	22,519,039

Flexible Pavement Design Option 1

Trial 4

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	4.23	7.83	7.83	4.23
2	Granular Base	40,000	0.14	1	8	26.93	26.93	8
3	Soil	7,000						

Flexible Pavement Design Option 2

Trial 5

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	4.23	7.83	7.83	4.23
2	Granular Base	40,000	0.14	1	6.31	14.86	14.86	6.31
3	Improved Roadbed (stabilized w/ agg)	15,000	0.11	1	8	15.36	15.36	8
4	Soil	7,000						

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\NDFP - New Design Flexible Pavement\NDFP3.xlsx

Project Name:
NDFP3

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Non-Interstate

Project Type:
New Design

Pavement Type(s):
Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	5.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	12
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	90.00%
Standard Normal Deviate:	-1.282
Subgrade Modulus, psi:	8,000
Initial Serviceability:	4.2
Terminal Serviceability:	3
Change in Serviceability:	1.2
Design Structural Number:	4.14
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	1,749,478
Total Other Vehicles (Classes 1-4):	33,240,084
Truck Damage Factor:	1.0088
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	277,389
Flexible Pavement Total Design ESALs (W18):	1,771,522

Flexible Pavement Design Option 1

Trial 6

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	4.14	7.67	7.67	4.14
2	Soil	8,000						

Flexible Pavement Design Option 2

Trial 7

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	2.08	3.85	3.85	2.08
2	Granular Base	40,000	0.14	1	4.14	14.71	14.71	4.14
3	Soil	8,000						

Flexible Pavement Design Option 3

Trial 8

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	2.08	3.85	3.85	2.08
2	Granular Base	40,000	0.14	1	3.15	7.64	7.64	3.15
3	Improved Roadbed (stabilized w/ agg)	15,000	0.11	1	4.14	9	9	4.14
4	Soil	8,000						

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\NDFP - New Design Flexible Pavement\NDFP4.xlsx

Project Name:

NDFP4

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Non-Interstate

Project Type:

New Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	5.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	12
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	90.00%
Standard Normal Deviate:	-1.282
Subgrade Modulus, psi:	7,000
Initial Serviceability:	4.2
Terminal Serviceability:	3
Change in Serviceability:	1.2
Design Structural Number:	4.37
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	1,749,478
Total Other Vehicles (Classes 1-4):	33,240,084
Truck Damage Factor:	1.0088
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	277,389
Flexible Pavement Total Design ESALs (W18):	1,771,522

Flexible Pavement Design Option 1

Trial 9

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	2.08	3.85	3.85	2.08
2	Granular Base	40,000	0.14	1	4.37	16.36	16.36	4.37
3	Soil	7,000						

Flexible Pavement Design Option 2

Trial 10

Layer	Material Type	Modulus, psi	Structural Coefficient	Drainage Coefficient	Required SN	Required Thickness, in.	Design Thickness, in.	Design SN
1	AC	800,000	0.54	1	2.08	3.85	3.85	2.08
2	Granular Base	40,000	0.14	1	3.15	7.64	7.64	3.15
3	Improved Roadbed (stabilized w/ agg)	15,000	0.11	1	4.37	11.09	11.09	4.37
4	Soil	7,000						

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Flexible Structural Design Module

NDFP-Trial 1

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	22,519,039
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	8,000 psi
Stage Construction	1
Calculated Design Structural Number	7.69 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	78	4	0.0002	0	16,374
2	22	4	0.9745	0	22,502,665

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	22,519,039

Growth	Compound
Total Calculated Cumulative ESALs	22,519,039

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	-	-	800,000	12	14.24	7.69
Total	-	-	-	-	-	-	-	14.24	7.69

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
Total	-	-	-	-	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

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Flexible Structural Design Module

NDFP-Trial 2

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	22,519,039
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	8,000 psi
Stage Construction	1
Calculated Design Structural Number	7.69 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	78	4	0.0002	0	16,374
2	22	4	0.9745	0	22,502,665

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	22,519,039

Growth	Compound
Total Calculated Cumulative ESALs	22,519,039

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	7.83	-	800,000	-	7.83	4.23
2	Granular Base	0.14	1	-	-	40,000	-	24.73	3.46
Total	-	-	-	-	-	-	-	32.56	7.69

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
Total	-	-	-	-	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

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Flexible Structural Design Module

NDFP-Trial 3

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	22,519,039
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	8,000 psi
Stage Construction	1
Calculated Design Structural Number	7.69 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	78	4	0.0002	0	16,374
2	22	4	0.9745	0	22,502,665

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	22,519,039

Growth	Compound
Total Calculated Cumulative ESALs	22,519,039

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	7.83	-	800,000	-	7.83	4.23
2	Granular Base	0.14	1	-	-	40,000	-	14.85	2.08
3	Improved Roadbed	0.11	1	-	-	15,000	-	12.58	1.38
Total	-	-	-	-	-	-	-	35.25	7.69

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
Total	-	-	-	-	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

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Flexible Structural Design Module

NDFP-Trial 4

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	22,519,039
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	7,000 psi
Stage Construction	1
Calculated Design Structural Number	8.00 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	78	4	0.0002	0	16,374
2	22	4	0.9745	0	22,502,665

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	22,519,039

Growth	Compound
Total Calculated Cumulative ESALs	22,519,039

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	7.83	-	800,000	-	7.83	4.23
2	Granular Base	0.14	1	-	-	40,000	-	26.94	3.77
Total	-	-	-	-	-	-	-	34.77	8.00

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
Total	-	-	-	-	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

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Flexible Structural Design Module

NDFP-Trial 5

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	22,519,039
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	7,000 psi
Stage Construction	1
Calculated Design Structural Number	8.00 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	78	4	0.0002	0	16,374
2	22	4	0.9745	0	22,502,665

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	22,519,039

Growth	Compound
Total Calculated Cumulative ESALs	22,519,039

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	7.83	-	800,000	-	7.83	4.23
2	Granular Base	0.14	1	-	-	40,000	-	14.85	2.08
3	Improved Roadbed	0.11	1	-	-	15,000	-	15.40	1.69
Total	-	-	-	-	-	-	-	38.07	8.00

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Flexible Structural Design Module

NDFP-Trial 6

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	1,771,522
Initial Serviceability	4.2
Terminal Serviceability	3
Reliability Level	90 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	8,000 psi
Stage Construction	1
Calculated Design Structural Number	4.15 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	6,648
2	5	3	1.0088	0	1,764,874

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	1,771,522

Growth	Compound
Total Calculated Cumulative ESALs	1,771,522

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	-	-	800,000	-	7.69	4.15
Total	-	-	-	-	-	-	-	7.69	4.15

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

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Flexible Structural Design Module

NDFP-Trial 7

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	1,771,522
Initial Serviceability	4.2
Terminal Serviceability	3
Reliability Level	90 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	8,000 psi
Stage Construction	1
Calculated Design Structural Number	4.15 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	6,648
2	5	3	1.0088	0	1,764,874

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	1,771,522

Growth	Compound
Total Calculated Cumulative ESALs	1,771,522

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	3.85	-	800,000	-	3.85	2.08
2	Granular Base	0.14	1	-	-	40,000	-	14.79	2.07
Total	-	-	-	-	-	-	-	18.64	4.15

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Auburn University

Flexible Structural Design Module

NDFP-Trial 8

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	1,771,522
Initial Serviceability	4.2
Terminal Serviceability	3
Reliability Level	90 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	8,000 psi
Stage Construction	1
Calculated Design Structural Number	4.15 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	6,648
2	5	3	1.0088	0	1,764,874

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	1,771,522

Growth	Compound
Total Calculated Cumulative ESALs	1,771,522

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	3.85	-	800,000	-	3.85	2.08
2	Granular Base	0.14	1	-	-	40,000	-	7.66	1.07
3	Improved Roadbed	0.11	1	-	-	15,000	-	9.08	1.00
Total	-	-	-	-	-	-	-	20.59	4.15

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Auburn University

Flexible Structural Design Module

NDFP-Trial 9

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	1,771,522
Initial Serviceability	4.2
Terminal Serviceability	3
Reliability Level	90 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	7,000 psi
Stage Construction	1
Calculated Design Structural Number	4.38 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	6,648
2	5	3	1.0088	0	1,764,874

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	1,771,522

Growth	Compound
Total Calculated Cumulative ESALs	1,771,522

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	3.85	-	800,000	-	3.85	2.08
2	Granular Base	0.14	1	-	-	40,000	-	16.44	2.30
Total	-	-	-	-	-	-	-	20.29	4.38

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Auburn University

Flexible Structural Design Module

NDFP-Trial 10

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	1,771,522
Initial Serviceability	4.2
Terminal Serviceability	3
Reliability Level	90 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	7,000 psi
Stage Construction	1
Calculated Design Structural Number	4.38 in

Simple ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	12
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	6,648
2	5	3	1.0088	0	1,764,874

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
Total	100	-	-	-	1,771,522

Growth	Compound
Total Calculated Cumulative ESALs	1,771,522

Layered Thickness Design

Thickness precision	Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.54	1	3.85	-	800,000	-	3.85	2.08
2	Granular Base	0.14	1	-	-	40,000	-	7.66	1.07
3	Improved Roadbed	0.11	1	-	-	15,000	-	11.17	1.23
Total	-	-	-	-	-	-	-	22.68	4.38

Appendix A.2

New Design Jointed Plain Concrete Pavement

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\NDJPCP - New Design Jointed Plain Concrete Pavement\NDJPCP.xlsx

Project Name:
NDJPCP1

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
New Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	5.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Rigid Pavement Design Option 1

Trial 1

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Asphalt		
Dowels:	No	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	90
Standard Normal Variate:	-1.282

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3
Change in Serviceability:	1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.6246
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	446,080
Total Design ESALs:	5,993,166

Slab Thickness

Required Slab Thickness, in.:	11.84	Design Slab Thickness, in.:	11.84

Rigid Pavement Design Option 1 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 103.23

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 2

Trial 2

Design Features

Construction Stages: 1
Pavement Type: JPCP (Jointed Plain)
Tie Bars Between Lanes: Yes
Shoulder Type: Asphalt
Dowels: No   Load Transfer Coefficient: 2.8
Drains: No   Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 12
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5   Modulus of Subgrade Reaction, pci: 1092

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 90
Standard Normal Variate: -1.282

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3
Change in Serviceability: 1.5

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 3,680,402
Total Other Vehicles (Class 1-4) in Performance Period: 69,927,631
Truck (Class 5-13) Damage Factor: 1.5821
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 434,437
Total Design ESALs: 5,836,749

Slab Thickness

Required Slab Thickness, in.: 10.23   Design Slab Thickness, in.: 10.23

Rigid Pavement Design Option 2 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 59.74

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 3

Trial 3

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Asphalt		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	90
Standard Normal Variate:	-1.282

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3
Change in Serviceability:	1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.6093
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	441,889
Total Design ESALs:	5,936,856

Slab Thickness

Required Slab Thickness, in.:	10.51	Design Slab Thickness, in.:	10.51

Rigid Pavement Design Option 3 - Steel

Dowel Bars

Diameter:	1+3/8"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Required Steel, % of Concrete Area:	0.04
Calculated Tie Bar Spacing, in:	116.29

Diameter:	#6 (0.750")
Recommended Spacing, in:	48
Length, in:	35

Rigid Pavement Design Option 4

Trial 4

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Asphalt		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	12		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	90
Standard Normal Variate:	-1.282

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3
Change in Serviceability:	1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.5385
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	422,494
Total Design ESALs:	5,676,283

Slab Thickness

Required Slab Thickness, in.:	8.8	Design Slab Thickness, in.:	8.8

Rigid Pavement Design Option 4 - Steel

Dowel Bars

Diameter: 1+1/8"
Spacing, in: 12
Length, in: 18

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 69.44

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 5

Trial 5

Design Features

Construction Stages: 1
Pavement Type: JPCP (Jointed Plain)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No
Drains: No

Load Transfer Coefficient: 2.8
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: None (or Surface Treatment)
Subbase Thickness, in: NA
Subbase Modulus, psi: NA
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5

Modulus of Subgrade Reaction, pci: 1092

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 90
Standard Normal Variate: -1.282

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3
Change in Serviceability: 1.5

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 3,680,402
Total Other Vehicles (Class 1-4) in Performance Period: 69,927,631
Truck (Class 5-13) Damage Factor: 1.6246
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 446,080
Total Design ESALs: 5,993,166

Slab Thickness

Required Slab Thickness, in.: 11.57

Design Slab Thickness, in.: 11.57

Rigid Pavement Design Option 5 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 105.64

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 6

Trial 6

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	No	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	12		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	90
Standard Normal Variate:	-1.282

