FINAL REPORT
Review and Evaluation of Concrete Pavement Design Method in Alabama
Research Project 931-107R

Submitted to
Alabama Department of Transportation (ALDOT)

Submitted by

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AASHO	American Association for Highway Officials
ALDOT	Alabama Department of Transportation
CRCP	Continuously Reinforced Concrete Pavement
DOT	Department of Transportation
FHWA	Federal Highway Administration
FWD	Falling Weight Deflectometer
JPCP	Jointed Plain Concrete Pavement
JRCP	Jointed Reinforced Concrete Pavement
LCCA	Life Cycle Cost Analysis
LTPP	Long Term Pavement Performance
MEPDG	Mechanistic Empirical Pavement Design Guide
NOAA	National Oceanic and Atmospheric Administration
PSI	Present Serviceability Index

EXECUTIVE SUMMARY

Concrete pavements constitute only about 2% of Alabama's highway system, yet they provide durable and low-maintenance performance capable of handling heavy traffic and environmental challenges. The Alabama Department of Transportation (ALDOT) currently utilizes the AASHTO 1993 design guide, which, while reliable, often produces conservative and overly thick slab designs. As cost efficiency and performance optimization become increasingly important in infrastructure design, questions have arisen regarding the necessity of tied concrete shoulders, particularly for lane-widening projects where their structural benefits may be marginal.

This research was undertaken to evaluate opportunities for enhancing Alabama's concrete pavement design practices to achieve a better balance between structural reliability, durability, and economy. The primary objectives were to: (1) review ALDOT's current design parameters, specifically reliability and terminal serviceability indices, and assess their influence on pavement thickness; (2) compare the cost-effectiveness of widened lanes (13–14 ft) with non-tied shoulders against conventional 12-ft lanes with tied shoulders; and (3) assess the feasibility of adopting the AASHTO 1998 Supplement to the Guide for Design of Pavement Structures (Part II: Rigid Pavement Design & Joint Design) and, if appropriate, develop a computational spreadsheet to support ALDOT implementation.

Across all evaluated conditions, results indicated that the AASHTO 1998 method yielded thicker pavement slabs than the AASHTO 1993 method by approximately 10–37%, depending on the selected reliability level, terminal serviceability index, and location. Consequently, construction costs derived from AASHTO 1998 were 7–46% higher per mile than those computed using AASHTO 1993. Designs employing widened lanes with non-tied shoulders required 1–2% thinner slabs and demonstrated 11–20% cost savings, depending on site conditions and design assumptions. Note that a load transfer coefficient (J) value of 2.9 was consistently used for all pavement types in this study. The selection of ALDOT-specific J values may help reduce conservative over-design or mitigate the risk of under-performance. These findings suggest that certain geometric configurations can partially offset the higher costs associated with more mechanistic design methods.

For future concrete pavement projects, the choice of design methodology should align with project priorities, traffic levels, and performance expectations. The AASHTO 1998 design method provides a more robust and comprehensive framework by explicitly accounting for joint performance, temperature gradients, edge support, and mid-slab tensile stresses. Although it typically results in slightly thicker and more costly designs, it offers improved reliability and long-term durability, particularly for high-traffic corridors and new pavement construction. In contrast, the AASHTO 1993 design method may be adequate for projects with lower traffic volumes or where budget constraints and acceptable risk levels justify a more economical design. However, adopting state-specific methods can be even more effective, as they modify or calibrate standard AASHTO procedures to reflect local conditions, materials, and experience, ensuring more accurate, practical, and cost-efficient pavement performance predictions within each state.

For lane widening projects, the decision between tied and non-tied shoulders should be based on a balanced evaluation of cost, performance, and maintenance implications. Tied shoulders enhance structural continuity, reduce slab deflection and fatigue cracking, and improve thermal movement

control, contributing to extended pavement life and reduced long-term maintenance. However, they increase both slab thickness and initial construction costs. Conversely, non-tied shoulders may be suitable for low-volume or low-traffic roadways, where cost savings outweigh the minor reduction in structural performance.

1. INTRODUCTION

1.1 Background

Although concrete pavement represents only about 2% of the highway system in Alabama, it offers a viable, long-lasting, and low-maintenance solution to address increasing heavy traffic and environmental challenges such as temperature variation, heavy rainfall, and waterlogging. While concrete generally has a higher initial construction cost than asphalt, it provides a longer service life and lower maintenance costs (Kuemmel et al., 2001; Hoel and Short, 2006).

Concrete pavements are designed to withstand traffic loads through flexural strength and to accommodate movements caused by expansion and contraction (Mayora and Pina, 2009). **Figure 1** illustrates a typical concrete pavement section with dowels at joints, showing the concrete slab placed over the subgrade and subbase or base layers. Concrete pavements include both longitudinal and transverse joints: longitudinal joints are typically located along the centerline of the pavement, while transverse joints are spaced at 12 to 20 ft for Jointed Plain Concrete Pavement (JPCP) and 20 to 30 ft for Jointed Reinforced Concrete Pavement (JRCP) (Aultman-Hall et al., 2004).

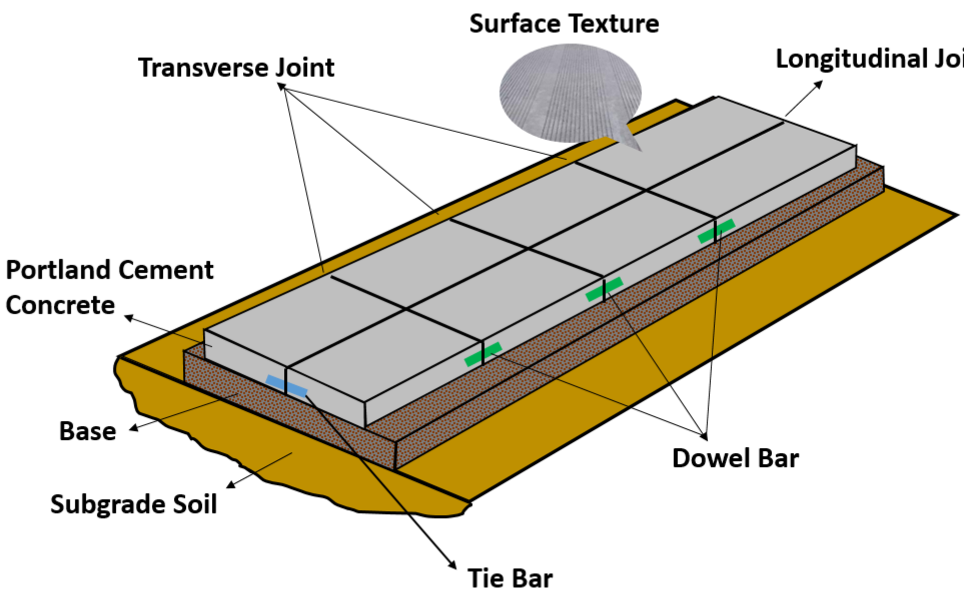


Figure 1. Typical concrete pavement structure.

1.2 Motivation of the Study

The Alabama Department of Transportation (ALDOT) has utilized the AASHTO 1993 design guide for rigid pavement design for several decades. This method is based on empirically derived statistical equations used to select materials and determine pavement thickness. Under this approach, a reliability level of 95% and a terminal serviceability index of 3.5 are typically applied for interstate pavements. While this ensures a conservative design, it can result in overly thick concrete slabs. Consequently, there is growing interest in evaluating the current rigid pavement design approach to identify opportunities for reducing slab thickness and improving cost efficiency.

Shoulder type also influences the required thickness of rigid pavement. Tied concrete shoulders have been widely used to reduce load-induced strains and deflections along the pavement edge (Colley et al., 1978; FHWA, 1990). However, questions remain regarding the necessity of tied concrete shoulders in lane-widening projects in Alabama. The addition of a tied concrete shoulder may be overly conservative, as the widened lane itself can reduce edge stress. Research on tied shoulders and lane widening dates back to the 1970s (Colley et al., 1978), highlighting the importance of re-evaluating the cost-effectiveness of tied concrete shoulders in modern resurfacing projects that incorporate lane widening in their design.

1.3 Objectives

The objectives of this study are established as follows:

1. Review and assess the current concrete pavement design method with respect to selection of reliability and terminal serviceability;
2. Evaluate the cost effectiveness of a wider slab (13'-14') and non-tied concrete shoulder vs a 12' slab and tied concrete shoulder;
3. Should ALDOT adopt the 1998 Supplement to the AASHTO Guide for Design of Pavement Structures Part II, Rigid Pavement Design & Rigid Pavement Joint Design. If yes, a spreadsheet to perform said calculations will be provided to ALDOT.

1.4 Organization of the Report

This report is organized into nine chapters, followed by references and an appendix. Chapter 1 introduces the background, motivation, and objectives of the study. Chapter 2 describes the study methodology, including the empirical design formulas, survey process, and design parameters used in the analysis. Chapter 3 provides a literature review on concrete pavement design, tied shoulders, and widened lanes. Chapter 4 presents the survey results, while Chapter 5 compares pavement thicknesses designed using the AASHTO 1993 and AASHTO 1998 methods for various Alabama locations and traffic levels. Chapter 6 further compares the pavement thicknesses of conventional lanes with tied shoulders and widened lanes with non-tied shoulders. Chapter 7 provides a cost comparison between AASHTO 1993 and AASHTO 1998 designs, and Chapter 8 compares the costs of conventional tied-shoulder and non-tied widened-lane configurations. Finally, Chapter 9 summarizes the key findings, presents the study conclusions, and outlines future research recommendations. The Reference section lists all cited sources, and Appendix A includes the survey questionnaire used in this study.

2. RESEARCH APPROACH

Chapter 2 presents the research methodology developed to achieve the study objectives. The chapter begins by describing the survey conducted to gather information on design methods and practices used in the Southeastern U.S. and other states. It then outlines the empirical formulas associated with various concrete pavement design methods. The subsequent sections identify the locations selected for the concrete pavement design analysis and detail the design input parameters used in the evaluation. These include traffic data and classification, climate conditions, concrete properties, base thickness and properties, reliability levels, and terminal serviceability.

Figure 2 illustrates the workflow for this study which is divided into two parts which are literature review and online survey, and comparative analysis using different design methods and lanes.

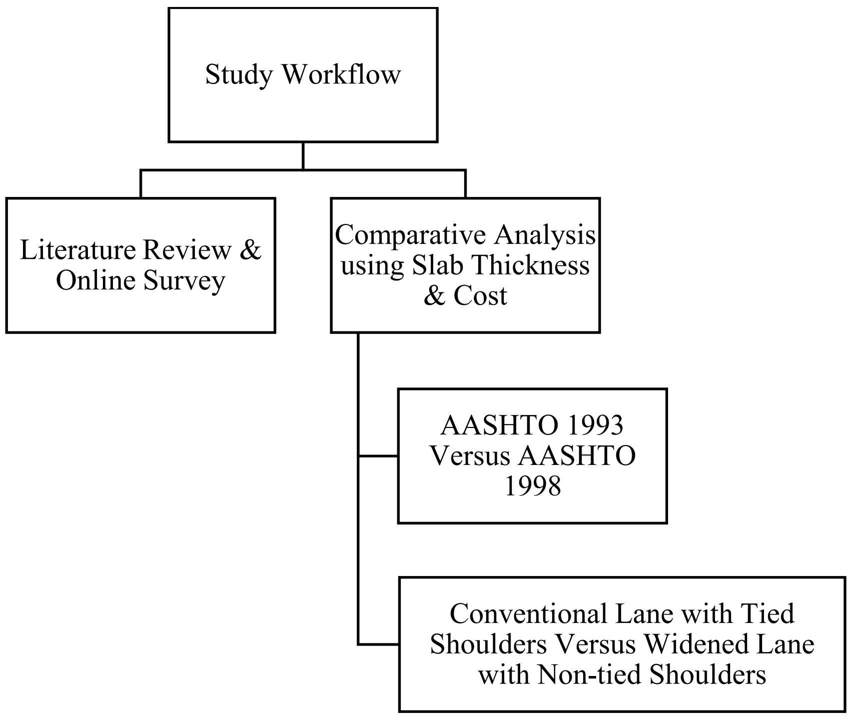


Figure 2. Workflow for comparative analysis of design methods.

The first part of this study involves a literature review and an online survey to collect accurate and relevant information on pavement design methodologies from previous studies and practitioner experience. An online survey, administered through Google Forms or Word documents, was conducted to gather insights from practitioners and state pavement engineers in regions with climate and traffic conditions similar to Alabama. The survey was designed to assess the current state of concrete pavement design methods in Alabama and other states and to identify gaps and research needs for developing more sustainable and cost-effective pavement designs.

The second part focuses on a comparative analysis of concrete pavement design methods, specifically, the AASHTO 1993 Design Guide and the AASHTO 1998 Supplement, and two lane configurations: lanes with tied shoulders and widened lanes without tied shoulders. This analysis evaluates slab thickness designs generated by the AASHTO 1998 Supplement compared to those from the AASHTO 1993 method and examines the associated costs to assess overall cost-effectiveness. The AASHTO 1998 Supplement incorporates improved characterization of base and subgrade support, validated through Long-Term Pavement Performance (LTPP) studies. It is also used in this study to compare lane configurations and identify the most economical design solution.

2.1 Survey

A total of 19 questions, including sub-questions, were included in the survey. The questionnaire was organized into three parts. Part I contained 10 questions focusing on concrete pavement design methods and parameters. Part II consisted of 3 questions related to concrete shoulder design and relevant studies, while Part III included 6 questions addressing pavement design software and cost analysis. **Figure 3** illustrates the logical sequence of questions as presented to the respondents. Detailed survey questions are provided in **Appendix A**. The survey was distributed to 13 states, including Alabama, Mississippi, Louisiana, Florida, Georgia, Arkansas, Texas, Tennessee, North Carolina, South Carolina, Ohio, Michigan, and Illinois. The survey results are presented in Chapter 4.