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3
Change in Serviceability:	1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.5821
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	434,437
Total Design ESALs:	5,836,749

Slab Thickness

Required Slab Thickness, in.:	9.95	Design Slab Thickness, in.:	9.95

Rigid Pavement Design Option 6 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 61.42

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 7

Trial 7

Design Features

Construction Stages: 1
Pavement Type: JPCP (Jointed Plain)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: Yes
Load Transfer Coefficient: 2.8
Drains: No
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: None (or Surface Treatment)
Subbase Thickness, in: NA
Subbase Modulus, psi: NA
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5
Modulus of Subgrade Reaction, pci: 1092

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 90
Standard Normal Variate: -1.282

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3
Change in Serviceability: 1.5

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 3,680,402
Total Other Vehicles (Class 1-4) in Performance Period: 69,927,631
Truck (Class 5-13) Damage Factor: 1.5821
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 434,437
Total Design ESALs: 5,836,749

Slab Thickness

Required Slab Thickness, in.: 9.83
Design Slab Thickness, in.: 9.83

Rigid Pavement Design Option 7 - Steel

Dowel Bars

Diameter: 1+1/4"
Spacing, in: 12
Length, in: 18

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 124.34

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 8

Trial 8

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	12		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 90
Standard Normal Variate: -1.282

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3
Change in Serviceability: 1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.485
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	407,838
Total Design ESALs:	5,479,382

Slab Thickness

Required Slab Thickness, in.: 8.02
Design Slab Thickness, in.: 8.02

Rigid Pavement Design Option 8 - Steel

Dowel Bars

Diameter: 1+1/8"
Spacing, in: 12
Length, in: 18

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 76.2

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

Rigid Pavement Design Option 9

Trial 9

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	Yes	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	12		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	90
Standard Normal Variate:	-1.282

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3
Change in Serviceability:	1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.4573
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	400,250
Total Design ESALs:	5,377,435

Slab Thickness

Required Slab Thickness, in.:	6.98	Design Slab Thickness, in.:	6.98

Rigid Pavement Design Option 9 - Steel

Dowel Bars

Diameter:	7/8"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Required Steel, % of Concrete Area:	0.07
Calculated Tie Bar Spacing, in:	87.55
Diameter:	#6 (0.750")
Recommended Spacing, in:	48
Length, in:	35

Rigid Pavement Design Option 10

Trial 10

Design Features

Construction Stages:	1		
Pavement Type:	JPCP (Jointed Plain)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	12		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	Yes		
Depth to Bedrock, in:	120		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	1092

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	90
Standard Normal Variate:	-1.282

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3
Change in Serviceability:	1.5

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	3,680,402
Total Other Vehicles (Class 1-4) in Performance Period:	69,927,631
Truck (Class 5-13) Damage Factor:	1.4573
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	400,250
Total Design ESALs:	5,377,435

Slab Thickness

Required Slab Thickness, in.:	7.41	Design Slab Thickness, in.:	7.41

Rigid Pavement Design Option 10 - Steel

Dowel Bars

Diameter:	1"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Required Steel, % of Concrete Area:	0.07
Calculated Tie Bar Spacing, in:	82.47
Diameter:	#6 (0.750")
Recommended Spacing, in:	48
Length, in:	35

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Rigid Structural Design Module

NDJPCP-Trial 1

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,993,166
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	4.1
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	11.84 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.6246	0	5,979,180
Total	100	-	-	-	5,993,166

Growth	Compound
Total Calculated Cumulative ESALs	5,993,166

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	11.84 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	103.6 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.051 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	11.8445667	12
Total	-	11.84	-

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Rigid Structural Design Module

NDJPCP-Trial 2

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,836,749
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	4.1
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	10.23 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.5821	0	5,822,763
Total	100	-	-	-	5,836,749

Growth Compound

Total Calculated Cumulative ESALs 5,836,749

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	10.23 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	60.0 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.088 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	10.2327423	12
2	Cement Treated Granular Base	12	12
Total	-	22.23	-

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NDJPCP-Trial 3

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,936,856
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	10.51 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.6093	0	5,922,870
Total	100	-	-	-	5,936,856

Growth Compound

Total Calculated Cumulative ESALs 5,936,856

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	10.51 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	116.8 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.045 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	1.375 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	10.5130357	12
Total	-	10.51	-

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Rigid Structural Design Module

NDJPCP-Trial 4

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,676,283
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	8.80 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.5385	0	5,662,298
Total	100	-	-	-	5,676,283

Growth	Compound
Total Calculated Cumulative ESALs	5,676,283

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	8.8 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	69.7 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.076 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	1.125 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	8.8020232	12
2	Cement Treated Granular Base	12	12
Total	-	20.80	-

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NDJPCP-Trial 5

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,993,166
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.9
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	11.57 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.6246	0	5,979,180
Total	100	-	-	-	5,993,166

Growth	Compound
Total Calculated Cumulative ESALs	5,993,166

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	11.57 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	106.1 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.050 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	11.5676355	12
Total	-	11.57	-

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Rigid Structural Design Module

NDJPCP-Trial 6

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,836,749
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.9
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	9.95 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.5821	0	5,822,763
Total	100	-	-	-	5,836,749

Growth	Compound
Total Calculated Cumulative ESALs	5,836,749

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	9.95 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	61.7 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.086 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	9.9462838	12
2	Cement Treated Granular Base	12	12
Total	-	21.95	-

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Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,836,749
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	9.83 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.5821	0	5,822,763
Total	100	-	-	-	5,836,749

Growth	Compound
Total Calculated Cumulative ESALs	5,836,749

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	9.83 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	124.8 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.042 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	1.25 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	9.8328445	12
Total	-	9.83	-

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NDJPCP-Trial 8

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,479,382
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	8.02 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.485	0	5,465,396
Total	100	-	-	-	5,479,382

Growth	Compound
Total Calculated Cumulative ESALs	5,479,382

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	8.02 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	76.5 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.069 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	1.125 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	8.0211328	12
2	Cement Treated Granular Base	12	12
Total	-	20.02	-

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NDJPCP-Trial 9

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,377,435
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	6.98 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.4573	0	5,363,449
Total	100	-	-	-	5,377,435

Growth	Compound
Total Calculated Cumulative ESALs	5,377,435

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	6.98 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	87.9 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.060 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	0.875 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	6.976792	12
2	Cement Treated Granular Base	12	12
Total	-	18.98	-

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Auburn University

Rigid Structural Design Module

NDJPCP-Trial 10

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	5,377,435
Initial Serviceability	4.5
Terminal Serviceability	3
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	1,092 psi/in
Reliability Level	90 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	7.41 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	10 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	1,092 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	95	3	0.0002	0	13,986
2	5	3	1.4573	0	5,363,449
Total	100	-	-	-	5,377,435

Growth	Compound
Total Calculated Cumulative ESALs	5,377,435

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	7.41 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	82.8 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.064 sq in/ft

Layer Information

Joint Spacing	- ft
Dowel Material	-
Dowel Diameter	1 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JPCP	7.4123603	12
2	Cement Treated Granular Base	12	12
Total	-	19.41	-

Appendix A.3

New Design Jointed Reinforced Concrete Pavement

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\NDJRCP - New Design Jointed Reinforced Concrete Pavement\NDJRCP.xlsx

Project Name:
NDJRCP1

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
New Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Rigid Pavement Design Option 1

Trial 1

Design Features

Construction Stages:	1		
Pavement Type:	JRCP (Jointed Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Asphalt		
Dowels:	No	Load Transfer Coefficient:	4.1
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	2.9	Modulus of Subgrade Reaction, pci:	18

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 85
Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 2.5
Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 1,472,161
Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871
Truck (Class 5-13) Damage Factor: 1.6066
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 177,117
Total Design ESALs: 2,379,600

Slab Thickness

Required Slab Thickness, in.: 9.7
Design Slab Thickness, in.: 9.7

Rigid Pavement Design Option 1 - Steel

No Dowel Bars

Diameter:	NA
Spacing, in:	NA
Length, in:	NA

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Required Steel, % of Concrete Area:	0.04
Calculated Tie Bar Spacing, in:	88.77
Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.045
Transverse Required % Steel:	0.018

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	45.8	114.5

Rigid Pavement Design Option 2

Trial 2

Design Features

Construction Stages: 1
Pavement Type: JRCP (Jointed Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Asphalt
Dowels: No | Load Transfer Coefficient: 4.1
Drains: No | Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 12
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5 | Modulus of Subgrade Reaction, pci: 709

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 85
Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 2.5
Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 1,472,161
Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871
Truck (Class 5-13) Damage Factor: 1.5457
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 170,444
Total Design ESALs: 2,289,946

Slab Thickness

Required Slab Thickness, in.: 7.86
Design Slab Thickness, in.: 7.86

Rigid Pavement Design Option 2 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 54.78

Diameter: #5 (0.625")
Recommended Spacing, in: 48
Length, in: 30

Temperature Steel Mesh

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Length, ft: 30
Slab Width, ft: 12
Longitudinal Required % Steel: 0.09
Transverse Required % Steel: 0.036

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	28.3	70.7

Rigid Pavement Design Option 3

Trial 3

Design Features

Construction Stages:	1		
Pavement Type:	JRCP (Jointed Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Asphalt		
Dowels:	Yes	Load Transfer Coefficient:	3.2
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	2.9	Modulus of Subgrade Reaction, pci:	18

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	85
Standard Normal Variate:	-1.038

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	2.5
Change in Serviceability:	2

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	1,472,161
Total Other Vehicles (Class 1-4) in Performance Period:	72,135,871
Truck (Class 5-13) Damage Factor:	1.5797
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	174,169
Total Design ESALs:	2,339,999

Slab Thickness

Required Slab Thickness, in.:	8.52	Design Slab Thickness, in.:	8.52

Rigid Pavement Design Option 3 - Steel

Dowel Bars

Diameter:	1+1/8"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Required Steel, % of Concrete Area:	0.04
Calculated Tie Bar Spacing, in:	101.07
Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.045
Transverse Required % Steel:	0.018

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	52.2	130.4

Rigid Pavement Design Option 4

Trial 4

Design Features

Construction Stages: 1
Pavement Type: JRCP (Jointed Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Asphalt
Dowels: Yes
Drains: No

Load Transfer Coefficient: 3.2
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 12
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5

Modulus of Subgrade Reaction, pci: 709

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 85
Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 2.5
Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 1,472,161
Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871
Truck (Class 5-13) Damage Factor: 1.5609
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 172,109
Total Design ESALs: 2,312,323

Slab Thickness

Required Slab Thickness, in.: 6.5

Design Slab Thickness, in.: 6.5

Rigid Pavement Design Option 4 - Steel

Dowel Bars

Diameter:	7/8"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Required Steel, % of Concrete Area:	0.07
Calculated Tie Bar Spacing, in:	66.24
Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.09
Transverse Required % Steel:	0.036

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	34.2	85.5

Rigid Pavement Design Option 5

Trial 5

Design Features

Construction Stages: 1
Pavement Type: JRCP (Jointed Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No
Drains: No

Load Transfer Coefficient: 3.9
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: None (or Surface Treatment)
Subbase Thickness, in: NA
Subbase Modulus, psi: NA
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 2.9

Modulus of Subgrade Reaction, pci: 18

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 85
Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 2.5
Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 1,472,161
Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871
Truck (Class 5-13) Damage Factor: 1.6066
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 177,117
Total Design ESALs: 2,379,600

Slab Thickness

Required Slab Thickness, in.: 9.5

Design Slab Thickness, in.: 9.5

Rigid Pavement Design Option 5 - Steel

No Dowel Bars

Diameter:	NA
Spacing, in:	NA
Length, in:	NA

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Required Steel, % of Concrete Area:	0.04
Calculated Tie Bar Spacing, in:	90.64
Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.045
Transverse Required % Steel:	0.018

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	46.8	117

Rigid Pavement Design Option 6

Trial 6

Design Features

Construction Stages: 1
Pavement Type: JRCP (Jointed Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No
Load Transfer Coefficient: 3.9
Drains: No
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 6
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5
Modulus of Subgrade Reaction, pci: 435

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 85
Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 2.5
Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 1,472,161
Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871
Truck (Class 5-13) Damage Factor: 1.5457
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 170,444
Total Design ESALs: 2,289,946

Slab Thickness

Required Slab Thickness, in.: 8.06
Design Slab Thickness, in.: 8.06

Rigid Pavement Design Option 6 - Steel

No Dowel Bars

Diameter:	NA
Spacing, in:	NA
Length, in:	NA

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Required Steel, % of Concrete Area:	0.07
Calculated Tie Bar Spacing, in:	53.42
Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.09
Transverse Required % Steel:	0.036