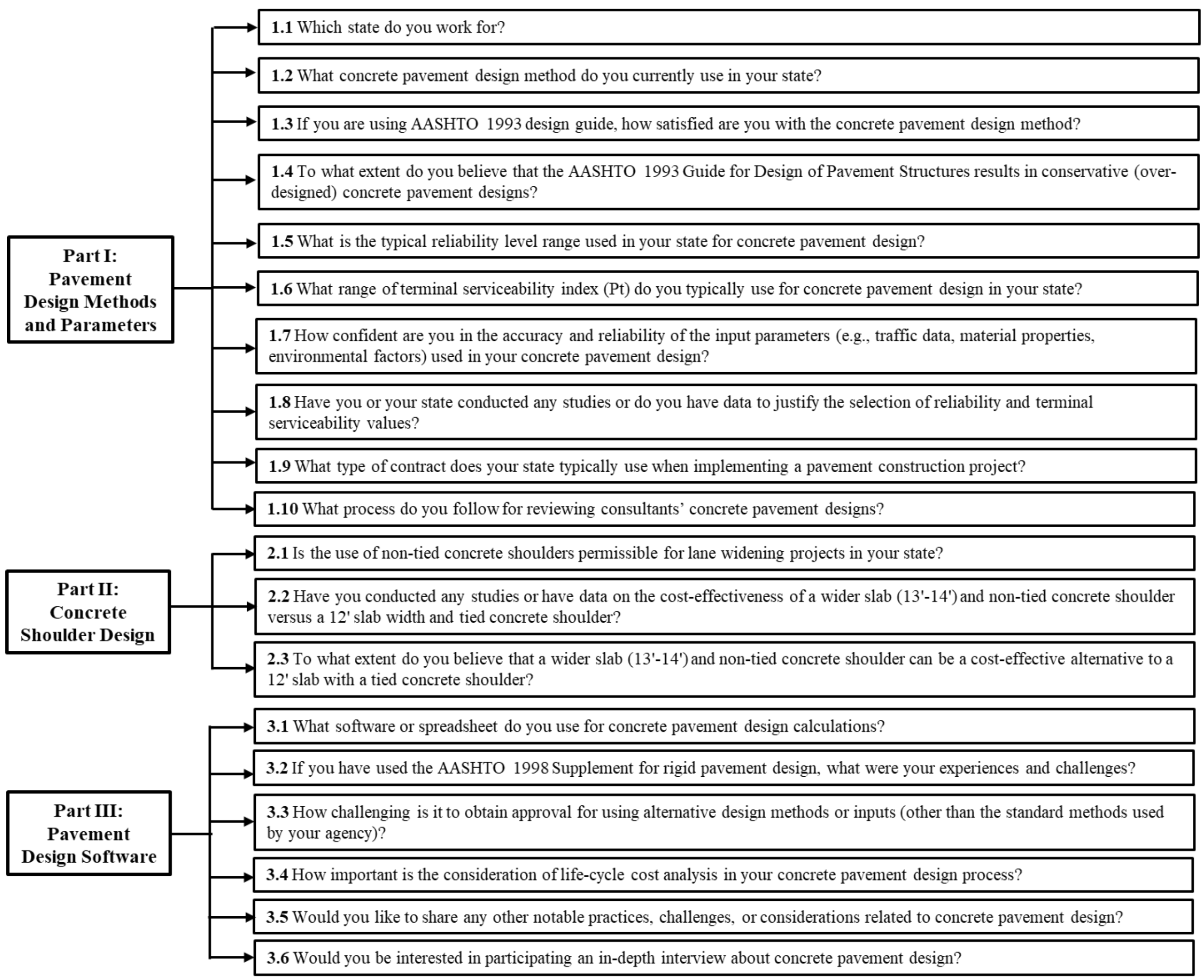


Figure 3. An overview of designed survey questions.

2.2 Comparative Analysis of Slab Thickness using AASHTO Design Methods

Concrete pavement design analysis requires appropriate methods to perform the necessary calculations. In this study, two empirical design methods, AASHTO 1993 and AASHTO 1998, were used. A comparative analysis between these two methods was conducted to determine the slab thickness for different design conditions and lane types. The AASHTO 1993 design method employs an empirical equation, as discussed in Chapter 3, while the AASHTO 1998 design method utilizes a set of equations for estimating the design thickness of concrete pavements, also described in Chapter 3.

2.2.1 Design Inputs

The parameters used for analysis from both design methods which are AASHTO 1993 design method and AASHTO 1998 supplement design method are discussed in this section. The empirical formula for both design methods require parameters to work on for designing the thickness of the concrete pavement.

2.2.1.1 Traffic Data

Traffic data are based on the 18-kip Equivalent Single Axle Loads (ESALs) vehicle data. According to the ALDOT, traffic data are classified into three types of traffic volumes, which are low, medium, and high traffic volume (ALDOT, 2022). **Table 1** classifies the traffic volume of 18-kips ESALs vehicles in the roads into low, medium, and high.

Table 1. Traffic Volume Classification by ESALs

Traffic Volume	Volume Range (ESALs)
Low	Less than or equal to 1,000,000
Medium	1,000,000 – 10,000,000
High	Greater than 10,000,000

For this analysis, traffic volumes from four locations (Mobile, Montgomery, Birmingham, and Huntsville) were considered and classified into three categories: low, medium, and high traffic volumes, as shown in **Figure 4** and **Table 2**. **Figure 4** illustrates the road network corresponding to the different traffic volume levels in these locations, where low traffic is shown in blue, medium traffic in purple, and high traffic in green.

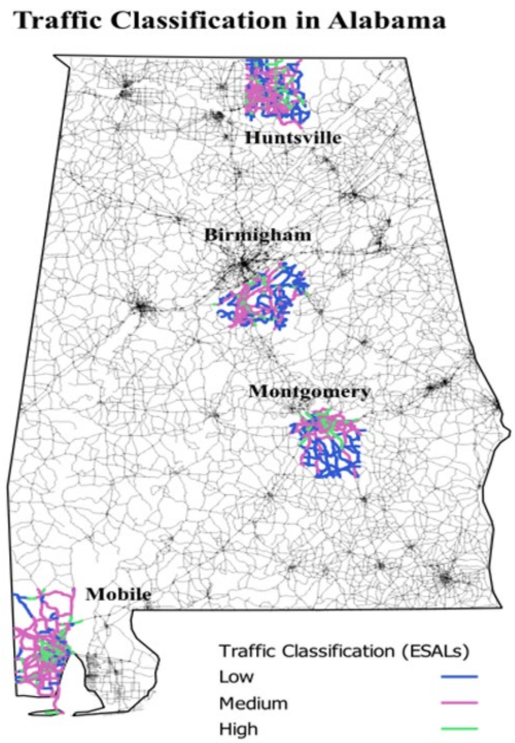


Figure 4. Traffic classification in Alabama.

Table 2. Traffic Volume for Mobile, Montgomery, Birmingham, and Huntsville

Location	Mobile	Montgomery	Birmingham	Huntsville
Low	364,456	325,092	659,007	397,712
Medium	4,535,273	1,668,490	2,721,815	3,283,770
High	17,257,709	18,777,973	12,937,174	19,327,711

Table 3 gives the data for low, medium, and high traffic volumes in those four locations in number of ESALs. This shows the different levels of traffic present in those four locations in Alabama. These numbers are the ESALs for all locations and their classification and are taken as AADT 2023 from Alabama Traffic and ESALs are calculated from the American Concrete Pavement Association (ACPA) calculator (Alabama Traffic Data, 2024; ACPA, 2024). Apart from AADT value, calculation of ESAL does contain inputs like directional distribution factor, lane distribution factor, design years, truck factor, and growth factor as described in Table 4. Therefore, other inputs for ESAL calculation are as follows in the following section:

Table 3. Inputs for ESAL Calculation

Inputs	Values
Directional Distribution (DD) factor, %	50
Lane Distribution (LD) factor, %	60
Design Years	25
Truck factor	1.7
Growth, %	3

2.2.1.2 Climate Data

Table 4 presents the climate data from the AASHTO 1998 supplement guide and National Weather Service give the data for 4 chosen locations, which are Mobile, Montgomery, Birmingham, and Huntsville (AASHTO, 1998; NOAA, 2024). The climate data contains mean annual wind speed, mean annual temperature, and mean annual precipitation for designing concrete pavement using the AASHTO 1998 design method.

Table 4. Climate data for Mobile, Montgomery, Birmingham, and Huntsville

Location	Mean Annual Wind Speed, mph	Mean Annual Temperature, °F	Mean annual Precipitation, inches
Mobile	9	67.5	64.6
Montgomery	6.7	67.5	49.2
Birmingham	7.2	62.2	52.2
Huntsville	8.4	62	58

2.2.1.3 Reliability and Terminal Serviceability

Reliability and terminal serviceability do play a significant role in designing concrete slabs and are the parameters that can define the traffic effects on the pavement and help to design appropriate concrete pavement thickness. Thus, changing the reliability and terminal serviceability index does change the thickness of the concrete. The values for reliability and terminal serviceability are entered into both the AASHTO 1993 design equation and the AASHTO 1998 Supplement design equation for getting the thickness of concrete pavement.

The terminal serviceability for calculating design thickness according to AASHTO 1993 and Alabama Department of Transportation specifications ranges from 1.5 to 3.5. **Table 5** shows the serviceability index values and present serviceability index.

Table 5. Serviceability Index and ΔPSI

Initial Serviceability, P_0	Terminal serviceability, P_t	$\Delta PSI = P_0 - P_t$
4.5	1.5	3.0
	2.0	2.5
	2.5	2.0
	3.0	1.5
	3.5	1.0

The reliability level for calculating design thickness is based on the Alabama Department of Transportation Specification, which states that primary arterial and interstate reliability ranges from 85 % to 99.99% shown in **Table 6**.

Table 6. Reliability Level and Standard Normal Deviation

Terminal serviceability, P_t	$\Delta PSI = P_0 - P_t$
85	-1.037
86	-1.08
87	-1.126
88	-1.175
89	-1.227
90	-1.282
91	-1.34
92	-1.405
93	-1.476
94	-1.555
95	-1.645
96	-1.751
97	-1.881
98	-2.054
99	-2.327
99.9	-3.09
99.99	-3.75

2.2.2 Other Inputs

The parameters other than traffic and climate data are needed for the calculation of design thickness using AASHTO 1993 and AASHTO 1998 supplement design methods are listed in **Table 7**.

Table 7. Other Parameters and Their Values

Parameters	Values
Overall standard deviation, S_0	0.39
Modulus of elasticity of concrete, psi, E_c	4,200,000
Flexure modulus of concrete, psi, $(S'_c)'$	650
Drainage coefficient, C_d	1.1
Joint load transfer coefficient, J	2.9
Modulus of subgrade reactions, psi/in, k	100
Poisson's ratio, μ	0.15
Base thickness, inches, H_b	6
Modulus of elasticity of base, psi, E_b	30,000
Edge support, E	0.94 for conventional 12' slab plus shoulders, and 0.92 for 2' widened slab in 12' conventional slab
Joints spacing	15' for JPCP and 30' for JRCP

2.3 Comparative Analysis of Slab Thickness for Tied Shoulders and Non-Tied Shoulders

Two different lane types, conventional 12-ft lanes with tied shoulders and widened lanes with non-tied shoulders, are compared in terms of the designed slab thickness using the AASHTO 1998 design method. This method was chosen because it provides different edge support factors depending on the lane type, which is relevant to this study (AASHTO, 1998). The AASHTO 1998 design tool (Excel) allows for slab thicknesses ranging from 7 to 15 inches. The analysis was conducted for JPCP, JRCP, and CRCP pavements at four locations: Mobile, Montgomery, Birmingham, and Huntsville, using the methodology described in Section 2.2.

2.4 Comparative Cost Analysis of Concrete Pavement

The comparative cost analysis of concrete pavement was conducted for (1) comparing AASHTO 1998 with AASHTO 1993; (2) comparing conventional 12' lanes with tied shoulders and widened lanes with non-tied shoulders.

2.4.1 Concrete Cost

Cost analysis of concrete pavement involved several parameters, including the volume of concrete and the size and length of tie bars, dowel bars, transverse bars, and longitudinal bars. The total volume of concrete was calculated for a one-mile segment for each pavement type. For a one-mile-long concrete pavement, the total cost of concrete is determined using Equation [1]:

$$Cost = C_u \times L \times W \times D \qquad [1]$$

where, C_u is the unit price of concrete ($/ft^3), L is the pavement length (1 mile = 5,280 ft), W is the total pavement width (lane plus shoulder), and D is the pavement thickness.

For example, for a concrete pavement with a 12-ft lane width, a 4-ft shoulder, and a thickness of 7 in., using a unit price of $8.33/ft^3, the total concrete cost is calculated as: $8.33/ft^3 × 5,280 ft × 16 ft × (7/12 ft) = $410,502. In this study, a unit price of $8.33/ft^3 was used consistently for all cost analyses.

2.4.2 Rebars Cost

The cost of reinforcing bars (rebars) is determined by multiplying the unit price ($/lb) by the total weight of steel required. Each type of concrete pavement includes different steel components. Dowel bars are placed at transverse joints to facilitate load transfer, tie bars are installed at longitudinal joints to hold adjacent lanes together, and reinforcing steel in JPCP or CRCP includes both longitudinal and transverse reinforcement. In this study, the following scenarios are considered:

- JPCP -Tied shoulder: Dowel bars were used to connect two slabs and tie bars were used to tie a shoulder to a lane.
- JPCP - Widened Lane: Dowel bars were used to connect two slabs and no tie bars were used.
- JRCP - Tied shoulder: Longitudinal and transverse bars were used along with dowel and tie bars.
- JRCP - Widened Lane: Longitudinal and transverse bars were used along with dowel bars but no tie bars were used.
- CRCP - Tied shoulder: Longitudinal bars were used along with tie bars.
- CRCP - Widened Lane: Only longitudinal bars were used.

The total weight of bars is calculated using Equation [2]:

$$W = n \times L_b \times w_u \qquad [2]$$

where, n is total number of bars, L_b is length of each bar, and w_u is unit weight of bar.

The unit weight (w_u) of the bar is determined by Equation [3].

$$w_u = 0.167 \times d^2 \qquad [3]$$

where, d is nominal bar diameter. Typical unit weights of standard bars are in **Table 8**.

Table 8. Typical Bars Size, Diameter and Unit Weight

Bar No.	Diameter	Weight (lb/ft)
#3	0.375	0.376
#4	0.600	0.668
#5	0.625	1.043
#6	0.750	1.502
#7	0.875	2.044
#8	1.000	2.670
#9	1.128	3.400
#10	1.270	4.300

The number of bars (n) are determined based on spacing and pavement geometry, as calculated in Equations [4] to [6], respectively.

For dowel bars (transverse joints),

$$n = \frac{Pavement\ Width}{Bar\ Spacing} \times Number\ of\ Joints \qquad [4]$$

For tie bars (longitudinal joints):

$$n = \frac{Pavement\ Width}{Tie\ Bar\ Spacing} \qquad [5]$$

For reinforcement steel (in CRCP):

$$n = \frac{Pavement\ Area}{Bar\ Spacing\ in\ Both\ Directions} \qquad [6]$$

For example, for a one-mile pavement, a width of 12 ft, tie bars of #5 (1.043 lb/ft), length of 30 inches (2.5 ft), bar spacing of 24 inches (2 ft), $n = \frac{5{,}280}{2} = 2{,}640\ bars$, W = 2,640 × 2.5 ft ×1.043 lb/ft = 6883.8 lb, and the total cost of tie bars = \$0.63/lb × 6883.8 lb = \$4,337.

For another example, for one-mile pavement, a width of 12 ft, dowel bars of #10 (4.303 lb/ft), length of 18 inches (1.5 ft), bar spacing of 12 inches (1 ft), joint spacing of 15 inches, n = $\frac{12}{1} \times \frac{5280}{15} = 2112\ bars$, W = 2112 × 1.5 ft × 4.30 ld/ft = 13,622.4 lb, and the total cost of dowel bars = \$0.43/lb × 13,622.4 lb = \$5,858.

The spacing of dowel bar is taken 12 in. while for tie bar 24 in. of spacing is considered. The size and cost of each material is shown in **Table 9**. The diameter and length of dowel and tie bar is the typically used value in JPCP design and is constant throughout the analysis for all four locations.

Table 9. Size and Unit Price of Materials

Material	Diameter	Length	Unit Price
Dowel Bar	#10 (1.27 in.)	18 in.	\$0.43/lb
Tie Bar	#5 (0.625 in.)	30 in.	\$0.63/lb
Longitudinal Bar	#6 (0.75 in.)	Calculated for 1 mile.	\$0.56/lb
Transverse Bar	#8 (1.00 in.)	Calculated for 1 mile.	\$0.7/ lb
Reinforcement ratio (#6 bar)	0.0025		
Reinforcement ratio (#8 bar)	0.0015		

For the conventional lane with tied shoulders, a lane width of 12 ft and a 4-ft shoulder were used, whereas a 14-ft width was adopted for the widened lane with non-tied shoulders.

2.5 Chapter Summary

This chapter outlines the research approach used to achieve the study's objectives, which is divided into four main parts. The first part involved online surveys and a literature review to understand the state-of-the-art concrete pavement design practices. The second part compared slab thicknesses using the AASHTO 1993 and AASHTO 1998 methods, including different lane types. This analysis accounted for traffic levels, climate conditions, material properties, reliability, terminal serviceability, and edge support for four Alabama cities: Mobile, Montgomery, Birmingham, and Huntsville. The third part conducted a cost-effectiveness analysis for one-mile pavement segments, considering slab size and unit costs.

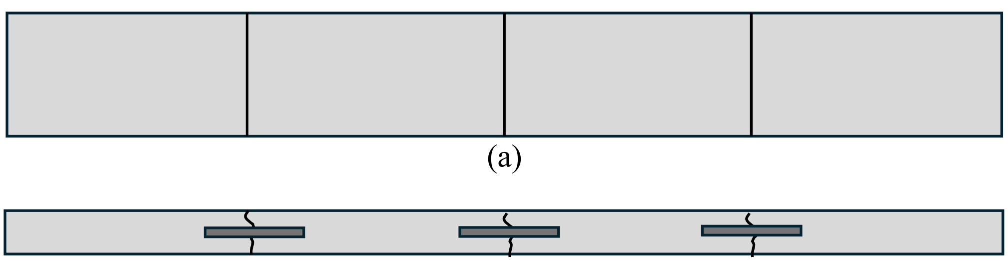
3. LITERATURE REVIEW

This chapter provides a comprehensive review of the literature on concrete pavement, concrete pavement design methods, and lane types, which are conventional lane with tied shoulders and wider lanes with non-tied shoulders. It also explores shoulders and widened lanes for the cost-effective choice for concrete pavement design.

3.1 Concrete Pavement Types

In general, concrete pavement has three different types which are JPCP, JRCP, and Continuously Reinforced Concrete Pavement (CRCP). JPCP consists of an unreinforced concrete slab of length 12 ft.-20 ft. having transverse contraction joints between slabs. Joints in JPCP are closely spaced so that the formation of cracks will not happen (Hussien and Hassan, 2018). Joints in JPCP are used to transfer load through aggregate locks and dowels. Aggregate locks in the joint help to transfer the load through the bearing stress of the aggregate particles between joints. Dowels are steel rods used to transfer loads across joints. JRCP consists of longer slabs of lengths 25 ft.-30 ft. with light reinforcements and transverse contraction joints between slabs. Steel reinforcement in the JRCP usually has a range of 0.1% to 0.25 % of the cross-sectional area of the slab. The load transfer in the JRCP is due to dowels, which are responsible for controlling the deterioration of the slab due to cracking and faulting (Xin et al., 2019). CRCP is the pavement that has heavy steel reinforcement in a longitudinal direction and no joints. Steel reinforcement in the CRCP is 0.4 to 0.8 % of the cross-sectional area of the slab. CRCP uses anchors at the pavement end so that it can resist cracking from shrinkage of concrete due to contraction (Bassett and Jung, 1985; Delatte, 2018).

Figure 5(a) shows the top view plan of a JPCP, where sawing is introduced to create joints to control transverse cracking. JPCP can be designed with or without dowel bars; however, doweled JPCP is the standard for high-volume or heavy-load pavements, while undoweled JPCP is typically used for low-volume roads. **Figure 5(b)** illustrates a doweled JPCP, where dowel bars are placed across the transverse joints to transfers loads between adjacent slabs. This load transfer mechanism helps control distresses such as cracking, faulting, corner breaking, and spalling under traffic loads (Huang, 2004; Delatte, 2014; TxDOT 2021).

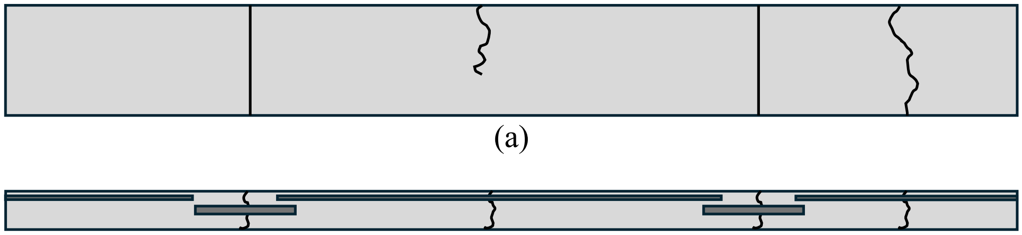


(a)

(b)

Figure 5. JPCP: (a) top view; (b) side view with dowels.

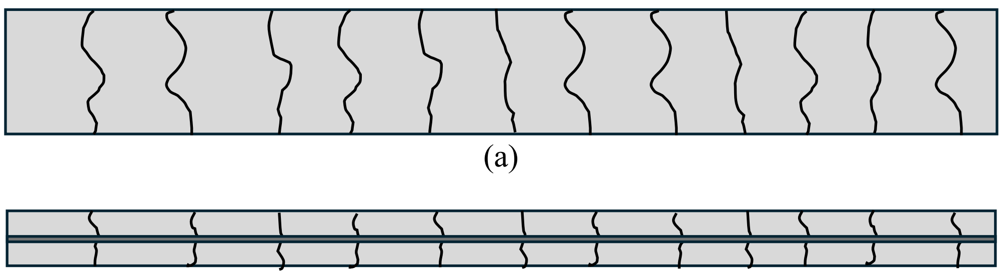
Figures 6 (a) and **6(b)** show the plan and section view of JRCP, respectively. JRCP has reinforcement in the slab and contains dowels in transverse joints for effective load transfer between adjacent concrete pavement slabs. However, due to longer joint spacing there may have cracks in the slab and can damage the structural integrity of the pavement (Huang, 2004; Delatte, 2014; TxDOT 2021).


(a)

(b)

Figure 6. JRCP: (a) top view; (b) side view.

Figures 7(a) and **7(b)** show the plan and section of CRCP. CRCP has no transverse joints, but it does contain micro controlling cracks developed during the construction of the pavement. These micro cracks in the pavement help pavement to distribute loads and strains (Huang, 2004; Delatte, 2014; TxDOT 2021).


(a)

(b)

Figure 7. CRCP: (a) top view; (b) side view.

Concrete pavement is a strong and reliable surface designed to withstand heavy loads and extreme weather, making it ideal for roads, highways and sidewalks. For the concrete pavement design, there are various methods such as empirical methods, mechanistic-empirical (M-E) methods, mechanistic methods, and other specialized methods like the Portland Cement Association (PCA) method, Federal Aviation Administration (FAA) design method, and state-specified design tables (Delatte, 2018; McKnight et al., 1998). The Alabama Department of Transportation (ALDOT) has adopted the AASHTO 1993 design guide for a long time which is based on an empirically statistical equation derived from the AASHO Road Test that selects material and determines pavement thickness (AASHTO, 1993). However, it lacks sensitivity to modern traffic and environmental conditions (Li et al., 2011). An increased interest is in assessing the current concrete pavement design that can potentially reduce concrete slab thickness for a more cost-effective design that leads for developing of more enhanced empirical methods like AASHTO 1998 (AASHTO, 1998). This study aims to compare AASHTO 1993 and AASHTO 1998 pavement design methods and assess effectiveness in design thickness and cost for Alabama concrete pavement structures with different reliability and terminal serviceability values.

In addition to design methods, configuration of lane also affects pavement performance and cost. Tied concrete shoulders have been used to reduce load strains and deflection at the shoulder edge (Tayabji et al., 1984). Adding a tied shoulder to concrete pavement makes the concrete pavement design thicker. However, a wider slab is less thick and can reduce stress edge (Colley, et al., 1978). This study will evaluate the application of widened lanes with non-tied shoulders to conventional lanes with tied shoulders, on the thickness of the slab and cost-effectiveness.

3.2 Concrete Pavement Design

Concrete pavement is low maintenance and durable, for which a concrete pavement design is necessary to accommodate the users' various needs. Concrete pavement is designed to have high speed and high traffic capacity; therefore, it is important to design the thickness of the slab to accommodate all traffic and provide a surface for transport (Li et al., 2011). According to FHWA (2017), empirical design methods based on Long Term Pavement Performance (LTPP) refer to a design approach that uses previously observed datasets from similar pavement to determine the pavement thickness and structure of the designed pavement. Empirical design methods like the AASHTO design guide use traffic volume, drainage, soil conditions, concrete properties, and pavement performance to design the concrete pavement thickness and other design parameters (Huang, 2004).

3.2.1 AASHTO 1993 Design Method

The American Association of State Highway Officials (AASHO) road test was the first test experiment that helped to study the relationship between various design parameters like axle loads, pavement thickness, and subgrade conditions. With the help of this AASHO road test, various empirical methods were developed, one of which was the AASHTO design guide method (AASHO, 1962). AASHTO 1993 was one of the methods that was developed with the help of the AASHO road test and had improvised and updated previous AASHTO design guide methods which were AASHTO 1972 and AASHTO 1986. AASHTO 1993 design guide method introduced improvements to earlier published AASHTO design guide method for accuracy and applicability of pavement design. The AASHTO 1993 refined ESALs and introduced an enhanced way of calculating growing traffic ESALs (AASHTO, 1993). It also expanded the reliability level of applications for traffic categories. Additionally, it introduced drainage coefficients and highlighted the moisture content in the subgrade and base layers for proper functioning of the pavement (Li et al., 2011). Also, it provided a clear understanding of the serviceability index for pavement distresses like rutting or cracking (FHWA, 1997). Furthermore, it provided updated guidance for determining soil subgrade with changing seasons. It introduced enhanced overlay design procedures and used Falling Weight Deflectometer (FWD) data. It considered life cycle cost analysis (LCCA) in pavement designs (AASHTO, 1993).

AASHTO 1993 design guide method comprises a design equation for the computation of thickness, as follows:

$$\log_{10}(W_{18}) = Z_r S_0 + 7.35\log_{10}(D+1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{(4.5-1.5)}\right]}{1+\frac{1.624*10^{7}}{(D+1)^{8.46}}} + (4.22 - 0.32)\, p_t \log_{10}\left[\frac{S'cCd(D^{0.75}-1.132)}{215.63J(D^{0.75} - \frac{18.42}{\left(\frac{Ec}{k}\right)^{0.23}})}\right] \quad [7]$$

where, W_{18} is the total number of 18-kip equivalent single axle load applications, Z_r is standard normal deviation, S_0 is combined standard error of the traffic prediction and performance prediction, D is thickness (inches) of pavement slab, ΔPSI is difference between the initial design serviceability index and the design terminal serviceability index, S'_c is modulus of rupture (psi) for Portland cement concrete used on a specific project, J is load transfer coefficient used to adjust for load transfer characteristics of a specific design, C_d is drainage coefficient, E_c is modulus of elasticity (psi) for Portland cement concrete, and k is modulus of subgrade reaction.

3.2.2 AASHTO 1998 Supplement Design Method

AASHTO 1993 Supplement design method despite being a reliable empirical method for designing concrete pavement, was unable to design pavement thickness for very high traffic volumes, and differential climatic conditions. It also had a limited description for layer interactions between components of the pavement structure i.e., subgrade, base/subbase, and concrete slab. Thus, to overcome these challenges, an interim design method was proposed in 1998, the AASHTO 1998 Supplement design method. AASHTO 1998 supplement was not based on the AASHO road test, but it contains various parameters that AASHO had developed. AASTO 1998 supplement was developed based on Long-Term Pavement Performance (LTPP) and NCHRP Project I-30 study (AASHTO, 1998). The improvements of the AASHTO 1998 supplement to AASHTO 1993 was introduction of a model based on layered elastic theory. It also predicted design parameters for any traffic, climate, and material properties. Additionally, it also incorporated fatigue and cracking models for performing prediction. Furthermore, it included joint spacing for the pavement (FHWA, 2010).

AASHTO 1998 Supplemental Design Guide Method as an improvement of the AASHTO 1993 Design Guide Method introduces additional considerations for reliability, stress analysis, and interaction between concrete slab properties, base materials, and subgrade reactions to refine the thickness of the concrete slab. AASHTO 1998 Supplemental Design Guide provides a bulk of equations for calculating the design thickness of the slab, as follows:

$$\log_{10} W' = \log_{10} W + (5.065 - 0.03295 \times P2^{2.4}) \times [\log_{10}(\frac{(S'c)'}{\sigma'_t}) - \log_{10}(\frac{690}{\sigma_t})] \quad [8]$$

$$\log_{10} W = \log_{10} R + \frac{G}{Y} \quad [9]$$

$$\log_{10} R = 5.85 + 7.35 \times \log_{10}(D + l) - 4.62 \log_{10}(L1 + L2) + 3.28 \log_{10} L2 \quad [10]$$

$$Y = 1.00 + 3.63 \times \frac{(L1 + L2)^{5.2}}{(D+1)^{8.46} \times L2^{3.52}} \quad [11]$$

$$G = \log_{10} (\frac{(P1 - P2)}{(P1 - 1.5)}) \quad [12]$$

$$\sigma'_t = \sigma_l \times E \times F [1.0 + 10^{(\log_{10} b)} \times TD] \quad [13]$$

$$\sigma_l = \frac{18000}{D^2} \times \{4.227 - 2.381 \times (\frac{180}{l})^{0.2} - 0.0015 \times [E_b \times \frac{H_b}{(1.4k)}]^{0.5} - 0.155 [H_b \times (\frac{E_b}{E_b})^{0.75}]^{0.5}\} \quad [14]$$

$$l = \{\frac{E_c \times D^3}{(12 \times (1-\mu^2) \times k)}\}^{0.25} \quad [15]$$

$$F = 1.177 - 4.3 \times 10^{-8} \times D E_b - 0.01155542 D + 6.27 \times 10^{-7} \times E_b - 0.000315 f \quad [16]$$

$$\log_b = -1.944 + 2.279 \times (\frac{D}{l}) + 0.0917 \times (\frac{L}{l}) - 433080 \times \frac{D^2}{kl^4} + (\frac{0.0614}{l}) \times (\frac{E_b \times H_b{}^{1.5}}{1.4k})^{0.5} - 438.642 \times \frac{D^2}{kl^2} - 498240 \times \frac{D^3 \times L}{kl^6} \quad [17]$$

$$\text{Effective positive TD} = 0.962 - (\frac{52.181}{D}) + 0.341 \times \text{WIND} + 0.184 \times \text{TEMP} - 0.00836 \times \text{PRECIP} \quad [18]$$

where, W' is number of 18- kip ESALs estimated for design traffic lane, W is number of 18-kip ESALs computed from the equation, D is testing concrete slab thickness in inches, L1 is load on a single or tandem axle in kips, L2 is axle code which is 1 for single axle and 2 for tandem axle, P2 is terminal serviceability index, $(S'_c)'$ equals to mean 28-day third point loading flexure strength measured in psi, σ_t is mid slab tensile stress due to load and temperature from the equation above with AASHO road test constants, σ'_t is mid slab tensile stress due to load and temperature from the equation above with AASHO road test constants, σ_l is mid slab tensile stress due to load only from the above equation, E_c is modulus of elasticity of concrete slab, psi, E_b is modulus of elasticity of base, psi, H_b is thickness of the base, inches, k is effective elastic modulus of subgrade support, psi/in, μ is Poisson's ratio for concrete, E is edge support adjustment factor whose values are 1.00 for a conventional 12-ft wide traffic lane, 0.94 for a conventional 12-ft-wide traffic lane plus tied concrete shoulder and 0.92 for a 2-ft widened slab with a conventional 12-ft lane width, F is ratio between slab stress at a given coefficient of friction (f) between the slab and base and slab stress at full friction from the above equation, L is joint spacing, inches, TD is effective positive temperature differential which is top of slab minus bottom of slab in °F, WIND is mean annual wind speed in mph, TEMP is mean annual temperature in °F and PRECIP is mean annual precipitation in inches. **Table 10** presents the values for parameters used in AASHTO 1998 by AASHO Road Test.