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	27.6	68.9

Rigid Pavement Design Option 7

Trial 7

Design Features

Construction Stages: 1
Pavement Type: JRCP (Jointed Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: Yes — Load Transfer Coefficient: 2.8
Drains: No — Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: None (or Surface Treatment)
Subbase Thickness, in: NA
Subbase Modulus, psi: NA
Subgrade Modulus, psi: 8,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 2.9 — Modulus of Subgrade Reaction, pci: 18

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 85
Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 2.5
Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 1,472,161
Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871
Truck (Class 5-13) Damage Factor: 1.5457
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 170,444
Total Design ESALs: 2,289,946

Slab Thickness

Required Slab Thickness, in.: 7.92 — Design Slab Thickness, in.: 7.92

Rigid Pavement Design Option 7 - Steel

Dowel Bars

Diameter:	1"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Required Steel, % of Concrete Area:	0.04
Calculated Tie Bar Spacing, in:	108.73

Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Subgrade
Friction Factor:	0.9
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.045
Transverse Required % Steel:	0.018

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	56.1	140.3

Rigid Pavement Design Option 8

Trial 8

Design Features

Construction Stages:	1		
Pavement Type:	JRCP (Jointed Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	6		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	435

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	85
Standard Normal Variate:	-1.038

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	2.5
Change in Serviceability:	2

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	1,472,161
Total Other Vehicles (Class 1-4) in Performance Period:	72,135,871
Truck (Class 5-13) Damage Factor:	1.5609
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	172,109
Total Design ESALs:	2,312,323

Slab Thickness

Required Slab Thickness, in.:	6.41	Design Slab Thickness, in.:	6.41

Rigid Pavement Design Option 8 - Steel

Dowel Bars

Diameter: 7/8"
Spacing, in: 12
Length, in: 18

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 67.17

Diameter: #5 (0.625")
Recommended Spacing, in: 48
Length, in: 30

Temperature Steel Mesh

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Length, ft: 30
Slab Width, ft: 12
Longitudinal Required % Steel: 0.09
Transverse Required % Steel: 0.036

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	34.7	86.7

Rigid Pavement Design Option 9

Trial 9

Design Features

Construction Stages:	1		
Pavement Type:	JRCP (Jointed Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	Yes	Load Transfer Coefficient:	2.8
Drains:	Yes	Drainage Coefficient:	1.2

Concrete Properties

Modulus of Rupture, psi: 650

Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	6		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	8,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	435

Variability & Reliability		Serviceability	
Standard Deviation:	0.39	Initial Serviceability:	4.5
Reliability, %:	85	Terminal Serviceability:	2.5
Standard Normal Variate:	-1.038	Change in Serviceability:	2

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	1,472,161
Total Other Vehicles (Class 1-4) in Performance Period:	72,135,871
Truck (Class 5-13) Damage Factor:	1.5609
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	172,109
Total Design ESALs:	2,312,323

Slab Thickness

Required Slab Thickness, in.: 5.53 Design Slab Thickness, in.: 5.53

Rigid Pavement Design Option 9 - Steel

Dowel Bars

Diameter:	3/4"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Required Steel, % of Concrete Area:	0.07
Calculated Tie Bar Spacing, in:	77.86
Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.09
Transverse Required % Steel:	0.036

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	40.2	100.5

Rigid Pavement Design Option 10

Trial 10

Design Features

Construction Stages: 1

Pavement Type: JRCP (Jointed Reinforced)

Tie Bars Between Lanes: Yes

Shoulder Type: Tied PCC

Dowels: Yes | Load Transfer Coefficient: 2.8

Drains: No | Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650

Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base

Subbase Thickness, in: 6

Subbase Modulus, psi: 1,500,000

Subgrade Modulus, psi: 8,000

Bedrock: Yes

Depth to Bedrock, in: 60

Loss of Support: 0.5 | Modulus of Subgrade Reaction, pci: 671

Variability & Reliability

Standard Deviation: 0.39

Reliability, %: 85

Standard Normal Variate: -1.038

Serviceability

Initial Serviceability: 4.5

Terminal Serviceability: 2.5

Change in Serviceability: 2

Traffic & ESALs

Performance Period, years: 20

Total Trucks (Class 5-13) in Performance Period: 1,472,161

Total Other Vehicles (Class 1-4) in Performance Period: 72,135,871

Truck (Class 5-13) Damage Factor: 1.5609

Other Vehicles (Class 1-4) Damage Factor: 0.0002

ESALs in Both Lanes and All Directions During First Year: 172,109

Total Design ESALs: 2,312,323

Slab Thickness

Required Slab Thickness, in.: 5.83 | Design Slab Thickness, in.: 5.83

Rigid Pavement Design Option 10 - Steel

Dowel Bars

Diameter:	3/4"
Spacing, in:	12
Length, in:	18

Tie Bars

Allowable Steel Working Stress, psi:	30,000
Distance to Nearest Free Edge, ft:	12
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Required Steel, % of Concrete Area:	0.07
Calculated Tie Bar Spacing, in:	73.85

Diameter:	#5 (0.625")
Recommended Spacing, in:	48
Length, in:	30

Temperature Steel Mesh

Allowable Steel Working Stress, psi:	30,000
Type of Material Beneath Slab:	Cement Treated Granular Base
Friction Factor:	1.8
Slab Length, ft:	30
Slab Width, ft:	12
Longitudinal Required % Steel:	0.09
Transverse Required % Steel:	0.036

	Longitudinal	Transverse
Diameter:	#4 (0.500")	#4 (0.500")
Maximum Bar Spacing:	38.1	95.3

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Rigid Structural Design Module

NDJRCP-Trial 1

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,379,600
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	4.1
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	9.70 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.6066	0	2,365,173
Total	100	-	-	-	2,379,600

Growth Compound

Total Calculated Cumulative ESALs 2,379,600

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	3.20
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results*
Calculated Percent Steel	0.04
Calculated Area of Steel	0.052 sq in/ft
Calculated Bar Spacing	45.0 in

*Note: These values are not represented by the inputs or an error occurred in calculation.

JRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	3.2	0.018	0.021	112.49
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-

*Note: These values are not represented by the inputs or an error occurred in calculation.

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	9.7 in
Friction Factor (F)	0.9
Percent of Yield Strength	100

Calculated Maximum Tie Bar Spacing	87.9 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.042 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	9.6968646	12
Total	-	9.70	-

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Rigid Structural Design Module

NDJRCP-Trial 2

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,289,946
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	4.1
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	7.86 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5457	0	2,275,519
Total	100	-	-	-	2,289,946

Growth	Compound
Total Calculated Cumulative ESALs	2,289,946

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	5.19
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.09
Calculated Area of Steel	0.085 sq in/ft
Calculated Bar Spacing	27.8 in

JRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	5.2	0.036	0.034	69.43
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	7.86 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.625 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	54.2 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.068 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	7.8555559	12
2	Cement Treated Granular Base	12	12
Total	-	19.86	-

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Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,339,999
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	8.52 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5797	0	2,325,572
Total	100	-	-	-	2,339,999

Growth Compound

Total Calculated Cumulative ESALs 2,339,999

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	2.81
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.04
Calculated Area of Steel	0.046 sq in/ft
Calculated Bar Spacing	51.2 in

JRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	2.8	0.018	0.018	128.01
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	8.52 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.625 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	100.0 in

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	1.125 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	8.5216316	12
Total	-	8.52	-

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Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,312,323
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	709 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.2
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	6.50 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	12 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	709 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5609	0	2,297,896
Total	100	-	-	-	2,312,323

Growth	Compound
Total Calculated Cumulative ESALs	2,312,323

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	4.29
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.09
Calculated Area of Steel	0.070 sq in/ft
Calculated Bar Spacing	33.6 in

JRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	4.3	0.036	0.028	83.94
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	6.5 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.625 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	65.6 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.056 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	0.875 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	6.4978852	12
2	Cement Treated Granular Base	12	12
Total	-	18.50	-

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Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,379,600
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.9
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	9.45 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.6066	0	2,365,173
Total	100	-	-	-	2,379,600

Growth Compound

Total Calculated Cumulative ESALs 2,379,600

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	3.12
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5 in
	Calculated Results
Calculated Percent Steel	0.04
Calculated Area of Steel	0.051 sq in/ft
Calculated Bar Spacing	46.2 in

JRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	3.1	0.018	0.020	115.38
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	9.45 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.625 in
	Calculated Results
Calculated Maximum Tie Bar Spacing	90.2 in

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	9.454593	12
Total	-	9.45	-

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NDJRCP-Trial 6

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,289,946
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	435 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	3.9
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	8.05 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	435 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5457	0	2,275,519
Total	100	-	-	-	2,289,946

Growth Compound

Total Calculated Cumulative ESALs 2,289,946

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	5.32
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.09
Calculated Area of Steel	0.087 sq in/ft
Calculated Bar Spacing	27.1 in

JRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	5.3	0.036	0.035	67.72
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	8.05 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.625 in
	Calculated Results
Calculated Maximum Tie Bar Spacing	52.9 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.070 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	- in
Dowel Length	- in
Dowel Space	- in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	8.0538652	12
2	Cement Treated Granular Base	6	12
Total	-	14.05	-

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NDJRCP-Trial 7

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,289,946
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	7.92 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5457	0	2,275,519
Total	100	-	-	-	2,289,946

Growth	Compound
Total Calculated Cumulative ESALs	2,289,946

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	2.61
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.04
Calculated Area of Steel	0.043 sq in/ft
Calculated Bar Spacing	55.1 in

JRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	2.6	0.018	0.017	137.75
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	7.92 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.625 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	107.6 in

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	1 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	7.9186802	12
Total	-	7.92	-

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Rigid Structural Design Module

NDJRCP-Trial 8

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,312,323
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	435 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	6.41 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	435 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5609	0	2,297,896
Total	100	-	-	-	2,312,323

Growth	Compound
Total Calculated Cumulative ESALs	2,312,323

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	4.23
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.09
Calculated Area of Steel	0.069 sq in/ft
Calculated Bar Spacing	34.0 in

JRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	4.2	0.036	0.028	85.10
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	6.41 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.625 in
	Calculated Results
Calculated Maximum Tie Bar Spacing	66.5 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.055 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	0.875 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	6.4092927	12
2	Cement Treated Granular Base	6	12
Total	-	12.41	-

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NDJRCP-Trial 9

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,312,323
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	435 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	5.53 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	435 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5609	0	2,297,896
Total	100	-	-	-	2,312,323

Growth Compound

Total Calculated Cumulative ESALs 2,312,323

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	3.65
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

	Calculated Results
Calculated Percent Steel	0.09
Calculated Area of Steel	0.060 sq in/ft
Calculated Bar Spacing	39.5 in

JRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	3.6	0.036	0.024	98.65
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	5.53 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.625 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	77.1 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.048 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	0.75 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	5.5287987	12
2	Cement Treated Granular Base	6	12
Total	-	11.53	-

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NDJRCP-Trial 10

Rigid Structural Design

Pavement Type	JRCP
18-kip ESALs Over Initial Performance Period	2,312,323
Initial Serviceability	4.5
Terminal Serviceability	2.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	671 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	5.83 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	8,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	5 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	671 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	14,427
2	2	3	1.5609	0	2,297,896
Total	100	-	-	-	2,312,323

Growth Compound

Total Calculated Cumulative ESALs 2,312,323

JRCP Longitudinal Steel Design

Lane	Width (ft)	Calculated Number of Bars/Lane
1	12	3.85
2	-	-
3	-	-
4	-	-
5	-	-

Tied PCC Outer Shoulder Width	- ft
Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5 in

Calculated Results

Calculated Percent Steel	0.09
Calculated Area of Steel	0.063 sq in/ft
Calculated Bar Spacing	37.4 in

JRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30
Bar or Wire Diameter	0.5

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-	-
2	12	-	3.8	0.036	0.025	93.58
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Lane	Width (ft)	Tied to Next Lane	Number of Bars/Slab Length	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
6	-	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	5.83 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.625 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	73.1 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	29.8 in
Calculated Area of Steel	0.050 sq in/ft

Layer Information

Joint Spacing	30 ft
Dowel Material	-
Dowel Diameter	0.75 in
Dowel Length	18 in
Dowel Space	12 in
Dowel Coating	-

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	JRCP	5.8282935	12
2	Cement Treated Granular Base	6	12
Total	-	11.83	-

Appendix A.4

New Design Continuously Reinforced Concrete Pavement

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Desigr

Project Name:

NDCRCP1

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

New Design

Pavement Type(s):

Rigid

 า Trials\NDCRCP - New Design Continuously Reinforced Concrete Pavement\NDCRCP.xlsx

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Rigid Pavement Design Option 1

Trial 1

Design Features

Construction Stages:	1		
Pavement Type:	CRCP (Continuously Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	No	Load Transfer Coefficient:	2.6
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	6,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	2.9	Modulus of Subgrade Reaction, pci:	15

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	95
Standard Normal Variate:	-1.647

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3.5
Change in Serviceability:	1

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	20,801,198
Total Other Vehicles (Class 1-4) in Performance Period:	187,210,779
Truck (Class 5-13) Damage Factor:	1.6339
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	2,688,477
Total Design ESALs:	34,024,519

Slab Thickness

Required Slab Thickness, in.:	13.72	Design Slab Thickness, in.:	13.72

Rigid Pavement Design Option 1 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 89.08

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 161

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 57,922
Computed Crack Spacing, ft: 4.2

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 34

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Slab Width, ft: 12
Transverse Required % Steel: 0.018

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 44.5

Rigid Pavement Design Option 2

Trial 2

Design Features

Construction Stages: 1
Pavement Type: CRCP (Continuously Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No
Drains: No

Load Transfer Coefficient: 2.6
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 6
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 6,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5

Modulus of Subgrade Reaction, pci: 350

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3.5
Change in Serviceability: 1

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 20,801,198
Total Other Vehicles (Class 1-4) in Performance Period: 187,210,779
Truck (Class 5-13) Damage Factor: 1.6269
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 2,676,972
Total Design ESALs: 33,878,911

Slab Thickness

Required Slab Thickness, in.: 12.67

Design Slab Thickness, in.: 12.67

Rigid Pavement Design Option 2 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 48.23

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 124

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 57,708
Computed Crack Spacing, ft: 4.2

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 35

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Width, ft: 12
Transverse Required % Steel: 0.036

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 24.1

Rigid Pavement Design Option 3

Trial 3

Design Features

Construction Stages:	1		
Pavement Type:	CRCP (Continuously Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	No	Load Transfer Coefficient:	2.6
Drains:	Yes	Drainage Coefficient:	1.2

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	6,000		
Bedrock:	No		
Depth to Bedrock, in:	NA		
Loss of Support:	2.9	Modulus of Subgrade Reaction, pci:	15

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	95
Standard Normal Variate:	-1.647

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3.5
Change in Serviceability:	1

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	20,801,198
Total Other Vehicles (Class 1-4) in Performance Period:	187,210,779
Truck (Class 5-13) Damage Factor:	1.6269
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	2,676,972
Total Design ESALs:	33,878,911

Slab Thickness

Required Slab Thickness, in.:	12.64	Design Slab Thickness, in.:	12.64

Rigid Pavement Design Option 3 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 96.69

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 193

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 57,186
Computed Crack Spacing, ft: 4.1

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 29

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Slab Width, ft: 12
Transverse Required % Steel: 0.018

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 48.3

Rigid Pavement Design Option 4

Trial 4

Design Features

Construction Stages: 1
Pavement Type: CRCP (Continuously Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No — Load Transfer Coefficient: 2.6
Drains: Yes — Drainage Coefficient: 1.2

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 6
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 6,000
Bedrock: No
Depth to Bedrock, in: NA
Loss of Support: 0.5 — Modulus of Subgrade Reaction, pci: 350

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3.5
Change in Serviceability: 1

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 20,801,198
Total Other Vehicles (Class 1-4) in Performance Period: 187,210,779
Truck (Class 5-13) Damage Factor: 1.6141
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 2,655,934
Total Design ESALs: 33,612,655

Slab Thickness

Required Slab Thickness, in.: 11.58 — Design Slab Thickness, in.: 11.58

Rigid Pavement Design Option 4 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 52.77

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 148

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 57,909
Computed Crack Spacing, ft: 4.2

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 30

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Width, ft: 12
Transverse Required % Steel: 0.036

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 26.4

Rigid Pavement Design Option 5

Trial 5

Design Features

Construction Stages: 1
Pavement Type: CRCP (Continuously Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No | Load Transfer Coefficient: 2.6
Drains: Yes | Drainage Coefficient: 1.2

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: None (or Surface Treatment)
Subbase Thickness, in: NA
Subbase Modulus, psi: NA
Subgrade Modulus, psi: 6,000
Bedrock: Yes
Depth to Bedrock, in: 60
Loss of Support: 2.9 | Modulus of Subgrade Reaction, pci: 17

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3.5
Change in Serviceability: 1

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 20,801,198
Total Other Vehicles (Class 1-4) in Performance Period: 187,210,779
Truck (Class 5-13) Damage Factor: 1.6269
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 2,676,972
Total Design ESALs: 33,878,911

Slab Thickness

Required Slab Thickness, in.: 12.61 | Design Slab Thickness, in.: 12.61

Rigid Pavement Design Option 5 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 96.92

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 190

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 57,640
Computed Crack Spacing, ft: 4.2

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 29

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Slab Width, ft: 12
Transverse Required % Steel: 0.018

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 48.5

Rigid Pavement Design Option 6

Trial 6

Design Features

Construction Stages: 1
Pavement Type: CRCP (Continuously Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No — Load Transfer Coefficient: 2.6
Drains: Yes — Drainage Coefficient: 1.2

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 6
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 6,000
Bedrock: Yes
Depth to Bedrock, in: 108
Loss of Support: 0.5 — Modulus of Subgrade Reaction, pci: 469

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3.5
Change in Serviceability: 1

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 20,801,198
Total Other Vehicles (Class 1-4) in Performance Period: 187,210,779
Truck (Class 5-13) Damage Factor: 1.5906
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 2,617,308
Total Design ESALs: 33,123,827

Slab Thickness

Required Slab Thickness, in.: 11.38 — Design Slab Thickness, in.: 11.38

Rigid Pavement Design Option 6 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 53.7

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 147

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.035
Computed Steel Stress, psi: 59,107
Computed Crack Spacing, ft: 4.3

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 29

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Width, ft: 12
Transverse Required % Steel: 0.036

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 26.9

Rigid Pavement Design Option 7

Trial 7

Design Features

Construction Stages: 1
Pavement Type: CRCP (Continuously Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No
Drains: No

Load Transfer Coefficient: 2.6
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: None (or Surface Treatment)
Subbase Thickness, in: NA
Subbase Modulus, psi: NA
Subgrade Modulus, psi: 6,000
Bedrock: Yes
Depth to Bedrock, in: 96
Loss of Support: 2.9

Modulus of Subgrade Reaction, pci: 16

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3.5
Change in Serviceability: 1

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 20,801,198
Total Other Vehicles (Class 1-4) in Performance Period: 187,210,779
Truck (Class 5-13) Damage Factor: 1.6339
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 2,688,477
Total Design ESALs: 34,024,519

Slab Thickness

Required Slab Thickness, in.: 13.7

Design Slab Thickness, in.: 13.7

Rigid Pavement Design Option 7 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 89.21

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 161

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 57,922
Computed Crack Spacing, ft: 4.2

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 34

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Slab Width, ft: 12
Transverse Required % Steel: 0.018

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 44.6

Rigid Pavement Design Option 8

Trial 8

Design Features

Construction Stages:	1		
Pavement Type:	CRCP (Continuously Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	No	Load Transfer Coefficient:	2.6
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	Cement Treated Granular Base		
Subbase Thickness, in:	6		
Subbase Modulus, psi:	1,500,000		
Subgrade Modulus, psi:	6,000		
Bedrock:	Yes		
Depth to Bedrock, in:	84		
Loss of Support:	0.5	Modulus of Subgrade Reaction, pci:	503

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	95
Standard Normal Variate:	-1.647

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3.5
Change in Serviceability:	1

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	20,801,198
Total Other Vehicles (Class 1-4) in Performance Period:	187,210,779
Truck (Class 5-13) Damage Factor:	1.6141
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	2,655,934
Total Design ESALs:	33,612,655

Slab Thickness

Required Slab Thickness, in.:	12.44	Design Slab Thickness, in.:	12.44

Rigid Pavement Design Option 8 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 49.12

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 122

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.033
Computed Steel Stress, psi: 57,043
Computed Crack Spacing, ft: 4.1

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 35

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Width, ft: 12
Transverse Required % Steel: 0.036

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 24.6

Rigid Pavement Design Option 9

Trial 9

Design Features

Construction Stages:	1		
Pavement Type:	CRCP (Continuously Reinforced)		
Tie Bars Between Lanes:	Yes		
Shoulder Type:	Tied PCC		
Dowels:	No	Load Transfer Coefficient:	2.6
Drains:	No	Drainage Coefficient:	1

Concrete Properties

Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000

Pavement Foundation

Subbase Type:	None (or Surface Treatment)		
Subbase Thickness, in:	NA		
Subbase Modulus, psi:	NA		
Subgrade Modulus, psi:	6,000		
Bedrock:	Yes		
Depth to Bedrock, in:	40		
Loss of Support:	2.9	Modulus of Subgrade Reaction, pci:	18

Variability & Reliability

Standard Deviation:	0.39
Reliability, %:	95
Standard Normal Variate:	-1.647

Serviceability

Initial Serviceability:	4.5
Terminal Serviceability:	3.5
Change in Serviceability:	1

Traffic & ESALs

Performance Period, years:	20
Total Trucks (Class 5-13) in Performance Period:	20,801,198
Total Other Vehicles (Class 1-4) in Performance Period:	187,210,779
Truck (Class 5-13) Damage Factor:	1.6339
Other Vehicles (Class 1-4) Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	2,688,477
Total Design ESALs:	34,024,519

Slab Thickness

Required Slab Thickness, in.:	13.68	Design Slab Thickness, in.:	13.68

Rigid Pavement Design Option 9 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Required Steel, % of Concrete Area: 0.04
Calculated Tie Bar Spacing, in: 89.34

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 158

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.033
Computed Steel Stress, psi: 56,353
Computed Crack Spacing, ft: 4

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 35

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Subgrade
Friction Factor: 0.9
Slab Width, ft: 12
Transverse Required % Steel: 0.018

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 44.7

Rigid Pavement Design Option 10

Trial 10

Design Features

Construction Stages: 1
Pavement Type: CRCP (Continuously Reinforced)
Tie Bars Between Lanes: Yes
Shoulder Type: Tied PCC
Dowels: No
Drains: No

Load Transfer Coefficient: 2.6
Drainage Coefficient: 1

Concrete Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000

Pavement Foundation

Subbase Type: Cement Treated Granular Base
Subbase Thickness, in: 6
Subbase Modulus, psi: 1,500,000
Subgrade Modulus, psi: 6,000
Bedrock: Yes
Depth to Bedrock, in: 30
Loss of Support: 0.5

Modulus of Subgrade Reaction, pci: 669

Variability & Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial Serviceability: 4.5
Terminal Serviceability: 3.5
Change in Serviceability: 1

Traffic & ESALs

Performance Period, years: 20
Total Trucks (Class 5-13) in Performance Period: 20,801,198
Total Other Vehicles (Class 1-4) in Performance Period: 187,210,779
Truck (Class 5-13) Damage Factor: 1.6141
Other Vehicles (Class 1-4) Damage Factor: 0.0002
ESALs in Both Lanes and All Directions During First Year: 2,655,934
Total Design ESALs: 33,612,655

Slab Thickness

Required Slab Thickness, in.: 12.25

Design Slab Thickness, in.: 12.25

Rigid Pavement Design Option 10 - Steel

No Dowel Bars

Diameter: NA
Spacing, in: NA
Length, in: NA

Tie Bars

Allowable Steel Working Stress, psi: 30,000
Distance to Nearest Free Edge, ft: 12
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Required Steel, % of Concrete Area: 0.07
Calculated Tie Bar Spacing, in: 49.89

Diameter: #6 (0.750")
Recommended Spacing, in: 48
Length, in: 35

CRCP Steel

Concrete Properties

28 Day Concrete Modulus of Rupture, psi: 650
28 Day Concrete Indirect Tensile Strenth, psi: 559
28 Day Concrete Shrinkage, in/in: 0.00036
Type of Coarse Aggregate: Gravel
Concrete Thermal Coefficient, in/in/F: 0.000006
Width of Slab, ft: 12
Tensile Stress in Slab due to Wheel Load, psi: 121

Longitudinal Steel Parameters and Design

Steel Thermal Coefficient, in/in/F: 0.000005
Allowable Steel Stress, psi: 62,180
Design Temperature Drop, F: 50

Computed Crack Width, in: 0.034
Computed Steel Stress, psi: 58,195
Computed Crack Spacing, ft: 4.2

Longitudinal Bar Diameter, in: #5 (0.625")
Number of Bars: 34

Transverse Steel Parameters and Design

Allowable Steel Working Stress, psi: 30,000
Type of Material Beneath Slab: Cement Treated Granular Base
Friction Factor: 1.8
Slab Width, ft: 12
Transverse Required % Steel: 0.036

Transverse Bar Diameter, in: #3 (0.375")
Maximum Spacing, in: 24.9

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Auburn University

Rigid Structural Design Module

NDCRCP-Trial 1

Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	34,024,519
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	15 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	13.71 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6339	0	33,987,077
Total	100	-	-	-	34,024,519

Growth	Compound
Total Calculated Cumulative ESALs	34,024,519

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	161 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.48 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane 2

Calculated Results*

Calculated Minimum % Steel	0.49 %
Calculated Maximum % Steel	0.59 %
Calculated Actual % Steel	0.50 %
Calculated Minimum # of Bars	31.6
Calculated Maximum # of Bars	38.1
Calculated Actual # of Bars	32

*Note: These values are not represented by the inputs or an error occurred in calculation.

CRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.018	0.030	44.74
3	12	-	0.018	0.030	44.74
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Distance to Free Edge	12 ft
Slab Thickness	13.71 in
Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

Calculated Results

Calculated Maximum Tie Bar Spacing	89.5 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.059 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	13.7139995	12
Total	-	13.71	-

1993 AASHTO Pavement Design

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Rigid Structural Design Module

NDCRCP-Trial 2

Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,878,911
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	350 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	12.67 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	6,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	350 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6269	0	33,841,468
Total	100	-	-	-	33,878,911

Growth	Compound
Total Calculated Cumulative ESALs	33,878,911

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	124 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.53 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane	2

Calculated Results

Calculated Minimum % Steel	0.55 %
Calculated Maximum % Steel	0.65 %
Calculated Actual % Steel	0.56 %
Calculated Minimum # of Bars	32.5
Calculated Maximum # of Bars	38.7
Calculated Actual # of Bars	33

CRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30

Bar or Wire Diameter 0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.036	0.055	24.22
3	12	-	0.036	0.055	24.22
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	12.67 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	48.4 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.109 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	12.6661054	12
2	Cement Treated Granular Base	6	12
Total	-	18.67	-

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Rigid Structural Design Module

NDCRCP-Trial 3

Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,878,911
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	15 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	12.64 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6269	0	33,841,468
Total	100	-	-	-	33,878,911

Growth	Compound
Total Calculated Cumulative ESALs	33,878,911

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	193 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.44 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane 2

Calculated Results

Calculated Minimum % Steel	0.45 %
Calculated Maximum % Steel	0.54 %
Calculated Actual % Steel	0.46 %
Calculated Minimum # of Bars	26.4
Calculated Maximum # of Bars	32.2
Calculated Actual # of Bars	27

CRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.018	0.027	48.56
3	12	-	0.018	0.027	48.56
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

Calculated Results

Calculated Maximum Tie Bar Spacing	97.1 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.055 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	12.6359648	12
Total	-	12.64	-

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Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,612,655
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	350 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	11.58 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	6,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	1,000 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	350 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6141	0	33,575,213
Total	100	-	-	-	33,612,655

Growth	Compound
Total Calculated Cumulative ESALs	33,612,655

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	148 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.5 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane	2

Calculated Results

Calculated Minimum % Steel	0.51 %
Calculated Maximum % Steel	0.61 %
Calculated Actual % Steel	0.52 %
Calculated Minimum # of Bars	27.7
Calculated Maximum # of Bars	33.2
Calculated Actual # of Bars	28

CRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30

Bar or Wire Diameter	0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.036	0.050	26.50
3	12	-	0.036	0.050	26.50
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	11.58 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	53.0 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.100 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	11.5756468	12
2	Cement Treated Granular Base	6	12
Total	-	17.58	-

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Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,878,911
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	17 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	12.61 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6269	0	33,841,468
Total	100	-	-	-	33,878,911

Growth	Compound
Total Calculated Cumulative ESALs	33,878,911

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	190 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.44 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane 2

Calculated Results

Calculated Minimum % Steel	0.45 %
Calculated Maximum % Steel	0.55 %
Calculated Actual % Steel	0.46 %
Calculated Minimum # of Bars	26.6
Calculated Maximum # of Bars	32.4
Calculated Actual # of Bars	27

CRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.018	0.027	48.65
3	12	-	0.018	0.027	48.65
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

Calculated Results

Calculated Maximum Tie Bar Spacing	97.3 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.054 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	12.6115214	12
Total	-	12.61	-

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Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,123,827
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	469 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1.2
Calculated Design Thickness	11.38 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	6,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	9 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	469 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.5906	0	33,086,385
Total	100	-	-	-	33,123,827

Growth	Compound
Total Calculated Cumulative ESALs	33,123,827

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	147 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.5 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane	2

Calculated Results

Calculated Minimum % Steel	0.51 %
Calculated Maximum % Steel	0.61 %
Calculated Actual % Steel	0.52 %
Calculated Minimum # of Bars	27.3
Calculated Maximum # of Bars	32.7
Calculated Actual # of Bars	28

CRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30

Bar or Wire Diameter 0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.036	0.049	26.97
3	12	-	0.036	0.049	26.97
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	11.38 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

Calculated Results

Calculated Maximum Tie Bar Spacing	53.9 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.098 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	11.3759224	12
2	Cement Treated Granular Base	6	12
Total	-	17.38	-

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Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	34,024,519
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	16 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	13.70 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6339	0	33,987,077
Total	100	-	-	-	34,024,519

Growth	Compound
Total Calculated Cumulative ESALs	34,024,519

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	161 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.48 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane 2

Calculated Results

Calculated Minimum % Steel	0.49 %
Calculated Maximum % Steel	0.59 %
Calculated Actual % Steel	0.50 %
Calculated Minimum # of Bars	31.6
Calculated Maximum # of Bars	38.0
Calculated Actual # of Bars	32

CRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.018	0.030	44.78
3	12	-	0.018	0.030	44.78
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

Calculated Results

Calculated Maximum Tie Bar Spacing	89.6 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.059 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	13.7014526	12
Total	-	13.70	-

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Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,612,655
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	503 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	12.44 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	6,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	7 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	503 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6141	0	33,575,213
Total	100	-	-	-	33,612,655

Growth	Compound
Total Calculated Cumulative ESALs	33,612,655

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	122 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.54 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane	2

Calculated Results

Calculated Minimum % Steel	0.55 %
Calculated Maximum % Steel	0.65 %
Calculated Actual % Steel	0.57 %
Calculated Minimum # of Bars	32.1
Calculated Maximum # of Bars	38.2
Calculated Actual # of Bars	33

CRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30

Bar or Wire Diameter 0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.036	0.054	24.66
3	12	-	0.036	0.054	24.66
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	12.44 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	49.3 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.107 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	12.43865	12
2	Cement Treated Granular Base	6	12
Total	-	18.44	-

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Auburn University

Rigid Structural Design Module

NDCRCP-Trial 9

Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	34,024,519
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	18 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	13.68 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6339	0	33,987,077
Total	100	-	-	-	34,024,519

Growth	Compound
Total Calculated Cumulative ESALs	34,024,519

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	158 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.48 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane 2

Calculated Results

Calculated Minimum % Steel	0.50 %
Calculated Maximum % Steel	0.60 %
Calculated Actual % Steel	0.50 %
Calculated Minimum # of Bars	31.8
Calculated Maximum # of Bars	38.3
Calculated Actual # of Bars	32

CRCP Transverse Steel Design

Friction Factor (F)	0.9
Steel Working Stress	30
Bar or Wire Diameter	0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.018	0.030	44.86
3	12	-	0.018	0.030	44.86
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Friction Factor (F)	0.9
Percent of Yield Strength	100
Bar Diameter	0.75 in

Calculated Results

Calculated Maximum Tie Bar Spacing	89.7 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.059 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	13.6778958	12
Total	-	13.68	-

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Auburn University

Rigid Structural Design Module

NDCRCP-Trial 10

Rigid Structural Design

Pavement Type	CRCP
18-kip ESALs Over Initial Performance Period	33,612,655
Initial Serviceability	4.5
Terminal Serviceability	3.5
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	4,200,000 psi
Mean Effective k-value	669 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	12.25 in

Effective Modulus of Subgrade Reaction

Period	Description	Roadbed Soil Resilient Modulus (psi)	Base Elastic Modulus (psi)
1	-	6,000	1,500,000

Base Type	Cement Treated Granular Base
Base Thickness	6 in
Depth to Bedrock	2.5 ft
Projected Slab Thickness	9 in
Loss of Support Category	0.5
Effective Modulus of Subgrade Reaction	669 psi/in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6141	0	33,575,213
Total	100	-	-	-	33,612,655

Growth	Compound
Total Calculated Cumulative ESALs	33,612,655

CRCP Longitudinal Steel Design

28-day Concrete Indirect Tensile Strength	559 psi
Concrete Shrinkage at 28 Days	0.00036 in/in
Thermal Coefficient of Concrete	6 (10^-6 in/in)/F
Thermal Coefficient of Reinforced Steel	5 (10^-6 in/in)/F
Design Temperature Drop	50 F
Tensile Stress Due to Wheel Load	121 psi
Allowable Steel Stress	62.18 ksi
Allowable Crack Width	0.54 in
Bar Diameter	0.625 in

Lane	Width (ft)
1	12
2	12
3	-
4	-
5	-

Lane	2

Calculated Results

Calculated Minimum % Steel	0.55 %
Calculated Maximum % Steel	0.66 %
Calculated Actual % Steel	0.56 %
Calculated Minimum # of Bars	31.7
Calculated Maximum # of Bars	37.7
Calculated Actual # of Bars	32

CRCP Transverse Steel Design

Friction Factor (F)	1.8
Steel Working Stress	30

Bar or Wire Diameter 0.375

Lane	Width (ft)	Tied to Next Lane	Percent Steel	Area of Steel (sq in/ft)	Bar Spacing (in)
1	-	-	-	-	-
2	12	-	0.036	0.053	25.05
3	12	-	0.036	0.053	25.05
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-

Tie Bar Steel Design

Steel Grade	30 ksi
Distance to Free Edge	12 ft
Slab Thickness	12.25 in
Friction Factor (F)	1.8
Percent of Yield Strength	100
Bar Diameter	0.75 in

	Calculated Results
Calculated Maximum Tie Bar Spacing	50.1 in
Recommended Maximum Tie Bar Spacing	48.0 in
Calculated Tie Bar Length	35.1 in
Calculated Area of Steel	0.106 sq in/ft

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	CRCP	12.2478258	12
2	Cement Treated Granular Base	6	12
Total	-	18.25	-

Appendix A.5

Overlay Design Flexible Pavement

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 1.xlsx

Project Name:
ODFP-Trial 1

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	7,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	6.76
Design Structural Number, Rounded:	7
Total Trucks (Classes 5-13):	6,436,511
Total Other Vehicles (Classes 1-4):	57,928,602
Truck Damage Factor:	0.9783
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	1,610,917
Flexible Pavement Total Design ESALs (W18):	6,308,425

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	6,308,425
Structural Number for Future Traffic, SNf:	6.76
Total Thickness of All Existing Pavement Layers (H1+H2), in:	11
Backcalculated Effective Pavement Modulus, psi:	200,000
Milling Thickness, in:	0
Existing Pavement Effective Structural Number, SNeff:	2.89
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	7.17
Design Structural Number, SNdes:	6.76

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 2.xlsx

Project Name:

ODFP-Trial 2

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Non-Interstate

Project Type:

Overlay Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	6,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	7.1
Design Structural Number, Rounded:	8
Total Trucks (Classes 5-13):	6,436,511
Total Other Vehicles (Classes 1-4):	57,928,602
Truck Damage Factor:	0.9745
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	1,604,671
Flexible Pavement Total Design ESALs (W18):	6,283,966

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	6,283,966
Structural Number for Future Traffic, SNf:	7.1
Total Thickness of All Existing Pavement Layers (H1+H2), in:	11
Backcalculated Effective Pavement Modulus, psi:	200,000
Milling Thickness, in:	0
Existing Pavement Effective Structural Number, SNeff:	2.89
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	7.8
Design Structural Number, SNdes:	7.1

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 3.xlsx

Project Name:

ODFP-Trial 3

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	6,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	7.1
Design Structural Number, Rounded:	8
Total Trucks (Classes 5-13):	6,436,511
Total Other Vehicles (Classes 1-4):	57,928,602
Truck Damage Factor:	0.9745
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	1,604,671
Flexible Pavement Total Design ESALs (W18):	6,283,966

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	6,283,966
Structural Number for Future Traffic, SNf:	7.1
Total Thickness of All Existing Pavement Layers (H1+H2), in:	16
Backcalculated Effective Pavement Modulus, psi:	200,000
Milling Thickness, in:	0
Existing Pavement Effective Structural Number, SNeff:	4.21
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	5.35
Design Structural Number, SNdes:	7.1