Table 10. AASHO Road Test Values

Parameters	**Value**
$(S'_c)'$	690 psi
E_c	4,200,000 psi
E_b	25,000 psi
H_b	6 in.
k	110 psi/ in.
μ	0.20
E	1.00
L	180 in.

The required or predicted design thickness value of the concrete slab is then given by the equation.

$$D = A_0 + A_1 \log_{10} W_{18R} \quad [19]$$

$$W_{18R} = 10^{(\log_{10} W_{18} + Z \times S_0)} \quad [20]$$

where, D is required slab thickness in inches, A_0 and A_1 are regression constants dependent on other design features, W_{18R} is design 18-kip ESALs for the specified level of design reliability R, W_{18} is estimated 18-kip ESALs over the design period in the design lane, Z is standard deviation from normal distribution table for a given level of reliability, and S_0 is overall standard deviation (AASHTO, 1998).

3.3 Lanes with Tied Shoulders and Widened Lanes with Non-tied Shoulders

As defined by AASHTO, a highway shoulder is a highway portion that accommodates stopped vehicles for emergency use and supports the base course laterally. Agencies describe shoulders as a temporary lane for traffic during rehabilitation. The use of shoulders is beneficial for the overall performance of the pavement and for maintaining the structural integrity of the main lane (AASHTO, 1993). Based on structural relationships, shoulders are either tied shoulders or non-tied shoulders. Tied shoulders are the shoulders connected with the main lane using steel reinforcement for reducing-edge stress and minimizing pavement distress. Non-tied shoulders are connected with the main lane using aggregate materials interlock between the shoulder and main lane interface (Turner et al., 1981; Fostinelli et al., 2018). **Figure 8** shows the typical concrete pavement with shoulders. Concrete slabs contain longitudinal joints and transverse joints.

Longitudinal joint and shoulder are tied using the tie bar, whereas two adjacent slabs are tied by using dowels. Tie bars and dowels are used in the pavement to effectively distribute traffic stress, load, and strain experienced over the pavement structure for durable and sustainable pavement structure (Miles et al., 2008).

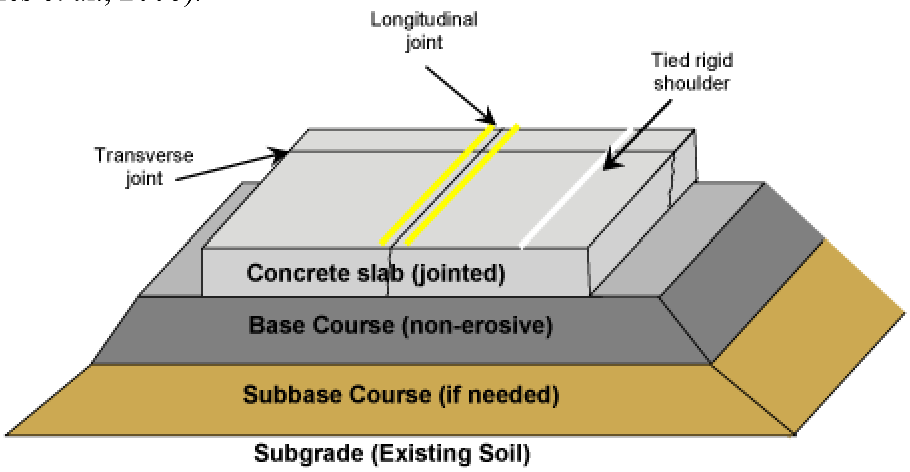


Figure 8. Concrete pavement with shoulder.

Figure 9 shows widened lanes with non-tied concrete shoulders. Widened lanes are the extended part of the traffic lane and are designed to accommodate extra traffic volume (Wang et al., 2014). The concrete structure contains dowels in it so that it can transfer strain from one slab to adjacent slab.

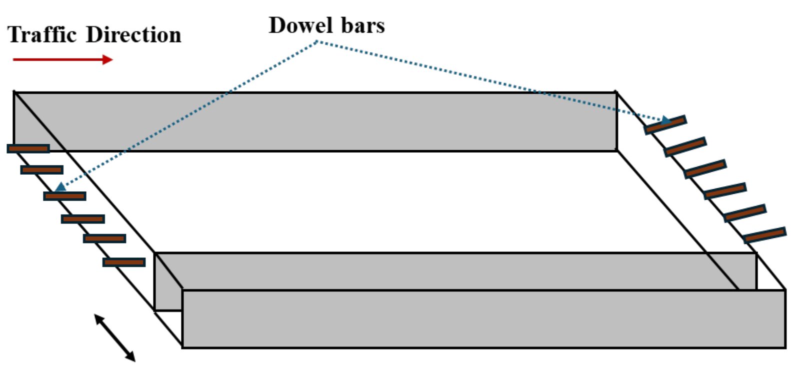


Figure 9. Widened lanes with non-tied concrete shoulders.

Concrete pavement with time requires rehabilitation to accommodate increasing traffic and various climatic effects on the pavement. Concrete pavement can either use a widened lane or design a new pavement with tied shoulders to fulfill the desired terminal serviceability, reliability, and structural capacity of the pavement. The use of widened lanes and tied shoulders in the pavement increases its performance by curing many drainage and strength problems. The performance of the concrete shoulders and widened lanes for the reduction of stress and strain from the free edge of the pavement to the point of load is analyzed by Colley et al. (1978). The strain and stress reduction from the edge of the pavement for the conventional slab also reduces the thickness of the concrete slab.

According to FHWA (2017), tied shoulders increase overall material use without improving pavement performance. Additionally, the construction and maintenance of tied shoulders require reinforcements other than main lane which contributes to cost (AASHTO, 1993). However, widened lanes require less material than lane with tied shoulder. Additionally, widened lane provides for future expansion and improves pavement performance to reduce maintenance costs (FHWA, 2010).

3.4 Reliability and Terminal Serviceability

The reliability of the pavement is defined as the probability that the pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the design period (AASHTO, 1993; Dalla Valle, 2015). According to Chou (1990), reliability refers to the probability that the pavement will perform in its design years. The increase in reliability increases pavement thickness and pavement durability, but also increases pavement costs (Li et al., 2011).

The pavement's terminal serviceability is the pavement's lowest index to serve the traffic before rehabilitation, resurfacing or reconstruction is necessary (AASHTO, 1993). Terminal serviceability is one of the key factors to the pavement performance. The terminal serviceability refers to the roughness present in the pavement (Riggins et al., 1985).

Reliability and terminal serviceability account for the pavement thickness to perform satisfactorily against distress on the pavement, high maintenance cost, and early pavement rehabilitation. Thus, changing either the reliability level or terminal serviceability changes the thickness of the concrete pavement and helps to understand pavement with better designs for durable, low maintenance, and sustainable concrete pavement designs (Chou, 1990).

3.5 Chapter Summary

This chapter provided a comprehensive overview of concrete pavements and their design considerations. It described three types of concrete pavements: JPCP (Jointed Plain Concrete Pavement), which consists of concrete slabs with joint spacing of 12–20 ft; JRCP (Jointed Reinforced Concrete Pavement), which includes concrete slabs with joint spacing of 25–30 ft and steel reinforcement; and CRCP (Continuously Reinforced Concrete Pavement), which has concrete slabs without joints and incorporates steel reinforcement.

The chapter highlighted that designing these pavements requires multiple inputs, including climate, traffic, reliability, terminal serviceability, and material properties. Additionally, it addressed two lane configurations: lanes with tied shoulders and wider lanes with non-tied shoulders.

Finally, the chapter emphasized the importance of reliability and terminal serviceability in determining pavement thickness. Reliability reflects the expected performance of the pavement over its design life, while terminal serviceability indicates the level of serviceability at which maintenance or rehabilitation becomes necessary. These factors are critical for designing durable, cost-effective, and sustainable concrete pavements.

4. SURVEY RESULTS

Chapter 4 presents the results of the concrete pavement design survey, covering the state-of-the-art practices in concrete pavement design, lanes with tied shoulders and widened lanes, reliability and terminal serviceability, and other design-related features.

4.1 Part I: Pavement Design Methods and Parameters

The survey was distributed to 13 states: Alabama, Mississippi, Louisiana, Florida, Georgia, Arkansas, Texas, Tennessee, North Carolina, South Carolina, Ohio, Michigan, and Illinois. Survey requests were sent to agencies such as state Departments of Transportation (DOT), Cemex, the National Ready Mixed Concrete Association (NRMCA), the National Concrete Pavement Technology Center (CPTECH), and the American Concrete Institute (ACI). Among the 13 states, nine responded to the survey, represented in purple on the figure, while the remaining four states, shown in gray, did not participate. **Figure 10** illustrates the states that participated in the survey.

Which state do you work for?

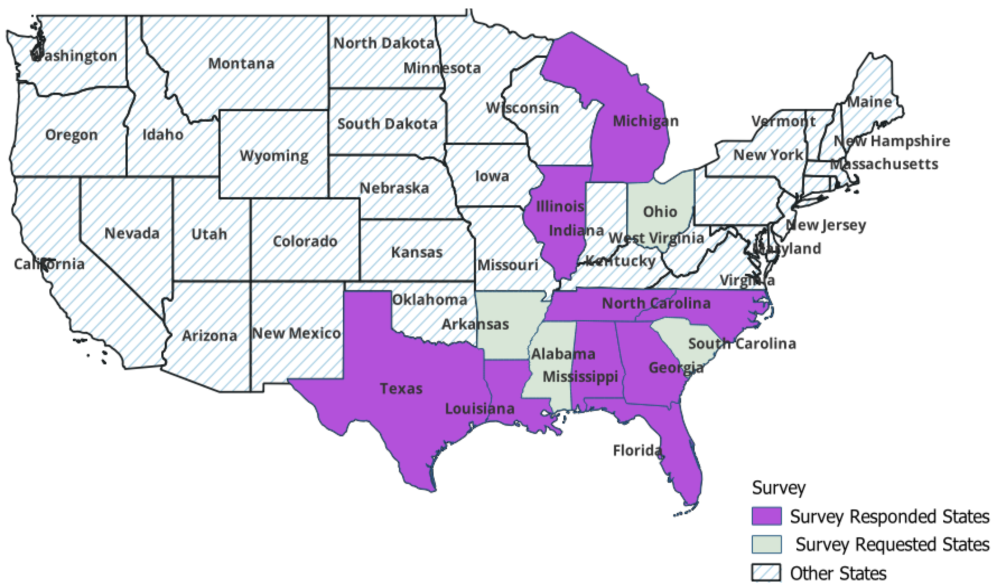


Figure 10. States participation in survey.

Figure 11 shows that, of the surveys returned, 71% were completed by state DOTs, and 29% were completed by industry representatives.

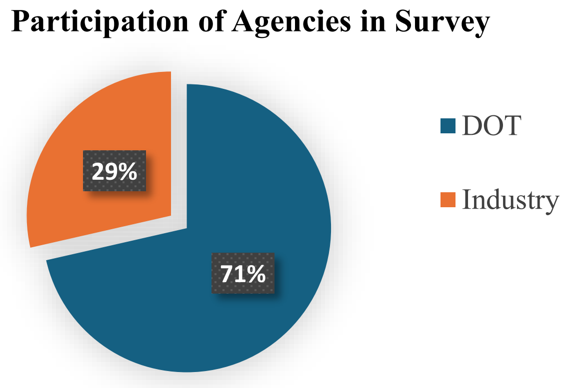


Figure 11. Responses on the participation of agencies in survey.

Figure 12 illustrates the survey responses for design method used by practitioners in the Southeastern US states. The design methods mentioned were the AASHTO 1972 Interim Guide, AASHTO 1993 Guide, AASHTO 1998 Supplement design guide, AASHTO Pavement ME, sate-specific design method, and other methods like design tables and studies from agencies. According to the survey responses, 65% of practitioners reported using the AASHTO 1993 design method, making it the most widely adopted approach. State-specific design methods were used by 14% of respondents. Each of the AASHTO 1972 Interim Guide, AASHTO 1998 Supplement, and AASHTO Pavement ME was selected by 7% of participants. Notably, none of the respondents indicated using other design methods such as design tables or agency-specific studies.

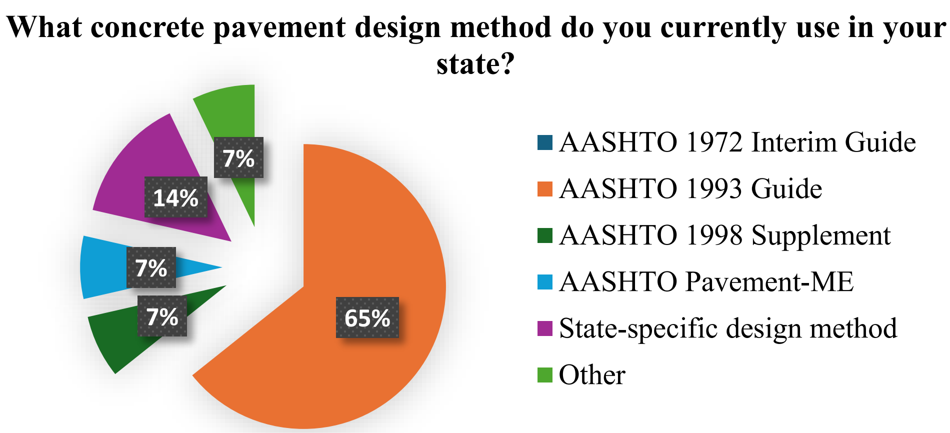


Figure 12. Survey responses for design method used by practitioners.

Figure 13 represents the responses on satisfaction level of practitioners using AASHTO 1993 design guide method for concrete pavement design. Respondents were asked to rate their satisfaction as very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied with AASHTO 1993 design guide. The survey results indicate mixed satisfaction with the AASHTO 1993 design guide. While 39% of respondents expressed satisfaction (8% very satisfied and 31% satisfied), a slightly higher proportion, 46%, reported dissatisfaction (38% dissatisfied and 8% very dissatisfied). An additional 15% remained neutral. These findings suggest that, although some practitioners find the AASHTO 1993 method acceptable, a significant portion of respondents perceive limitations or shortcomings in the design guide, highlighting the need for potential improvements or updates.

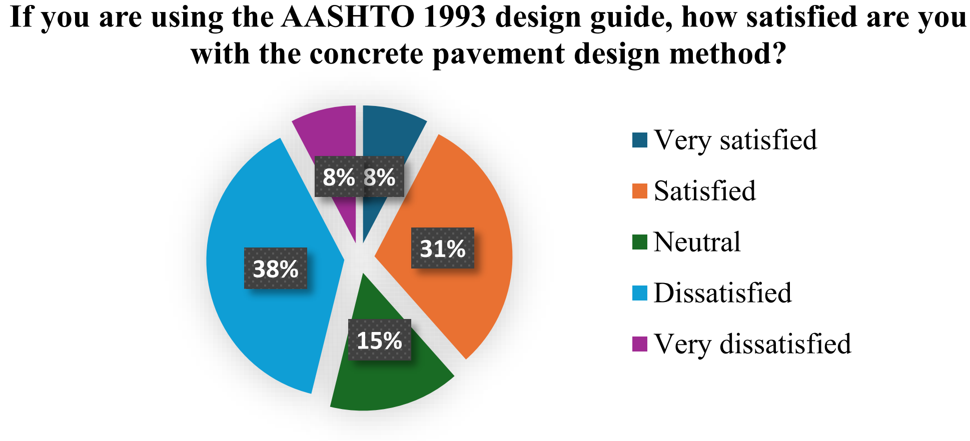


Figure 13. Responses on the level of satisfaction on using the AASHTO 1993 design method.