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 4.xlsx

Project Name:
ODFP-Trial 4

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	6,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	7.1
Design Structural Number, Rounded:	8
Total Trucks (Classes 5-13):	6,436,511
Total Other Vehicles (Classes 1-4):	57,928,602
Truck Damage Factor:	0.9745
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	1,604,671
Flexible Pavement Total Design ESALs (W18):	6,283,966

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	6,283,966
Structural Number for Future Traffic, SNf:	7.1
Total Thickness of All Existing Pavement Layers (H1+H2), in:	16
Backcalculated Effective Pavement Modulus, psi:	400,000
Milling Thickness, in:	0
Existing Pavement Effective Structural Number, SNeff:	5.31
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	3.31
Design Structural Number, SNdes:	7.1

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 5.xlsx

Project Name:
ODFP-Trial 5

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	6,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	7.1
Design Structural Number, Rounded:	8
Total Trucks (Classes 5-13):	6,436,511
Total Other Vehicles (Classes 1-4):	57,928,602
Truck Damage Factor:	0.9745
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	1,604,671
Flexible Pavement Total Design ESALs (W18):	6,283,966

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	6,283,966
Structural Number for Future Traffic, SNf:	7.1
Total Thickness of All Existing Pavement Layers (H1+H2), in:	16
Backcalculated Effective Pavement Modulus, psi:	400,000
Milling Thickness, in:	4
Existing Pavement Effective Structural Number, SNeff:	3.98
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	5.78
Design Structural Number, SNdes:	7.1

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 6.xlsx

Project Name:

ODFP-Trial 6

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	6,000
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	4.82
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	487,189
Total Other Vehicles (Classes 1-4):	23,872,254
Truck Damage Factor:	1.0529
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	116,445
Flexible Pavement Total Design ESALs (W18):	517,736

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	517,736
Structural Number for Future Traffic, SNf:	4.82
Total Thickness of All Existing Pavement Layers (H1+H2), in:	16
Backcalculated Effective Pavement Modulus, psi:	400,000
Milling Thickness, in:	4
Existing Pavement Effective Structural Number, SNeff:	3.98
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	1.56
Design Structural Number, SNdes:	4.82

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 7.xlsx

Project Name:
ODFP-Trial 7

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	5,500
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	5
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	487,189
Total Other Vehicles (Classes 1-4):	23,872,254
Truck Damage Factor:	1.0529
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	116,445
Flexible Pavement Total Design ESALs (W18):	517,736

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	517,736
Structural Number for Future Traffic, SNf:	5
Total Thickness of All Existing Pavement Layers (H1+H2), in:	16
Backcalculated Effective Pavement Modulus, psi:	400,000
Milling Thickness, in:	4
Existing Pavement Effective Structural Number, SNeff:	3.98
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	1.89
Design Structural Number, SNdes:	5

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 8.xlsx

Project Name:

ODFP-Trial 8

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	5,500
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	5
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	487,189
Total Other Vehicles (Classes 1-4):	23,872,254
Truck Damage Factor:	1.0529
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	116,445
Flexible Pavement Total Design ESALs (W18):	517,736

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	517,736
Structural Number for Future Traffic, SNf:	5
Total Thickness of All Existing Pavement Layers (H1+H2), in:	24
Backcalculated Effective Pavement Modulus, psi:	400,000
Milling Thickness, in:	4
Existing Pavement Effective Structural Number, SNeff:	6.63
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	0
Design Structural Number, SNdes:	6.63

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 9.xlsx

Project Name:
ODFP-Trial 9

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	5,500
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	5
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	487,189
Total Other Vehicles (Classes 1-4):	23,872,254
Truck Damage Factor:	1.0529
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	116,445
Flexible Pavement Total Design ESALs (W18):	517,736

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	517,736
Structural Number for Future Traffic, SNf:	5
Total Thickness of All Existing Pavement Layers (H1+H2), in:	11
Backcalculated Effective Pavement Modulus, psi:	200,000
Milling Thickness, in:	2
Existing Pavement Effective Structural Number, SNeff:	2.37
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	4.87
Design Structural Number, SNdes:	5

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODFP - Overlay Design Flexible Pavement\ODFP Trial 10.xlsx

Project Name:

ODFP-Trial 10

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Flexible

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	100.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Flexible Pavement Design Parameters

Performance Period (years):	8
Construction Stages:	1
Standard Deviation:	0.49
Reliability:	95.00%
Standard Normal Deviate:	-1.647
Subgrade Modulus, psi:	5,500
Initial Serviceability:	4.2
Terminal Serviceability:	3.5
Change in Serviceability:	0.7
Design Structural Number:	5
Design Structural Number, Rounded:	5
Total Trucks (Classes 5-13):	487,189
Total Other Vehicles (Classes 1-4):	23,872,254
Truck Damage Factor:	1.0529
Other Damage Factor:	0.0002
ESALs in Both Lanes and All Directions During First Year:	116,445
Flexible Pavement Total Design ESALs (W18):	517,736

AC Overlay AC Design

Future Design ESALs over Design Period, Nf:	517,736
Structural Number for Future Traffic, SNf:	5
Total Thickness of All Existing Pavement Layers (H1+H2), in:	11
Backcalculated Effective Pavement Modulus, psi:	200,000
Milling Thickness, in:	6
Existing Pavement Effective Structural Number, SNeff:	1.32
AC Overlay Structural Coefficient:	0.54
Required Overlay Thickness, in:	6.81
Design Structural Number, SNdes:	5

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Overlay Design Module

ODFP-Trial 1

AC Overlay of AC Pavement

Structural Number for Future Traffic 6.76 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	2.89	3.87

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	6,308,425
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	7,000 psi
Calculated Structural Number for Future Traffic	6.76 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	11 in
Backcalculated Effective Pavement Modulus	200,000 psi
Milling Thickness	0 in
Effective Existing Pavement SN (SNEff)	2.89 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	11,586
2	10	4	0.9783	0	6,296,839
Total	100	-	-	-	6,308,425

Growth	Compound
Total Calculated Cumulative ESALs	6,308,425

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	7.17	3.87	$387.00
Total	-	-	-	-	-	-	-	7.17	3.87	$387.00

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Overlay Design Module

ODFP-Trial 2

AC Overlay of AC Pavement

Structural Number for Future Traffic	7.1 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	2.89	4.21

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	6,283,966
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	6,000 psi
Calculated Structural Number for Future Traffic	7.10 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	11 in
Backcalculated Effective Pavement Modulus	200,000 psi
Milling Thickness	0 in
Effective Existing Pavement SN (SNEff)	2.89 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	11,586
2	10	4	0.9745	0	6,272,380
Total	100	-	-	-	6,283,966

Growth	Compound
Total Calculated Cumulative ESALs	6,283,966

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	7.80	4.21	$421.00
Total	-	-	-	-	-	-	-	7.80	4.21	$421.00

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Overlay Design Module

ODFP-Trial 3

AC Overlay of AC Pavement

Structural Number for Future Traffic 7.1 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	4.21	2.89

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	6,283,966
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	6,000 psi
Calculated Structural Number for Future Traffic	7.10 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	16 in
Backcalculated Effective Pavement Modulus	200,000 psi
Milling Thickness	0 in
Effective Existing Pavement SN (SNEff)	4.21 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	11,586
2	10	4	0.9745	0	6,272,380
Total	100	-	-	-	6,283,966

Growth Compound

Total Calculated Cumulative ESALs 6,283,966

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	5.35	2.89	$289.00
Total	-	-	-	-	-	-	-	5.35	2.89	$289.00

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ODFP-Trial 4

AC Overlay of AC Pavement

Structural Number for Future Traffic 7.1 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	5.31	1.79

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	6,283,966
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	6,000 psi
Calculated Structural Number for Future Traffic	7.10 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	16 in
Backcalculated Effective Pavement Modulus	400,000 psi
Milling Thickness	0 in
Effective Existing Pavement SN (SNEff)	5.31 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	11,586
2	10	4	0.9745	0	6,272,380
Total	100	-	-	-	6,283,966

Growth Compound

Total Calculated Cumulative ESALs 6,283,966

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	3.31	1.79	$179.00
Total	-	-	-	-	-	-	-	3.31	1.79	$179.00

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Overlay Design Module

ODFP-Trial 5

AC Overlay of AC Pavement

Structural Number for Future Traffic	7.1 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	3.98	3.12

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	6,283,966
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	6,000 psi
Calculated Structural Number for Future Traffic	7.10 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	16 in
Backcalculated Effective Pavement Modulus	400,000 psi
Milling Thickness	4 in
Effective Existing Pavement SN (SNEff)	3.98 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	11,586
2	10	4	0.9745	0	6,272,380
Total	100	-	-	-	6,283,966

Growth Compound

Total Calculated Cumulative ESALs 6,283,966

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	5.78	3.12	$312.00
Total	-	-	-	-	-	-	-	5.78	3.12	$312.00

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Overlay Design Module

ODFP-Trial 6

AC Overlay of AC Pavement

Structural Number for Future Traffic	4.82 in	

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	3.98	0.84

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	517,736
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	6,000 psi
Calculated Structural Number for Future Traffic	4.82 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	16 in
Backcalculated Effective Pavement Modulus	400,000 psi
Milling Thickness	4 in
Effective Existing Pavement SN (SNEff)	3.98 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	4,774
2	2	3	1.0529	0	512,961
Total	100	-	-	-	517,736

Growth Compound

Total Calculated Cumulative ESALs 517,736

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	1.56	0.84	$84.00
Total	-	-	-	-	-	-	-	1.56	0.84	$84.00

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Overlay Design Module

ODFP-Trial 7

AC Overlay of AC Pavement

Structural Number for Future Traffic 5 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	3.98	1.02

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	517,736
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	5,500 psi
Calculated Structural Number for Future Traffic	5.00 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	16 in
Backcalculated Effective Pavement Modulus	400,000 psi
Milling Thickness	4 in
Effective Existing Pavement SN (SNEff)	3.98 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	4,774
2	2	3	1.0529	0	512,961
Total	100	-	-	-	517,736

Growth Compound

Total Calculated Cumulative ESALs 517,736

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	1	120	12	1.89	1.02	$102.00
Total	-	-	-	-	-	-	-	1.89	1.02	$102.00

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Overlay Design Module

ODFP-Trial 8

AC Overlay of AC Pavement

Structural Number for Future Traffic 5 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	6.63	0.00

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	517,736
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	5,500 psi
Calculated Structural Number for Future Traffic	5.00 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	24 in
Backcalculated Effective Pavement Modulus	400,000 psi
Milling Thickness	4 in
Effective Existing Pavement SN (SNEff)	6.63 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	4,774
2	2	3	1.0529	0	512,961
Total	100	-	-	-	517,736

Growth Compound

Total Calculated Cumulative ESALs 517,736

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	0	120	12	0.00	0.00	$0.00
Total	-	-	-	-	-	-	-	0.00	0.00	$0.00

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Overlay Design Module

ODFP-Trial 9

AC Overlay of AC Pavement

Structural Number for Future Traffic 5 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	2.37	2.63

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	517,736
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	5,500 psi

Calculated Structural Number for Future Traffic 5.00 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	11 in
Backcalculated Effective Pavement Modulus	200,000 psi
Milling Thickness	2 in

Effective Existing Pavement SN (SNEff) 2.37 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	4,774
2	2	3	1.0529	0	512,961
Total	100	-	-	-	517,736

Growth Compound

Total Calculated Cumulative ESALs 517,736

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	0	120	12	4.87	2.63	$263.00
Total	-	-	-	-	-	-	-	4.87	2.63	$263.00

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
Auburn University

Overlay Design Module

ODFP-Trial 10

AC Overlay of AC Pavement

Structural Number for Future Traffic	5 in

Design Method	Effective Existing Structural Number (in)	Overlay Structural Number (in)
Component Analysis	-	-
Remaining Life	-	-
Non-Destructive Testing	1.32	3.68

Structural Number for Future Traffic

Future 18-kip ESALs Over Design Period	517,736
Initial Serviceability	4.2
Terminal Serviceability	3.5
Reliability Level	95 %
Overall Standard Deviation	0.49
Subgrade Resilient Modulus	5,500 psi
Calculated Structural Number for Future Traffic	5.00 in

Effective Structural Number - Non-Destructive Testing

Total Pavement Thickness	11 in
Backcalculated Effective Pavement Modulus	200,000 psi
Milling Thickness	6 in
Effective Existing Pavement SN (SNEff)	1.32 in

Future Simple ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	8
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	4,774
2	2	3	1.0529	0	512,961
Total	100	-	-	-	517,736

Growth	Compound
Total Calculated Cumulative ESALs	517,736

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
Total	-	-	-	-	-	-

*Note: This value is not represented by the inputs or an error occurred in calculation.