Figure 14 illustrates responses on the reliability level range used by the practitioners in their state, categorized into six groups: 50-60, 61-70, 71-80, 81-90, and 91-99.99, and does not apply. Survey responses revealed that 74% of the practitioners reported using a reliability range of 91 % to 99.9 %, and 26% use a range of 81 % to 90% while designing a concrete pavement in their state.

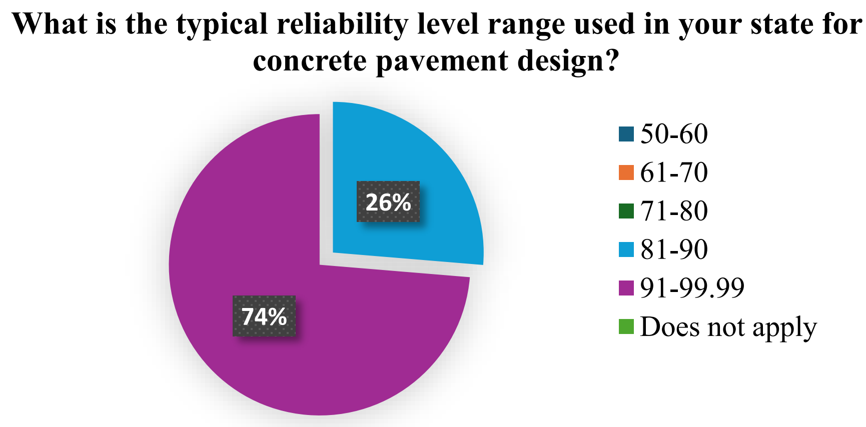


Figure 14. Responses on the reliability range used by practitioners in their state.

Figure 15 illustrates the specific reliability values used by the agencies while designing concrete pavement. The survey revealed that 50% of practitioners typically use a 95% reliability level followed by 30% who use 90 % and 10% who use 85% reliability level. Also, 5% of respondents reported using a 97% reliability level, and another 5% use 99% reliability level while designing a concrete pavement in their states.

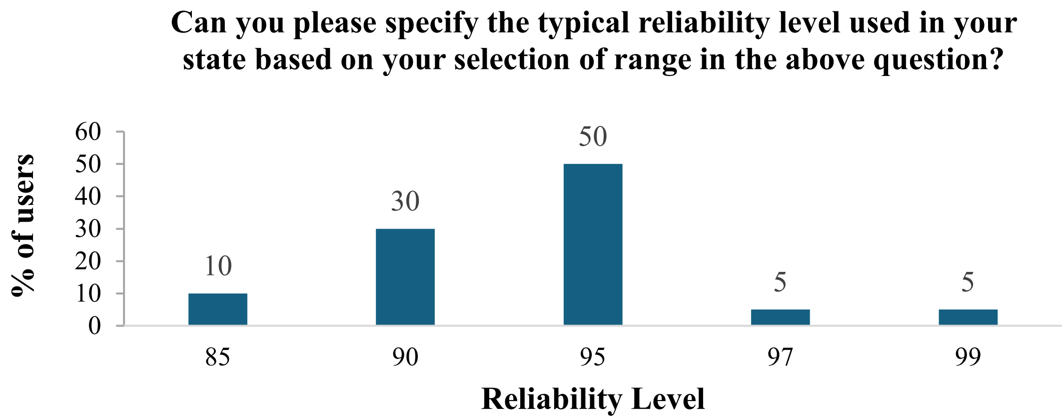


Figure 15. Responses on the specific reliability used by practitioners.

Terminal serviceability index values ranged from 1.5 to 3.5 and were classified into four groups: 1.5–2.0, 2.1–2.5, 2.6–3.0, and 3.1–3.5. **Figure 16** presents the survey results of practitioners selected by practitioners in their respective states when designing concrete pavements. Survey results indicate that 50% of practitioners use a terminal serviceability index within the range of 2.1–2.5, followed by 25% use 2.6–3.0, and 20% use 3.1–3.5, and only 5% used 1.5–2.0.

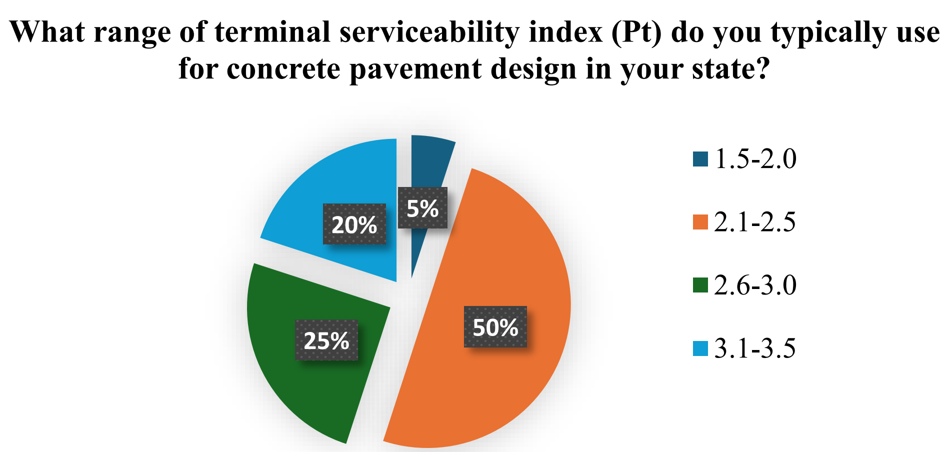


Figure 16. Responses on terminal serviceability index range used by the practitioners in their state.

When asked about specific terminal serviceability index values, **Figure 17** illustrates the typical values used by practitioners in their respective states when designing concrete pavements. Survey results indicate that 44% of practitioners use a value of 2.5, while 17% use values of 3.0 and 3.5 each. A value of 2.0 is used by 11% of practitioners, and 6% reported using 2.75, with another 6% using 2.8.

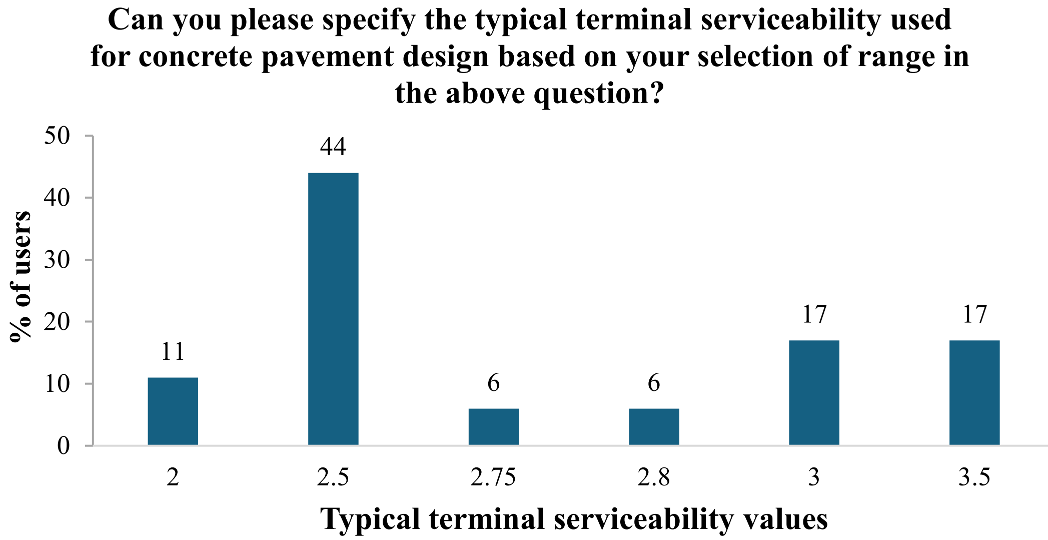


Figure 17. Responses on specific terminal serviceability index used by the practitioners.

Figure 18 illustrates the confidence in accuracy and reliability of input parameters used in their design methods. Confidence level were divided into five categories: Extremely confident, very confident, moderately confident, slightly confident, and not confident at all. According to the survey, 50% of the respondents expressed moderate confidence in their input parameters, 22% were very confident, 14% were slightly confident, and another 14% were not confident at all. Notably, none of the respondents were extremely confident in the accuracy and reliability of input parameters they use.

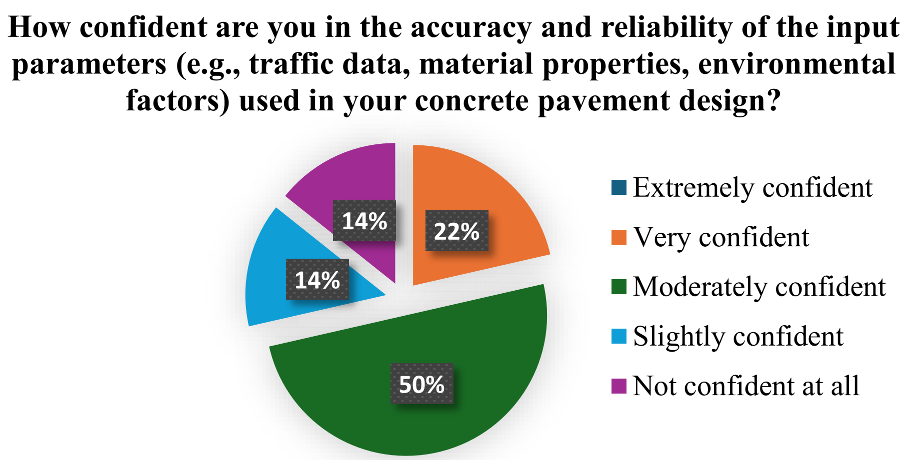


Figure 18. Responses on how confident in the accuracy and reliability of input parameters.

Figure 19 shows the survey response to whether practitioners or their state have supporting data or studies for selecting reliability level and terminal serviceability values. According to the survey results, 36 % of the respondents indicated that the study had been done for the selection of the reliability and terminal serviceability. They also stated that these values were based on traffic volume, pavement performance, following asphalt design, roadway classification, and studies from different agencies and universities. The remaining 64 % reported that no such studies had been carried out in their state.

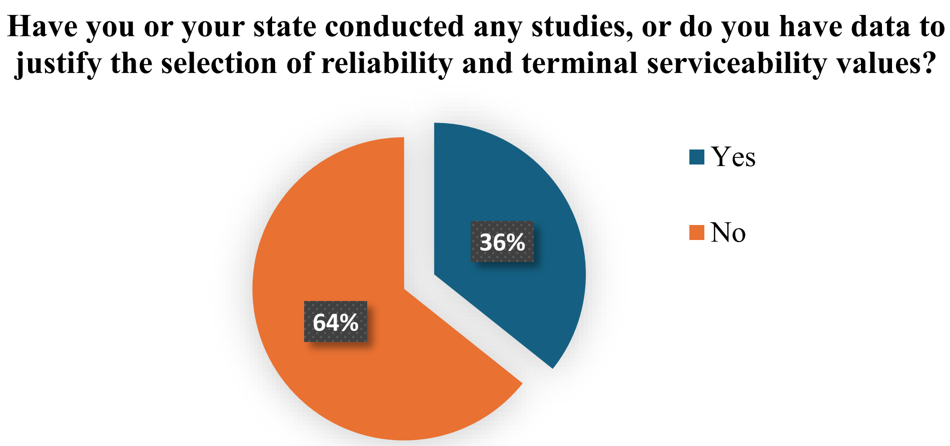


Figure 19. Responses on the selection study for reliability and terminal serviceability.

Figure 20 illustrates survey responses regarding the types of contracts agencies use to implement pavement construction projects. The results show that 64% of respondents rely on external contractors, while 36% use in-house resources for constructing concrete pavements in their state. None of the respondents reported using public-private partnerships or joint ventures for project implementation.

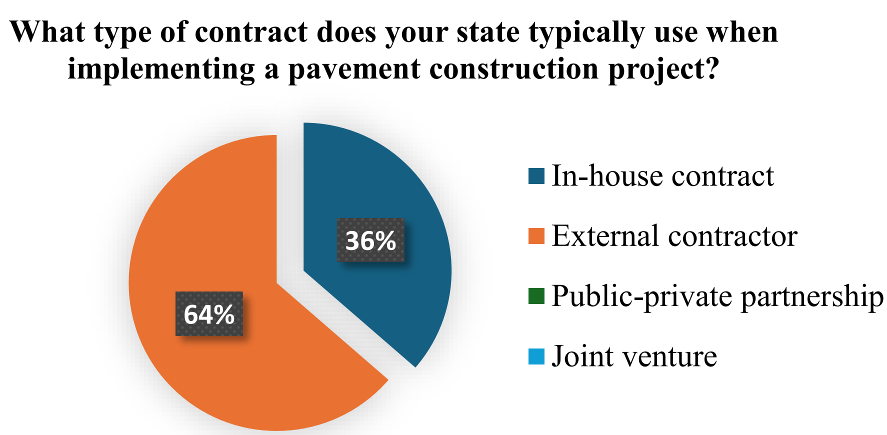


Figure 20. Responses on types of contract implementation.

Figure 20 illustrates the survey responses on a process of reviewing consultants' concrete pavement design by the agencies. The survey result showed 86 % of the practitioners reported conducting detailed review checks. Spot-check reviews and other methods, such as reviews guided by local ACPA chapter or DOT requests, were each selected by 7% of respondents. None reported using consultants' expertise and experience for review.

What process do you follow for reviewing consultants' concrete pavement designs?

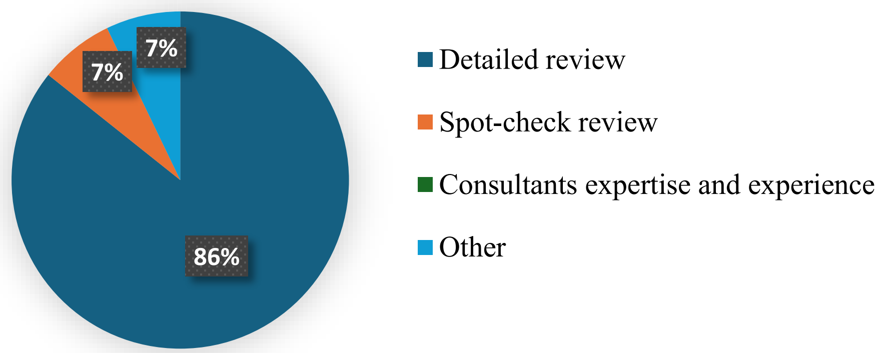


Figure 21. Responses on reviewing consultants' concrete pavement designs process.

4.2 Part II: Concrete Shoulder Design

Figure 22 shows the survey responses regarding the permissibility of using non-tied shoulders for lane widening projects in the respondent's states. There were no responses for the use of non-tied concrete shoulders in lane widening projects. However, 64% responded that the use of non-tied shoulders in lane widening depends on specific project conditions, while 36 % responded no permissibility on the use of a non-tied shoulder. The practitioners stated that the conditions where non-tied shoulders may be permitted are limited spaces, excellent subgrade conditions, city streets, low-traffic roads, and number of lanes.

Is the use of non-tied concrete shoulders permissible for lane widening projects in your state?

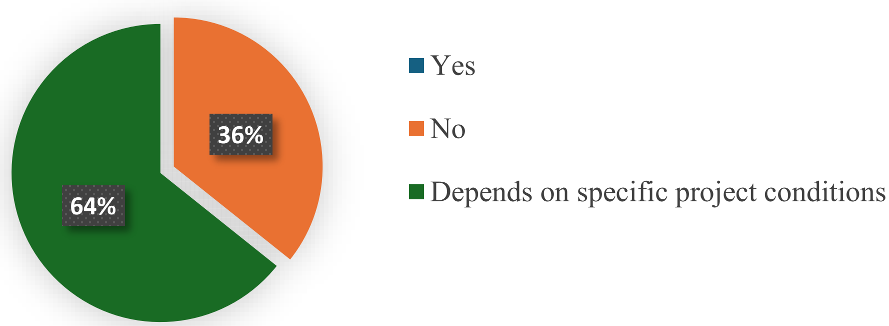


Figure 22. Responses on the permissibility of non-tied concrete shoulders in lane widening projects.

Figure 23 illustrates survey responses regarding studies on the cost-effectiveness of a wider slab and non-tied shoulder against a 12 ft. slab with tied shoulder. According to the results, 28% of the responders have conducted the studies. Some of the responders explained that the studies consisted of testing the difference of edge deflections for each design method, moving loads in widened lanes analysis, and also some calculation showing 1' widening costs same as 1" of concrete thickness. Meanwhile, 43% reported that no studies were performed, and 29 % were not sure about these types of studies.

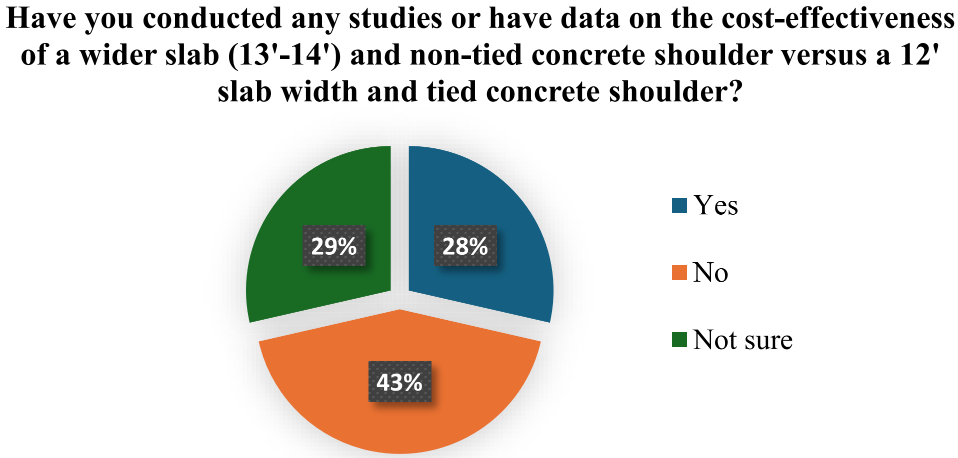


Figure 23. Responses on the status of studies on the cost-effectiveness of a wider slab and non-tied shoulder versus a 12 ft. slab with tied shoulder.

Figure 24 presents survey responses on whether practitioners believe widened lanes are more cost-effective than conventional 12 ft. slab with tied shoulders. The survey results showed that 22% of the respondents believe widened lanes are significantly more cost-effective, while 14% believe they are moderately more cost-effective. Another 14% consider them only slightly more cost effective, and 14% believe they are not cost-effective at all. Additionally, 36% of respondents remained neutral, expressing no clear preference between the two design approaches.

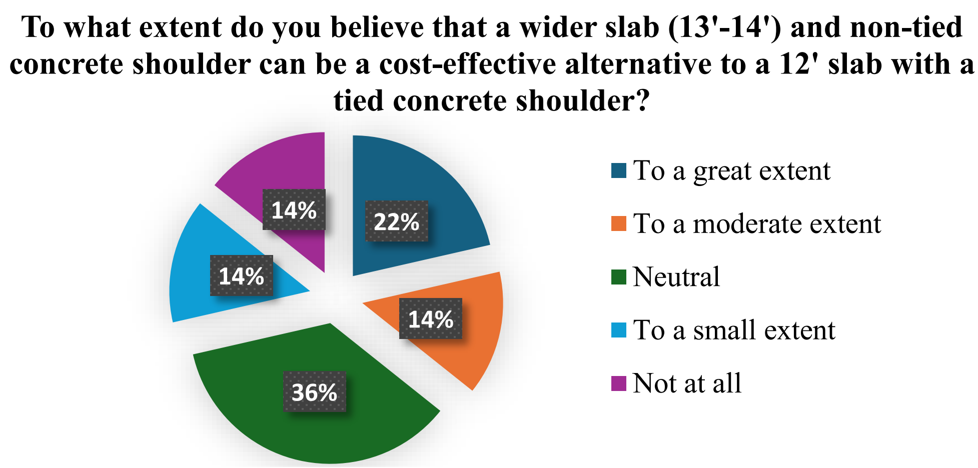


Figure 24. Responses on believing in the cost-effectiveness of widened lane than 12 ft. slab with tied shoulders.

4.3 Part III: Pavement Design Software

Figure 25 illustrates the software used by the practitioners for designing the concrete pavement. The survey result showed 50% of the practitioners responded that they use agency-developed spreadsheets, while 36 % responded that they use commercial software such as DARWin 3.1

(AASHTO 1993), JPCP (AASHTO 1993), Pavement-ME, Pavementdesigner.org, WinPAS, FEM, and AASHTOWare. The survey results also showed 14% who responded with others for calculation of concrete pavement design use design tables for the calculation.

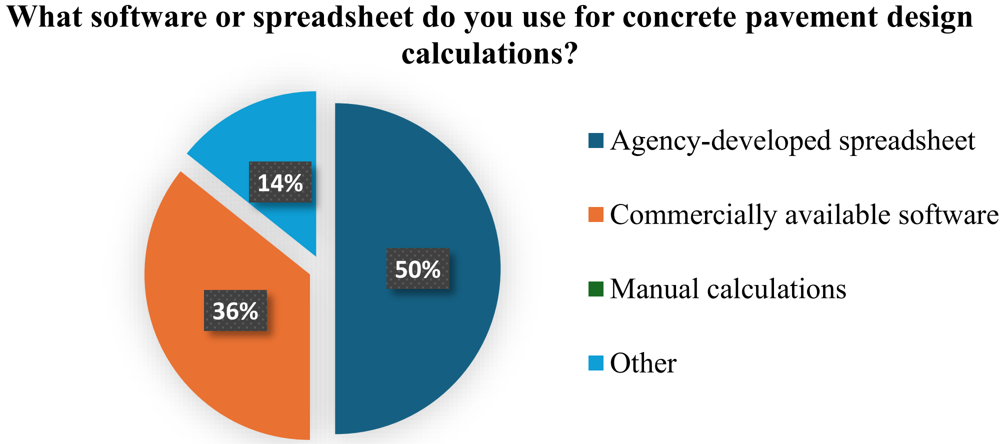


Figure 25. Responses on the software for concrete pavement design calculations.

Survey responders shared that the AASHTO 1998 designs have not much difference from the AASHTO 1993 designs, although they have slightly thinner designs than the AASHTO 1993 designs. Additionally, this method serves as an interim step toward the development of Mechanistic-Empirical Pavement Design Guide (MEPDG)/AASHTOWare's Pavement-ME (PMED), making it less preferable. One of the respondents described that the users have to define so many variables for using AASHTO 1998 design method, making the designing process uncomfortable and difficult to apply in practical design scenarios.

Figure 26 illustrates the result of the approval rate of alternative design methods by agencies other than their own design methods. The survey results showed 57% of the respondents responded to the challenges of getting approval of designs using alternate design methods other than the agencies specified. The survey results also showed 36% responded moderately challenging while 7% of the respondents were not challenged by their agencies for having approval on using alternative concrete pavement design methods.

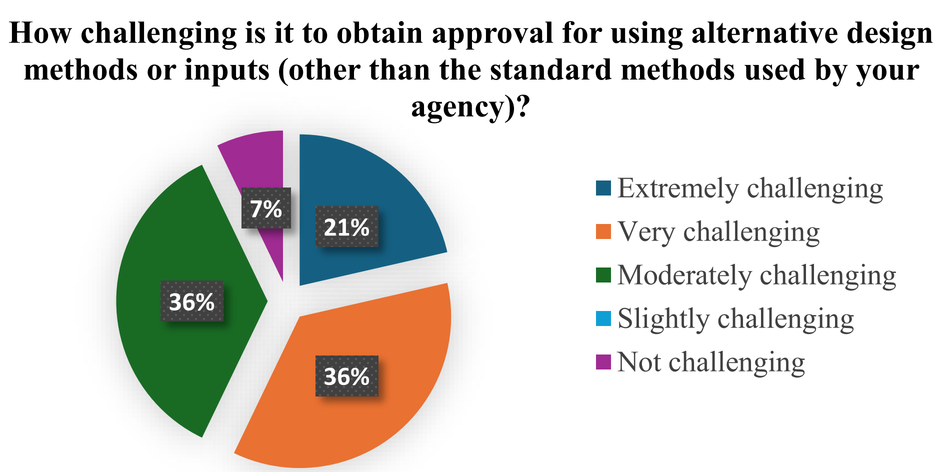


Figure 26. Responses on the approval for alternative design methods by agencies.

Figure 27 illustrates consideration of Life-cycle cost analysis in concrete pavement design by the agencies. The survey results showed 57% of the responders considered Life-cycle cost analysis to be important in the concrete pavement design process, 14 % of the responders did not consider it as they believe in Alternate Design Alternate Bid (ADAB) and believe in difficulty in maintenance cost analysis while 29 % of the responders responded with their neutral view on Life-cycle cost analysis.

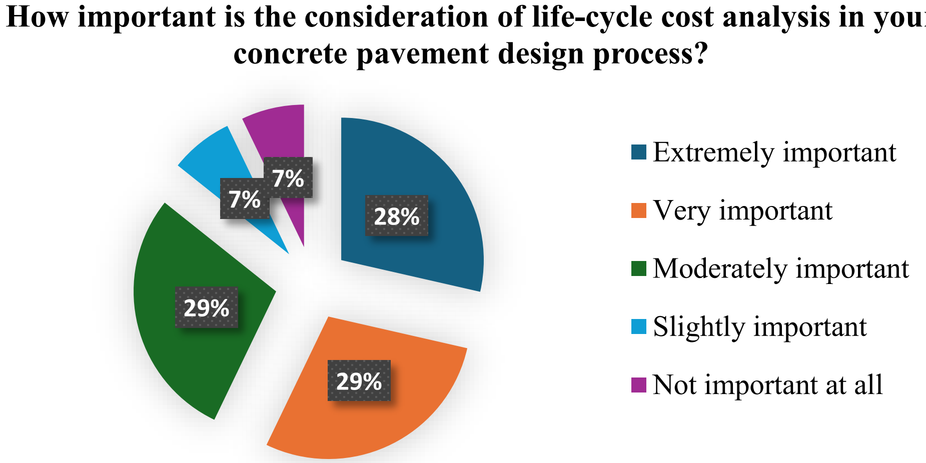


Figure 27. Responses on consideration of life-cycle cost analysis in concrete pavement design.

The respondents shared notable practices, challenges, and considerations in concrete pavement design. One challenge is the selection of the wrong pavement, which leads to overdesigning. The use of widened slabs with non-tied shoulder should be considered when there is no change in traffic volume for a lane along with striping and saw cut methods. Concrete pavement design is a function of various parameters, so it should be considered as a unique project each time. A lack of studies and uncommon input parameters can create difficulties in the design process. Other considerations include existing facility conditions, material type and cost, interest rates, and asphalt rates. Some respondents also noted spalling as a key design factor. Additionally, many states prefer not to change from their own specified design process, which makes the designs overdesigned and costlier.

4.4 Chapter Summary

This chapter presented the results of a survey conducted using Google Forms and Word documents to understand concrete pavement design practices across selected states. The survey provided valuable insights into current design methods, with the AASHTO 1993 method identified as the most commonly used approach among practitioners.

The survey also captured practitioners' perspectives on key design parameters, including reliability and terminal serviceability, which were reported to range between 91%–99.99% and 2.0–2.5, respectively. Additionally, responses highlighted the use of wider lanes with non-tied shoulders versus conventional lanes with tied shoulders. Practitioners generally indicated that wider lanes could be a suitable option, depending on project-specific conditions and their professional experience.

Information on software usage for concrete pavement design was also collected, showing that both state-specified and commercial design software are widely employed. The survey further revealed challenges associated with the selection and application of design parameters, the adoption of the AASHTO 1998 design method, and the continued reliance on AASHTO 1993 designs.

In conclusion, this chapter demonstrates that there is no single, uniform method for designing concrete pavements; practices vary depending on project requirements and design parameters. Despite this variation, most states reported similar experiences and challenges, reflecting common considerations and constraints faced by practitioners in the field.

5. COMPARISON OF THICKNESS BETWEEN AASHTO 1993 AND AASHTO 1998 DESIGN METHODS

This chapter presents the analytical results obtained using the AASHTO 1993 and AASHTO 1998 design methods and provides a comparative evaluation of their design outcomes.

5.1 JPCP Concrete Thickness Differences Between AASHTO 1998 and 1993

The comparison between the two design methods was conducted for JPCP with a joint spacing of 15 feet. This section presents the design thickness of JPCP slabs under varying reliability and terminal serviceability conditions for four locations: Mobile, Montgomery, Birmingham, and Huntsville. Traffic volume and climate data for these locations, as described in Chapter 3, were used in this comparative analysis.

5.1.1 High Traffic Condition

Table 11(a) to 11(e) present the JPCP concrete thickness for high-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5.

Note that ***Dc*** in the tables represents the calculated thickness, obtained from AASHTO equations or software, and may include fractional values (e.g., 9.23 in.). ***D*** represents the recommended design thickness, rounded up to the nearest 0.5-inch increment (e.g., 9.5 in. or 10 in.) to ensure structural adequacy and practicality during construction. This rounding practice follows both the AASHTO 1993 and 1998 design procedures, as well as ALDOT standards.