Optimized Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Cost (sq yd/in)	Min Thick (Di)(in)	Max Thick (in)	Width (ft)	Optimum Thick (in)	Calculated SN (in)	Calculated Cost (sq yd)
1	AC Overlay	0.54	1	$54.00	0	120	12	6.81	3.68	$368.00
Total	-	-	-	-	-	-	-	6.81	3.68	$368.00

Appendix A.6

Overlay Design Rigid Pavement

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP AC-PCC-Trial 1.xlsx

Project Name:
ODRP AC-PCC--Trial 1

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

AC Overlay of AC-PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation:	0.39
Reliability, %:	95
Standard Normal Variate:	-1.647

Serviceability

Initial:	4.5
Terminal:	3
Change in Serviceability:	1.5

Existing Asphalt Properties

Existing AC Thickness, in:	3
AC Milling Thickness, in:	0
AC-PCC Interface Condition:	Unbonded

Existing Concrete Properties

Existing PCC Thickness, in:	12
Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000
Load Transfer Coefficient:	2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci:	300
Drainage Coefficient:	1

Traffic Information

Total Design Trucks (Classes 5 - 13):	20,801,198
Truck Damage Factor:	1.6246
Total Other Vehicles (Classes 1 - 4):	187,210,779
Other Vehicle Damage Factor:	0.0002
Percent Trucks (Classes 5-13) in Design Lane:	85
Percent Trucks (Classes 5-13) in Design Direction:	50
ESALs in all lanes and both directions during first year:	2,673,192
Total Rigid Design ESALs:	33,831,068

Future Required Structural Capacity

Slab Thickness for Future Traffic, in:	12.35

Existing Structural Capacity

Number of Unrepaired Deteriorated Reflection Cracks, per mile:	30

AC Overlay of AC-PCC

Number of Unrepaired Punchouts, per mile: 28
Number of Expansion Joints, Exceptionally Wide Joints
(>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 25
Total Joints, Cracks, Punchouts, Patches per mile: 83

Joints and Cracks Adjustment Factor: 0.8
PCC Durability Adjustment Factor: 0.9
AC Quality Adjustment Factor: 1

Effective Existing Pavement Thickness, in: 10.14

Overlay Design Thickness

AC Overlay Thickness, in: 4.27

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP AC-PCC-Trial 2.xlsx

Project Name:
ODRP AC-PCC-Trial 2

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

AC Overlay of AC-PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Existing Asphalt Properties

Existing AC Thickness, in: 3
AC Milling Thickness, in: 0
AC-PCC Interface Condition: Bonded

Existing Concrete Properties

Existing PCC Thickness, in: 10
Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 100
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 20,801,198
Truck Damage Factor: 1.6329
Total Other Vehicles (Classes 1 - 4): 187,210,779
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 85
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 2,686,834

Total Rigid Design ESALs: 34,003,718

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 12.85

Existing Structural Capacity

Number of Unrepaired Deteriorated Reflection Cracks, per mile: 15

AC Overlay of AC-PCC

Number of Unrepaired Punchouts, per mile: 10
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 13
Total Joints, Cracks, Punchouts, Patches per mile: 38

Joints and Cracks Adjustment Factor: 0.9
PCC Durability Adjustment Factor: 0.9
AC Quality Adjustment Factor: 0.8

Effective Existing Pavement Thickness, in: 9.3

Overlay Design Thickness

AC Overlay Thickness, in: 6.4

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP AC-PCC-Trial 3.xlsx

Project Name:

ODRP AC-PCC-Trial 3

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

AC Overlay of AC-PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation:	0.39
Reliability, %:	95
Standard Normal Variate:	-1.647

Serviceability

Initial:	4.5
Terminal:	3
Change in Serviceability:	1.5

Existing Asphalt Properties

Existing AC Thickness, in:	3
AC Milling Thickness, in:	0
AC-PCC Interface Condition:	Bonded

Existing Concrete Properties

Existing PCC Thickness, in:	12
Modulus of Rupture, psi:	650
Elastic Modulus, psi:	4,200,000
Load Transfer Coefficient:	2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci:	20
Drainage Coefficient:	1

Traffic Information

Total Design Trucks (Classes 5 - 13):	20,801,198
Truck Damage Factor:	1.6329
Total Other Vehicles (Classes 1 - 4):	187,210,779
Other Vehicle Damage Factor:	0.0002
Percent Trucks (Classes 5-13) in Design Lane:	85
Percent Trucks (Classes 5-13) in Design Direction:	50
ESALs in all lanes and both directions during first year:	2,686,834
Total Rigid Design ESALs:	34,003,718

Future Required Structural Capacity

Slab Thickness for Future Traffic, in:	13.31

Existing Structural Capacity

Number of Unrepaired Deteriorated Reflection Cracks, per mile:	15

AC Overlay of AC-PCC

Number of Unrepaired Punchouts, per mile: 15
Number of Expansion Joints, Exceptionally Wide Joints
(>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 12
Total Joints, Cracks, Punchouts, Patches per mile: 42

Joints and Cracks Adjustment Factor: 0.89
PCC Durability Adjustment Factor: 0.9
AC Quality Adjustment Factor: 0.8

Effective Existing Pavement Thickness, in: 10.81

Overlay Design Thickness

AC Overlay Thickness, in: 4.75

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP AC-PCC-Trial 4.xlsx

Project Name:

ODRP AC-PCC-Trial 4

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

AC Overlay of AC-PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Existing Asphalt Properties

Existing AC Thickness, in: 6
AC Milling Thickness, in: 2
AC-PCC Interface Condition: Unbonded

Existing Concrete Properties

Existing PCC Thickness, in: 10
Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 20
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 20,801,198
Truck Damage Factor: 1.6329
Total Other Vehicles (Classes 1 - 4): 187,210,779
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 85
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 2,686,834

Total Rigid Design ESALs: 34,003,718

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 13.31

Existing Structural Capacity

Number of Unrepaired Deteriorated Reflection Cracks, per mile: 30

AC Overlay of AC-PCC

Number of Unrepaired Punchouts, per mile:	27
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile:	25
Total Joints, Cracks, Punchouts, Patches per mile:	82
Joints and Cracks Adjustment Factor:	0.8
PCC Durability Adjustment Factor:	1
AC Quality Adjustment Factor:	0.9
Effective Existing Pavement Thickness, in:	9.8

Overlay Design Thickness

AC Overlay Thickness, in: 6.34

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP AC-PCC-Trial 5.xlsx

Project Name:

ODRP AC-PCC-Trial 5

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	45,000
Number of Lanes in Design Direction:	2
Growth Rate (%):	4.00%
Truck Percentage (Classes 5 - 13):	10.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	85.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

AC Overlay of AC-PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Existing Asphalt Properties

Existing AC Thickness, in: 6
AC Milling Thickness, in: 2
AC-PCC Interface Condition: Bonded

Existing Concrete Properties

Existing PCC Thickness, in: 12
Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 100
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 20,801,198
Truck Damage Factor: 1.6329
Total Other Vehicles (Classes 1 - 4): 187,210,779
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 85
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 2,686,834

Total Rigid Design ESALs: 34,003,718

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 12.85

Existing Structural Capacity

Number of Unrepaired Deteriorated Reflection Cracks, per mile: 30

AC Overlay of AC-PCC

Number of Unrepaired Punchouts, per mile:	27
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile:	25
Total Joints, Cracks, Punchouts, Patches per mile:	82
Joints and Cracks Adjustment Factor:	0.8
PCC Durability Adjustment Factor:	1
AC Quality Adjustment Factor:	1
Effective Existing Pavement Thickness, in:	11.6

Overlay Design Thickness

AC Overlay Thickness, in: 2.56

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP PCC-PCC-Trial 6.xlsx

Project Name:
ODRP PCC-PCC-Trial 6

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Unbonded PCC Overlay on Existing PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Concrete Overlay Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 700
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 1,324,945
Truck Damage Factor: 1.4573
Total Other Vehicles (Classes 1 - 4): 64,922,284
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 90
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 160,757

Total Rigid Design ESALs: 1,943,826

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 6.82

Existing Structural Capacity

Existing PCC Thickness, in: 4

Number of Unrepaired Deteriorated Joints, per mile: 20
Number of Unrepaired Deteriorated Cracks, per mile: 15
Number of Unrepaired Punchouts, per mile: 15
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 15

Unbonded PCC Overlay on Existing PCC

Total Joints, Cracks, Punchouts, Patches per mile: 65

Joints and Cracks Adjustment Factor: 0.95

Effective Existing Pavement Thickness, in: 3.8

Overlay Design Thickness

Unbonded PCC Overlay Thickness, in: 5.66

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP PCC-PCC-Trial 7.xlsx

Project Name:
ODRP PCC-PCC Trial 7

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Unbonded PCC Overlay on Existing PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Concrete Overlay Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 400
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 1,324,945
Truck Damage Factor: 1.4573
Total Other Vehicles (Classes 1 - 4): 64,922,284
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 90
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 160,757

Total Rigid Design ESALs: 1,943,826

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 7.43

Existing Structural Capacity

Existing PCC Thickness, in: 6

Number of Unrepaired Deteriorated Joints, per mile: 50
Number of Unrepaired Deteriorated Cracks, per mile: 50
Number of Unrepaired Punchouts, per mile: 50
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 50

Unbonded PCC Overlay on Existing PCC

Total Joints, Cracks, Punchouts, Patches per mile: 200

Joints and Cracks Adjustment Factor: 0.9

Effective Existing Pavement Thickness, in: 5.4

Overlay Design Thickness

Unbonded PCC Overlay Thickness, in: 5.1

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:

C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP PCC-PCC-Trial 8.xlsx

Project Name:

ODRP PCC-PCC Trial 8

Project Description:

Describe Project Here...

Project Setting:

Urban

Route Type:

Interstate

Project Type:

Overlay Design

Pavement Type(s):

Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Unbonded PCC Overlay on Existing PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Concrete Overlay Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 200
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 1,324,945
Truck Damage Factor: 1.485
Total Other Vehicles (Classes 1 - 4): 64,922,284
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 90
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 163,793

Total Rigid Design ESALs: 1,980,527

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 7.94

Existing Structural Capacity

Existing PCC Thickness, in: 8

Number of Unrepaired Deteriorated Joints, per mile: 20
Number of Unrepaired Deteriorated Cracks, per mile: 20
Number of Unrepaired Punchouts, per mile: 20
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 20

Unbonded PCC Overlay on Existing PCC

Total Joints, Cracks, Punchouts, Patches per mile: 80

Joints and Cracks Adjustment Factor: 0.95

Effective Existing Pavement Thickness, in: 7.6

Overlay Design Thickness

Unbonded PCC Overlay Thickness, in: 2.3

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP PCC-PCC-Trial 9.xlsx

Project Name:
ODRP PCC-PCC Trial 9

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Unbonded PCC Overlay on Existing PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Concrete Overlay Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 50
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 1,324,945
Truck Damage Factor: 1.5385
Total Other Vehicles (Classes 1 - 4): 64,922,284
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 90
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 169,655

Total Rigid Design ESALs: 2,051,412

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 8.56

Existing Structural Capacity

Existing PCC Thickness, in: 5

Number of Unrepaired Deteriorated Joints, per mile: 45
Number of Unrepaired Deteriorated Cracks, per mile: 45
Number of Unrepaired Punchouts, per mile: 45
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 45

Unbonded PCC Overlay on Existing PCC

Total Joints, Cracks, Punchouts, Patches per mile: 180

Joints and Cracks Adjustment Factor: 0.91

Effective Existing Pavement Thickness, in: 4.55

Overlay Design Thickness

Unbonded PCC Overlay Thickness, in: 7.25

ADAPT Version 3.03 - BETA TESTING VERSION

Alabama Design & Analysis of Pavement Thickness

File Location and Name:
C:\Users\dvb0007\OneDrive\Documents\Master Degree Courses\Research\ALDOT DATA SERVER\ADAPT Design Trials\ODRP - Overlay Design Rigid Pavement\ODRP PCC-PCC-Trial 10.xlsx

Project Name:
ODRP PCC-PCC Trial 10

Project Description:
Describe Project Here...