Table 11. Comparison of JPCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for High Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.23	10.5	1.27	13.77	9.35	10.5	1.15	12.3	8.83	9.79	0.96	10.91	9.39	10.44	1.05	11.17
	D	9.5	10.5	1	10.53	9.5	10.5	1	10.53	9	10	1	11.11	9.5	10.5	1	10.53
90	*Dc*	9.55	10.84	1.29	13.55	9.67	10.84	1.17	12.09	9.13	10.11	0.98	10.7	9.71	10.78	1.07	10.98
	D	10	11	1	10	10	11	1	10	9.5	10.5	1	10.53	10	11	1	10
95	*Dc*	10.03	11.37	1.34	13.31	10.16	11.37	1.21	11.87	9.6	10.6	1	10.4	10.21	11.31	1.1	10.79
	D	10.5	11.5	1	9.52	10.5	11.5	1	9.52	10	11	1	10	10.5	11.5	1	9.52
99.9	*Dc*	11.01	12.41	1.4	12.71	11.15	12.42	1.27	11.37	10.54	11.59	1.05	9.95	11.2	12.35	1.15	10.26
	D	11.5	12.5	1	8.7	11.5	12.5	1	8.7	11	12	1	9.09	11.5	12.5	1	8.7

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.52	10.77	1.25	13.11	9.65	10.78	1.13	11.75	9.11	10.04	0.93	10.26	9.69	10.72	1.03	10.64
	D	10	11	1	10	10	11	1	10	9.5	10.5	1	10.53	10	11	1	10
90	*Dc*	9.85	11.12	1.27	12.9	9.98	11.13	1.15	11.54	9.42	10.37	0.95	10.06	10.02	11.07	1.05	10.45
	D	10	11.5	1.5	15	10	11.5	1.5	15	9.5	10.5	1	10.53	10.5	11.5	1	9.52
95	*Dc*	10.35	11.66	1.31	12.62	10.49	11.67	1.18	11.28	9.91	10.88	0.97	9.82	10.53	11.61	1.08	10.22
	D	10.5	12	1.5	14.29	10.5	12	1.5	14.29	10	11	1	10	11	12	1	9.09
99.9	*Dc*	11.36	12.73	1.37	12.06	11.51	12.74	1.23	10.73	10.88	11.89	1.01	9.32	11.56	12.68	1.12	9.73
	D	11.5	13	1.5	13.04	12	13	1	8.33	11	12	1	9.09	12	13	1	8.33

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.89	11.11	1.22	12.38	10.02	11.12	1.1	11.02	9.45	10.37	0.92	9.69	10.06	11.07	1.01	10.03
	D	10	11.5	1.5	15	10.5	11.5	1	9.52	9.5	10.5	1	10.53	10.5	11.5	1	9.52
90	*Dc*	10.23	11.47	1.24	12.16	10.36	11.48	1.12	10.81	9.78	10.71	0.93	9.48	10.41	11.43	1.02	9.84
	D	10.5	11.5	1	9.52	10.5	11.5	1	9.52	10	11	1	10	10.5	11.5	1	9.52
95	*Dc*	10.75	12.03	1.28	11.92	10.89	12.04	1.15	10.58	10.29	11.24	0.95	9.27	10.94	11.98	1.04	9.55
	D	11	12.5	1.5	13.64	11	12.5	1.5	13.64	10.5	11.5	1	9.52	11	12	1	9.09
99.9	*Dc*	11.79	13.14	1.35	11.44	11.94	13.15	1.21	10.12	11.29	12.28	0.99	8.77	11.99	13.09	1.1	9.15
	D	12	13.5	1.5	12.5	12	13.5	1.5	12.5	11.5	12.5	1	8.7	12	13.5	1.5	12.5

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.37	11.57	1.2	11.6	10.5	11.59	1.09	10.35	9.92	10.81	0.89	9.02	10.55	11.53	0.98	9.3
	D	10.5	12	1.5	14.29	11	12	1	9.09	10	11	1	10	11	12	1	9.09
90	*Dc*	10.72	11.95	1.23	11.44	10.86	11.96	1.1	10.11	10.26	11.17	0.91	8.88	10.91	11.91	1	9.17
	D	11	12	1	9.09	11	12	1	9.09	10.5	11.5	1	9.52	11	12	1	9.09
95	*Dc*	11.27	12.53	1.26	11.2	11.41	12.54	1.13	9.87	10.79	11.71	0.92	8.57	11.46	12.49	1.03	8.96
	D	11.5	13	1.5	13.04	11.5	13	1.5	13.04	11	12	1	9.09	11.5	12.5	1	8.7
99.9	*Dc*	12.36	13.68	1.32	10.72	12.51	13.7	1.19	9.49	11.83	12.8	0.97	8.17	12.57	13.64	1.07	8.54
	D	12.5	14	1.5	12	13	14	1	7.69	12	13	1	8.33	13	14	1	7.69

(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.07	12.26	1.19	10.75	11.21	12.28	1.07	9.54	10.59	11.47	0.88	8.32	11.26	12.23	0.97	8.62
	D	11.5	12.5	1	8.7	11.5	12.5	1	8.7	11	11.5	0.5	4.55	11.5	12.5	1	8.7
90	*Dc*	11.44	12.65	1.21	10.58	11.59	12.68	1.09	9.39	10.95	11.84	0.89	8.1	11.64	12.62	0.98	8.4
	D	11.5	13	1.5	13.04	12	13	1	8.33	11	11	1	9.09	12	13	1	8.33
95	*Dc*	12.02	13.26	1.24	10.32	12.17	13.29	1.12	9.16	11.51	12.42	0.91	7.91	12.23	13.24	1.01	8.28
	D	12.5	13.5	1	8	12.5	13.5	1	8	12	12.5	0.5	4.17	12.5	13.5	1	8
99.9	*Dc*	13.17	14.48	1.31	9.95	13.34	14.51	1.17	8.77	12.62	13.57	0.95	7.53	13.4	14.45	1.05	7.86
	D	13.5	14.5	1	7.41	13.5	15	1.5	11.11	13	14	1	7.69	13.5	14.5	1	7.41

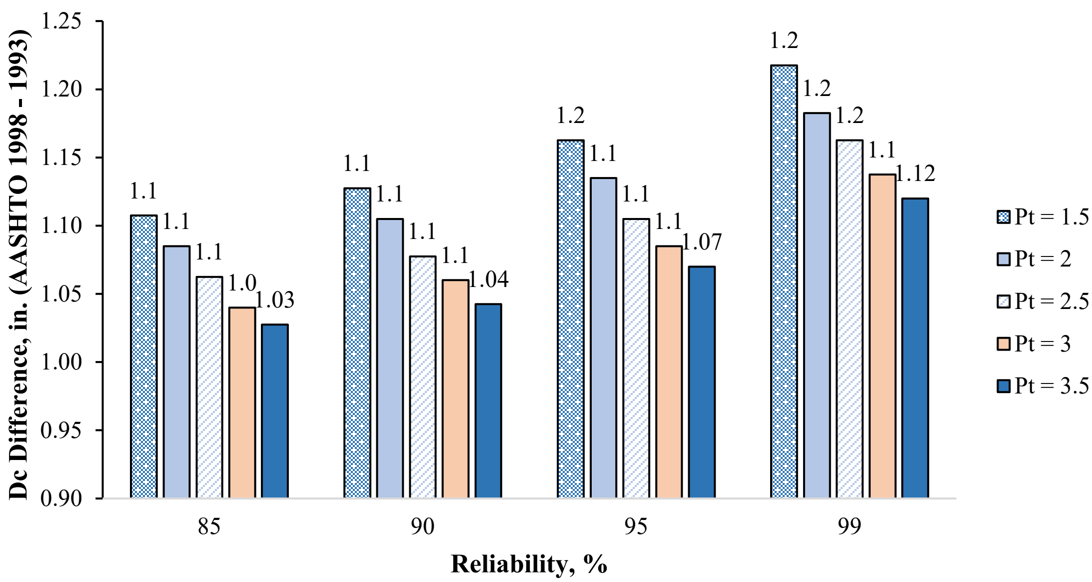
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{\text{Thickness designed by} AASHTO 1998 - \text{Thickness designed by } AASHTO\ 1993}{\text{Thickness designed by } AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

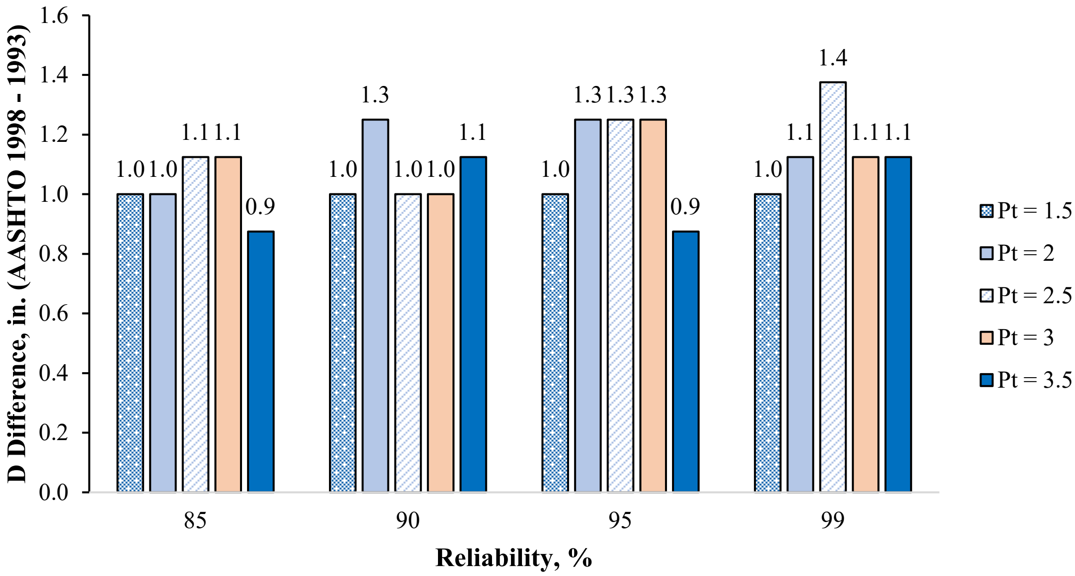
It was observed from **Tables 11(a)** to **11(e)** that, at each terminal serviceability index level, pavement thickness increases with higher reliability from 85% to 99%. This is because higher reliability requires the pavement to meet or exceed the terminal serviceability index with greater probability over its design life. To account for uncertainties in traffic loads, material properties, construction quality, and environmental conditions, the pavement is designed thicker to ensure adequate structural capacity and long-term performance.

It was also observed from **Table 11(a) to 11(e)** that higher terminal serviceability index (Pt) values correspond to increased concrete thickness. The terminal serviceability index represents the minimum acceptable ride quality or functional performance at the end of a pavement's design life, before it is considered to have failed functionally and requires rehabilitation. It directly affects the designed thickness of a concrete pavement in the AASHTO design method. A higher terminal serviceability index (Pt) means the pavement must remain smoother and more functional at the end of its design life. In other words, it cannot deteriorate as much before being considered unacceptable. Because of this stricter performance requirement, the pavement must be stronger and more durable, which the AASHTO design method achieves by requiring a thicker concrete slab. As Pt increases, the design requires thicker concrete slabs to maintain smoother performance and serviceability over time. Lower Pt values permit more deterioration and therefore result in thinner designs.

Figures 28(a) and **28(b)** illustrates the average differences in computed thickness and rounded designed thickness, respectively. At high traffic level, the AASHTO 1998 method consistently produces thicker JPCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, ***Dc*** is 1.11 inches thicker (10.35% increase), and ***D*** is 1.09 inches thicker (10.04% increase). These results indicate that AASHTO 1998 generally recommends thicker JPCP concrete for high traffic condition. The figures also show that the difference between the two methods is more pronounced at higher reliability levels.



(a)



(b)

Figure 28. JPCP concrete thickness differences between AASHTO 1998 and 1993 for high-traffic conditions: (a) computed; (b) designed.

5.1.2 Medium Traffic Condition

Table 12(a) to 12(e) present the JPCP concrete thickness for medium-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at medium traffic level, the AASHTO 1998 method yields a higher thickness compared to the AASHTO 1993 method.

Table 12. Comparison of JPCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for Medium Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.49	8.63	1.14	15.21	6.38	7.34	0.96	15.08	6.9	7.77	0.87	12.54	7.12	8.04	0.92	13
	D	7.5	9	1.5	20	6.5	7.5	1	15.38	7	8	1	14.29	7.5	8.5	1	13.33
90	*Dc*	7.76	8.92	1.16	15.01	6.61	7.59	0.98	14.82	7.15	8.02	0.87	12.14	7.37	8.31	0.94	12.77
	D	8	9	1	12.5	7	8	1	14.29	7.5	8.5	1	13.33	7.5	8.5	1	13.33
95	*Dc*	8.16	9.36	1.2	14.66	6.97	7.97	1	14.39	7.53	8.42	0.89	11.78	7.76	9.17	1.41	18.18
	D	8.5	9.5	1	11.76	7	8	1	14.29	8	8.5	0.5	6.25	8	9.5	1.5	18.75
99.9	*Dc*	8.98	10.23	1.25	13.93	7.68	8.73	1.05	13.66	8.29	9.23	0.94	11.28	8.54	10.03	1.49	17.44
	D	9	10.5	1.5	16.67	8	9	1	12.5	8.5	9.5	1	11.76	9	10.5	1.5	16.67

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.71	8.85	1.14	14.78	6.53	7.5	0.97	14.89	7.09	7.95	0.86	12.13	7.31	8.24	0.93	12.66
	D	8	9	1	12.5	7	7.5	0.5	7.14	7.5	8	0.5	6.67	7.5	8.5	1	13.33
90	*Dc*	7.99	9.14	1.15	14.4	6.78	7.76	0.98	14.51	7.35	8.22	0.87	11.79	7.58	8.51	0.93	12.23
	D	8	9.5	1.5	18.75	7	8	1	14.29	7.5	8.5	1	13.33	8	9	1	12.5
95	*Dc*	8.42	9.59	1.17	13.96	7.16	8.16	1	14.01	7.75	8.64	0.89	11.41	7.99	8.94	0.95	11.85
	D	8.5	10	1.5	17.65	7.5	8.5	1	13.33	8	9	1	12.5	8	9	1	12.5
99.9	*Dc*	9.26	10.49	1.23	13.25	7.91	8.95	1.04	13.14	8.55	9.46	0.91	10.62	8.81	9.79	0.98	11.15
	D	9.5	10.5	1	10.53	8	9	1	12.5	9	9.5	0.5	5.56	9	10	1	11.11

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8	9.12	1.12	14.07	6.73	7.72	0.99	14.72	7.34	8.2	0.86	11.78	7.57	8.49	0.92	12.08
	D	8	9.5	1.5	18.75	7	8	1	14.29	7.5	8.5	1	13.33	8	8.5	0.5	6.25
90	*Dc*	8.29	9.43	1.14	13.77	7	7.99	0.99	14.16	7.62	8.48	0.86	11.34	7.86	8.78	0.92	11.71
	D	8.5	9.5	1	11.76	7	8	1	14.29	8	8.5	0.5	6.25	8	9	1	12.5
95	*Dc*	8.73	9.9	1.17	13.34	7.41	8.41	1	13.53	8.04	8.91	0.87	10.8	8.29	9.23	0.94	11.31
	D	9	10	1	11.11	7.5	8.5	1	13.33	8.5	9	0.5	5.88	8.5	9.5	1	11.76
99.9	*Dc*	9.62	10.83	1.21	12.6	8.21	9.23	1.02	12.48	8.88	9.77	0.89	10.05	9.14	10.11	0.97	10.56
	D	10	11	1	10	8.5	9.5	1	11.76	9	10	1	11.11	9.5	10.5	1	10.53

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.38	9.5	1.12	13.32	7.02	8.03	1.01	14.32	7.68	8.54	0.86	11.16	7.94	8.85	0.91	11.49
	D	8.5	9.5	1	11.76	7.5	8.5	1	13.33	8	9	1	12.5	8	9	1	12.5
90	*Dc*	8.69	9.82	1.13	12.96	7.32	8.32	1	13.68	7.98	8.84	0.86	10.75	8.24	9.15	0.91	11.03
	D	9	10	1	11.11	7.5	8.5	1	13.33	8	9	1	12.5	8.5	9.5	1	11.76
95	*Dc*	9.16	10.31	1.15	12.53	7.76	8.76	1	12.9	8.43	9.29	0.86	10.16	8.7	9.62	0.92	10.61
	D	9.5	10.5	1	10.53	8	9	1	12.5	8.5	9.5	1	11.76	9	10	1	11.11
99.9	*Dc*	10.09	11.28	1.19	11.83	8.61	9.61	1	11.67	9.31	10.19	0.88	9.43	9.59	10.53	0.94	9.78
	D	10.5	11.5	1	9.52	9	10	1	11.11	9.5	10.5	1	10.53	10	11	1	10