Project Setting:
Urban

Route Type:
Interstate

Project Type:
Overlay Design

Pavement Type(s):
Rigid

Traffic Inputs

Two Way Annual Average Daily Traffic (AADT):	15,000
Number of Lanes in Design Direction:	1
Growth Rate (%):	3.00%
Truck Percentage (Classes 5 - 13):	2.00%
Percent Trucks (Classes 5 - 13) in Design Lane:	90.00%
Percent Trucks (Classes 5 - 13) in Design Direction:	50.00%

Unbonded PCC Overlay on Existing PCC

Future Required Structural Capacity

Variability and Reliability

Standard Deviation: 0.39
Reliability, %: 95
Standard Normal Variate: -1.647

Serviceability

Initial: 4.5
Terminal: 3
Change in Serviceability: 1.5

Concrete Overlay Properties

Modulus of Rupture, psi: 650
Elastic Modulus, psi: 4,200,000
Load Transfer Coefficient: 2.8

Subsurface Properties

Static Modulus of Subgrade Reaction, pci: 15
Drainage Coefficient: 1

Traffic Information

Total Design Trucks (Classes 5 - 13): 1,324,945
Truck Damage Factor: 1.5385
Total Other Vehicles (Classes 1 - 4): 64,922,284
Other Vehicle Damage Factor: 0.0002
Percent Trucks (Classes 5-13) in Design Lane: 90
Percent Trucks (Classes 5-13) in Design Direction: 50
ESALs in all lanes and both directions during first year: 169,655

Total Rigid Design ESALs: 2,051,412

Future Required Structural Capacity

Slab Thickness for Future Traffic, in: 8.86

Existing Structural Capacity

Existing PCC Thickness, in: 7

Number of Unrepaired Deteriorated Joints, per mile: 20
Number of Unrepaired Deteriorated Cracks, per mile: 20
Number of Unrepaired Punchouts, per mile: 20
Number of Expansion Joints, Exceptionally Wide Joints (>1in) or Full Depth, Full-Lane-Width AC Patches, per mile: 20

Unbonded PCC Overlay on Existing PCC

Total Joints, Cracks, Punchouts, Patches per mile: 80

Joints and Cracks Adjustment Factor: 0.95

Effective Existing Pavement Thickness, in: 6.65

Overlay Design Thickness

Unbonded PCC Overlay Thickness, in: 5.85

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Overlay Design Module

ODRP AC/PCC-Trial 1

AC Overlay of AC/PCC Pavement

Pavement Thickness for Future Traffic 12.35 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	10.13	4.29

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	33,831,068
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	300 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1

Calculated Thickness for Future Traffic 12.35 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	12 in
Existing AC Thickness	3 in
AC Milling Thickness	0 in
Rut Depth	- in
Durability Adjustment Factor	0.9
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	1
Number of Deteriorated Joints	- per mi
Number of Deteriorated Cracks	30 per mi
Number of Unrepaired Punchouts	28 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	25 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.80
Calculated Effective Pavement Thickness	10.13 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple

Total Calculated Cumulative ESALs - *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6246	0	33,793,626
Total	100	-	-	-	33,831,068

Growth Compound

Total Calculated Cumulative ESALs 33,831,068

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	AC Overlay	4.2880258	12
2	AC	3	12
3	PCC	12	12
Total	-	19.29	-

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Overlay Design Module

ODRP AC/PCC-Trial 2

AC Overlay of AC/PCC Pavement

Pavement Thickness for Future Traffic	12.85 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	9.28	6.43

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	34,003,718
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	100 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	12.85 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	10 in
Existing AC Thickness	3 in
AC Milling Thickness	0 in
Rut Depth	- in
Durability Adjustment Factor	0.9
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	0.8
Number of Deteriorated Joints	- per mi
Number of Deteriorated Cracks	15 per mi
Number of Unrepaired Punchouts	10 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	13 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.90
Calculated Effective Pavement Thickness	9.28 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6329	0	33,966,276
Total	100	-	-	-	34,003,718

Growth	Compound
Total Calculated Cumulative ESALs	34,003,718

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	AC Overlay	6.4325563	12
2	AC	3	12
3	PCC	10	12
Total	-	19.43	-

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Overlay Design Module

ODRP AC/PCC-Trial 3

AC Overlay of AC/PCC Pavement

Pavement Thickness for Future Traffic 13.31 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	10.79	4.79

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	34,003,718
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	20 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1

Calculated Thickness for Future Traffic 13.31 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	12 in
Existing AC Thickness	3 in
AC Milling Thickness	0 in
Rut Depth	- in
Durability Adjustment Factor	0.9
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	0.8
Number of Deteriorated Joints	- per mi
Number of Deteriorated Cracks	15 per mi
Number of Unrepaired Punchouts	15 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	12 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.89
Calculated Effective Pavement Thickness	10.79 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6329	0	33,966,276
Total	100	-	-	-	34,003,718

Growth	Compound
Total Calculated Cumulative ESALs	34,003,718

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	AC Overlay	4.7869944	12
2	AC	3	12
3	PCC	12	12
Total	-	19.79	-

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Overlay Design Module

ODRP AC/PCC-Trial 4

AC Overlay of AC/PCC Pavement

Pavement Thickness for Future Traffic	13.31 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	9.82	6.31

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	34,003,718
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	20 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	13.31 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	10 in
Existing AC Thickness	6 in
AC Milling Thickness	2 in
Rut Depth	- in
Durability Adjustment Factor	1
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	0.9
Number of Deteriorated Joints	- per mi
Number of Deteriorated Cracks	30 per mi
Number of Unrepaired Punchouts	27 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	25 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.80
Calculated Effective Pavement Thickness	9.82 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6329	0	33,966,276
Total	100	-	-	-	34,003,718

Growth	Compound
Total Calculated Cumulative ESALs	34,003,718

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	AC Overlay	6.3117243	12
2	AC	6	12
3	PCC	10	12
Total	-	22.31	-

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Overlay Design Module

ODRP AC/PCC-Trial 5

AC Overlay of AC/PCC Pavement

Pavement Thickness for Future Traffic 12.85 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	11.62	2.52

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	34,003,718
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	100 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1

Calculated Thickness for Future Traffic 12.85 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	12 in
Existing AC Thickness	6 in
AC Milling Thickness	2 in
Rut Depth	- in
Durability Adjustment Factor	1
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	1
Number of Deteriorated Joints	- per mi
Number of Deteriorated Cracks	30 per mi
Number of Unrepaired Punchouts	27 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	25 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.80
Calculated Effective Pavement Thickness	11.62 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	45,000
Number of Lanes in Design Direction	2
Percent of All Trucks in Design Lane	85 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	90	4	0.0002	0	37,442
2	10	4	1.6329	0	33,966,276
Total	100	-	-	-	34,003,718

Growth	Compound
Total Calculated Cumulative ESALs	34,003,718

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	AC Overlay	2.5210027	12
2	AC	6	12
3	PCC	12	12
Total	-	20.52	-

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Overlay Design Module

ODRP PCC-PCC-Trial 6

Unbonded PCC Overlay of PCC or AC/PCC Pavement

Pavement Thickness for Future Traffic 6.82 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	3.81	5.66
Remaining Life	-	-

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	1,943,826
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	700 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	6.82 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	4 in
Existing AC Thickness	- in
AC Milling Thickness	- in
Rut Depth	- in
Durability Adjustment Factor	-
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	-
Number of Deteriorated Joints	20 per mi
Number of Deteriorated Cracks	15 per mi
Number of Unrepaired Punchouts	15 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	15 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.95
Calculated Effective Pavement Thickness	3.81 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	12,984
2	2	3	1.4573	0	1,930,842
Total	100	-	-	-	1,943,826

Growth	Compound
Total Calculated Cumulative ESALs	1,943,826

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	Unbonded PCC Overlay	5.6565272	12
2	PCC	4	12
Total	-	9.66	-

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Overlay Design Module

ODRP PCC-PCC-Trial 7

Unbonded PCC Overlay of PCC or AC/PCC Pavement

Pavement Thickness for Future Traffic 7.43 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	5.4	5.10
Remaining Life	-	-

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	1,943,826
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	400 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	7.43 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	6 in
Existing AC Thickness	- in
AC Milling Thickness	- in
Rut Depth	- in
Durability Adjustment Factor	-
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	-
Number of Deteriorated Joints	50 per mi
Number of Deteriorated Cracks	50 per mi
Number of Unrepaired Punchouts	50 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	50 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.90
Calculated Effective Pavement Thickness	5.40 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	12,984
2	2	3	1.4573	0	1,930,842
Total	100	-	-	-	1,943,826

Growth	Compound
Total Calculated Cumulative ESALs	1,943,826

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	Unbonded PCC Overlay	5.1034204	12
2	PCC	6	12
Total	-	11.10	-

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Overlay Design Module

ODRP PCC-PCC-Trial 8

Unbonded PCC Overlay of PCC or AC/PCC Pavement

Pavement Thickness for Future Traffic 7.93 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	7.58	2.33
Remaining Life	-	-

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	1,980,527
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	200 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	7.93 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	8 in
Existing AC Thickness	- in
AC Milling Thickness	- in
Rut Depth	- in
Durability Adjustment Factor	-
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	-
Number of Deteriorated Joints	20 per mi
Number of Deteriorated Cracks	20 per mi
Number of Unrepaired Punchouts	20 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	20 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.95
Calculated Effective Pavement Thickness	7.58 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	12,984
2	2	3	1.485	0	1,967,543
Total	100	-	-	-	1,980,527

Growth	Compound
Total Calculated Cumulative ESALs	1,980,527

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	Unbonded PCC Overlay	2.3299142	12
2	PCC	8	12
Total	-	10.33	-

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

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Overlay Design Module

ODRP PCC-PCC-Trial 9

Unbonded PCC Overlay of PCC or AC/PCC Pavement

Pavement Thickness for Future Traffic 8.56 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	4.55	7.25
Remaining Life	-	-

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	2,051,412
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	50 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	8.56 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	5 in
Existing AC Thickness	- in
AC Milling Thickness	- in
Rut Depth	- in
Durability Adjustment Factor	-
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	-
Number of Deteriorated Joints	45 per mi
Number of Deteriorated Cracks	45 per mi
Number of Unrepaired Punchouts	45 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	45 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.91
Calculated Effective Pavement Thickness	4.55 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	12,984
2	2	3	1.5385	0	2,038,427
Total	100	-	-	-	2,051,412

Growth	Compound
Total Calculated Cumulative ESALs	2,051,412

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	Unbonded PCC Overlay	7.2505931	12
2	PCC	5	12
Total	-	12.25	-

1993 AASHTO Pavement Design

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Overlay Design Module

ODRP PCC-PCC-Trial 10

Unbonded PCC Overlay of PCC or AC/PCC Pavement

Pavement Thickness for Future Traffic	8.86 in

Design Method	Effective Existing Overlay Thickness (in)	Overlay Thickness (in)
Condition Survey	6.64	5.87
Remaining Life	-	-

Pavement Thickness for Future Traffic

Future 18-kip ESALs Over Design Period	2,051,412
Initial Serviceability	4.5
Terminal Serviceability	3
PCC Modulus of Rupture	650 psi
PCC Elastic Modulus	4,200,000 psi
Static k-value	15 psi/in
Reliability Level	95 %
Overall Standard Deviation	0.39
Load Transfer Coefficient, J	2.8
Overall Drainage Coefficient, Cd	1
Calculated Thickness for Future Traffic	8.86 in

Effective Pavement Thickness - Condition Survey Method

Existing PCC Thickness	7 in
Existing AC Thickness	- in
AC Milling Thickness	- in
Rut Depth	- in
Durability Adjustment Factor	-
Fatigue Damage Adjustment Factor	-
AC Quality Adjustment Factor	-
Number of Deteriorated Joints	20 per mi
Number of Deteriorated Cracks	20 per mi
Number of Unrepaired Punchouts	20 per mi
Number of Expansion Joints,	-
Exceptionally Wide Joints, or AC Full Depth Patches	20 per mi

Calculated Results

Calculated Joints and Cracks Adjustment Factor	0.95
Calculated Effective Pavement Thickness	6.64 in

Future Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	- %
Average Initial Truck Factor (ESALs/truck)	-
Annual Truck Factor Growth Rate	- %
Annual Truck Volume Growth Rate	- %
Growth	Simple
Total Calculated Cumulative ESALs	- *

*Note: This value is not represented by the inputs or an error occurred in calculation.

Future Rigorous ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	15,000
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	90 %
Percent Trucks in Design Direction	50 %

Vehicle Class	Percent of ADT	Annual % Growth	Average Initial Truck Factor (ESALs/ Truck)	Annual % Growth in Truck Factor	Accumulated 18-kip ESALs over Performance Period
1	98	3	0.0002	0	12,984
2	2	3	1.5385	0	2,038,427
Total	100	-	-	-	2,051,412

Growth	Compound
Total Calculated Cumulative ESALs	2,051,412

Layer Information

Layer	Material Description	Thickness (in)	One Dir Width (ft)
1	Unbonded PCC Overlay	5.8660038	12
2	PCC	7	12
Total	-	12.87	-