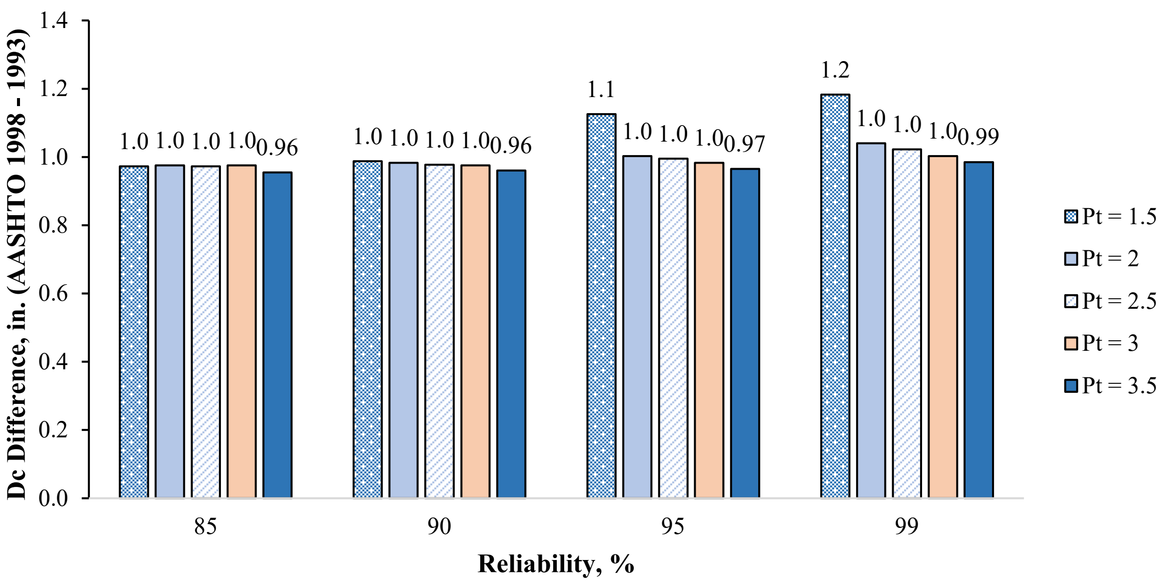
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.97	10.06	1.09	12.2	7.51	8.51	1	13.33	8.22	9.06	0.84	10.22	8.49	9.38	0.89	10.45
	D	9	10.5	1.5	16.67	8	9	1	12.5	8.5	9.5	1	11.76	8.5	9.5	1	11.76
90	*Dc*	9.29	10.4	1.11	11.9	7.83	8.82	0.99	12.65	8.54	9.38	0.84	9.84	8.81	9.71	0.9	10.16
	D	9.5	10.5	1	10.53	8	9	1	12.5	9	9.5	0.5	5.56	9	10	1	11.11
95	*Dc*	9.79	10.92	1.13	11.53	8.3	9.29	0.99	11.9	9.02	9.86	0.84	9.33	9.3	10.2	0.9	9.69
	D	10	11	1	10	8.5	9.5	1	11.76	9.5	10	0.5	5.26	9.5	10.5	1	10.53
99.9	*Dc*	10.77	11.94	1.17	10.86	9.2	10.19	0.99	10.74	9.95	10.81	0.86	8.65	10.25	11.17	0.92	9.02
	D	11	12	1	9.09	9.5	10.5	1	10.53	10	11	1	10	10.5	11.5	1	9.52

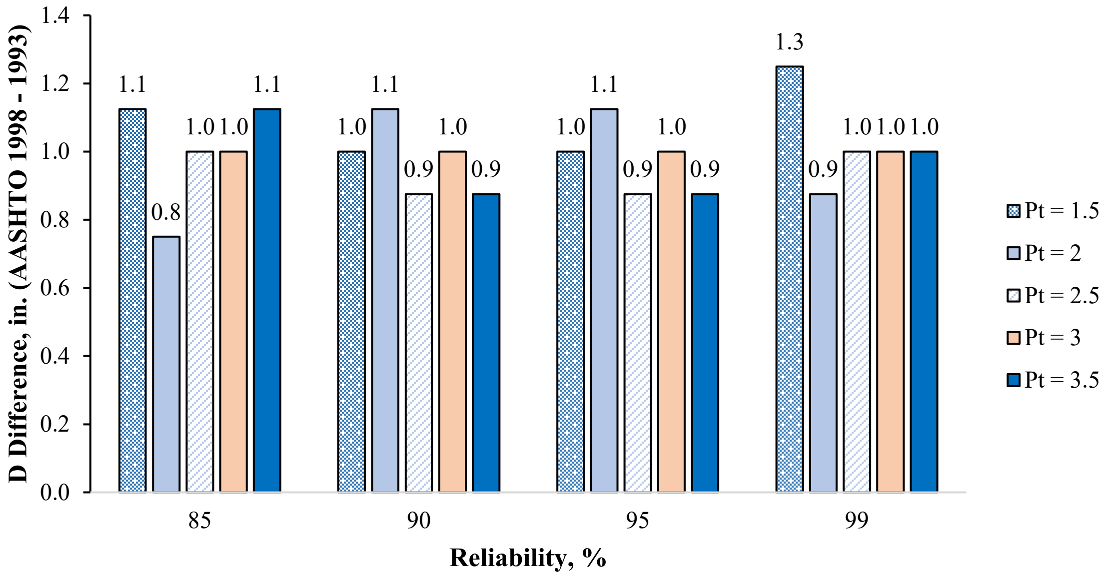
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- % Diff. $= \frac{Thickness\ designed\ by AASHTO 1998 - Thickness\ designed\ by\ AASHTO\ 1993}{Thickness\ designed\ by\ AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 29(a) and **29(b)** illustrate the average differences in computed thickness and rounded designed thickness, respectively, for medium-traffic conditions. The AASHTO 1998 method consistently produces thicker JPCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, ***Dc*** is 1.00 inch thicker (12.39% increase), and ***D*** is 0.99 inch thicker (11.44% increase). These results are consistent with the observations for high-traffic conditions.



(a)



(b)

Figure 29. JPCP concrete thickness differences between AASHTO 1998 and 1993 for medium-traffic conditions: (a) computed; (b) designed.

5.1.3 Low Traffic Condition

Table 13(a) to 13(e) present the JPCP concrete thickness for low-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at low traffic level, the AASHTO 1998 method yields a higher thickness than the AASHTO 1993 method. It should be noted that the AASHTO 1998 Excel-based design tool utilized for pavement thickness calculations provides output values only within the range of 7 to 15 inches. Under low-traffic conditions, certain computed thicknesses were less than 7 inches; therefore, corresponding cells in the table are left blank.

Table 13. Comparison of JPCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for Low Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	6.01	7.04	1.03	17.14	-	-	-	-	6.62	7.47	0.85	12.83	-	-	-	-
	D	6.5	7.5	1	15.38	-	-	-	-	7	7.5	0.5	7.14	-	-	-	-

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	6.13	7.19	1.06	17.25	-	-	-	-	6.79	7.64	0.85	12.56	6.23	7.09	0.86	13.88
	D	6.5	7.5	1	15.38	-	-	-	-	7	8	1	14.29	6.5	7.5	1	15.38

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	6.27	7.13	0.86	13.64	-	-	-	-
	D	-	-	-	-	-	-	-	-	6.5	7.5	1	15.38	-	-	-	-
99.9	*Dc*	6.3	7.38	1.08	17.19	6.17	7.16	0.99	16.13	7.01	7.87	0.86	12.26	6.4	7.28	0.88	13.75
	D	6.5	7.5	1	15.38	6.5	7.5	1	15.38	7.5	8	0.5	6.67	6.5	7.5	1	15.38

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	6.52	7.4	0.88	13.54	-	-	-	-
	D	-	-		-	-	-	-	-	7	7.5	0.5	7.14	-	-	-	-
99.9	*Dc*	6.54	7.66	1.12	17.06	6.39	7.43	1.04	16.19	7.33	8.19	0.86	11.71	6.66	7.56	0.9	13.54
	D	10.5	11.5	1	9.52	9	10	1	11.11	9.5	10.5	1	10.53	10	11	1	10

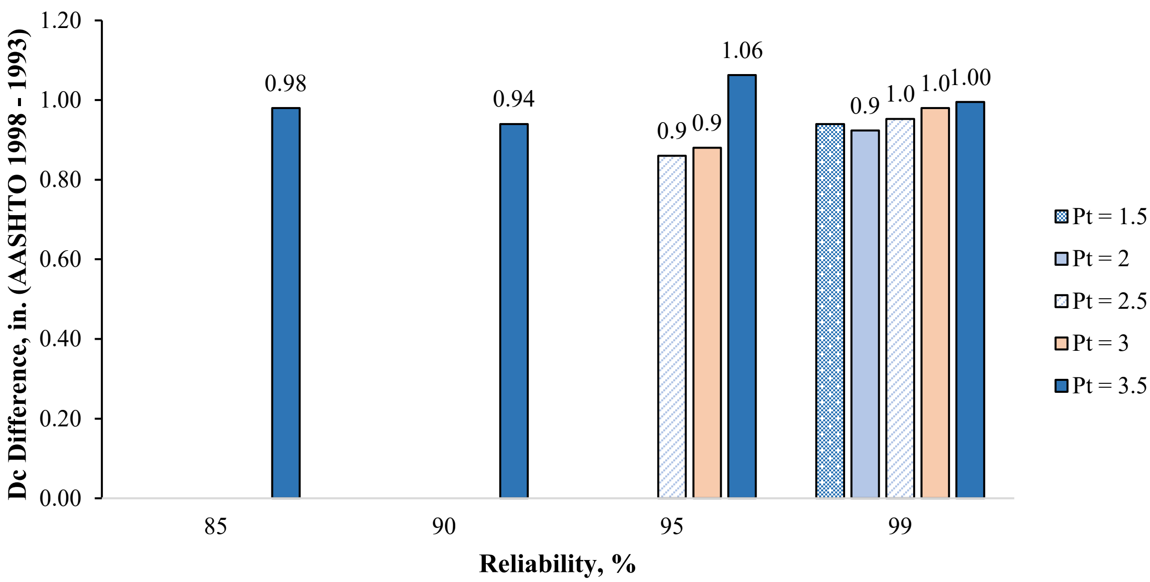
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	6.11	7.09	0.98	15.95	-	-	-	-
	D	-	-	-	-	-	-	-	-	6.5	7.5	1	15.38	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	6.45	7.39	0.94	14.65	-	-	-	-
	D	-	-	-	-	-	-	-	-	6.5	7.5	1	14.29	-	-	-	-
95	*Dc*	6.05	7.27	1.22	20.24	5.88	7.02	1.14	19.37	6.94	7.84	0.9	12.96	6.18	7.17	0.99	16.1
	D	6.5	7.5	1	15.38	6	7.5	1.5	25	7	8	1	14.29	6.5	7.5	1	15.38
99.9	*Dc*	6.97	8.11	1.14	16.35	6.8	7.87	1.07	15.77	7.84	8.69	0.85	10.79	7.1	8.02	0.92	12.93
	D	7	8.5	1.5	21.43	7	8	1	14.29	8	9	1	12.5	7.5	8.5	1	13.33

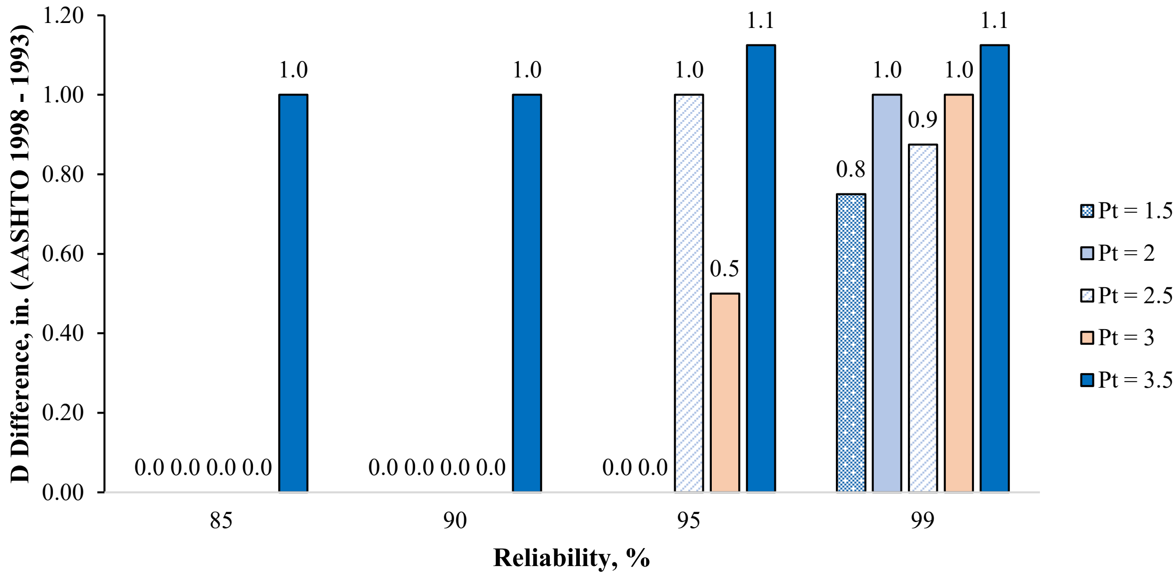
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- % Diff. $= \frac{Thickness\ designed\ by AASHTO 1998 - Thickness\ designed\ by\ AASHTO\ 1993}{Thickness\ designed\ by\ AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 30(a) and **30(b)** illustrate the average differences in computed thickness and rounded designed thickness, respectively, for low-traffic conditions. Based on the available data, the AASHTO 1998 method yields thicker JPCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, the computer thickness is 0.95 inch higher (14.79% increase), and rounded designed value is 0.94 inch higher (14.18% increase). These results are consistent with the observations for medium- and high-traffic conditions.



(a)



(b)

Figure 30. JPCP concrete thickness differences between AASHTO 1998 and 1993 for low-traffic conditions: (a) computed; (b) designed.

5.2 JRCP Concrete Thickness Differences Between AASHTO 1998 and 1993

Similarly, this section presents the design thickness of JRCP slabs under varying reliability and terminal serviceability conditions for four locations in Alabama: Mobile, Montgomery, Birmingham, and Huntsville.

5.2.1 High Traffic Condition

Table 14(a) to 14(e) present the JRCP concrete thickness for high-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at high traffic level, the AASHTO 1998 method yields a higher thickness compared to the AASHTO 1993 method.

Table 14. Comparison of JRCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for High Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.23	11.99	2.76	29.90	9.35	12.14	2.79	29.84	8.83	11.52	2.69	30.46	9.39	12.18	2.79	29.71
	D	9.5	12	2.5	26.32	9.5	12.5	3.0	31.58	9	12	3.0	33.33	9.5	12.5	3.0	31.58
90	*Dc*	9.55	12.36	2.81	29.42	9.67	12.51	2.84	29.37	9.13	11.88	2.75	30.12	9.71	12.56	2.85	29.35
	D	10	12.5	2.5	25.00	10	13	3.0	30.00	9.5	12	2.5	26.32	10	13	3.0	30.00
95	*Dc*	10.03	12.93	2.90	28.91	10.16	13.08	2.92	28.74	9.6	12.43	2.83	29.48	10.21	13.13	2.92	28.60
	D	10.5	13	2.5	23.81	10.5	13.5	3.0	28.57	10	12.5	2.5	25.00	10.5	13.5	3.0	28.57
99.9	*Dc*	11.01	14.05	3.04	27.61	11.15	14.21	3.06	27.44	10.54	13.51	2.97	28.18	11.2	14.27	3.07	27.41
	D	11.5	14.5	3.0	26.09	11.5	14.5	3.0	26.09	11	14	3.0	27.27	11.5	14.5	3.0	26.09

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.52	12.27	2.75	28.89	9.65	12.41	2.76	28.60	9.11	11.79	2.68	29.42	9.69	12.46	2.77	28.59
	D	10	12.5	2.5	25.00	10	12.5	2.5	25.00	9.5	12	2.5	26.32	10	12.5	2.5	25.00
90	*Dc*	9.85	12.64	2.79	28.32	9.98	12.79	2.81	28.16	9.42	12.15	2.73	28.98	10.02	12.84	2.82	28.14
	D	10	13	3.0	30.00	10	13	3.0	30.00	9.5	12.5	3.0	31.58	10.5	13	2.5	23.81
95	*Dc*	10.35	13.22	2.87	27.73	10.49	13.37	2.88	27.45	9.91	12.71	2.80	28.25	10.53	13.43	2.90	27.54
	D	10.5	13.5	3.0	28.57	10.5	13.5	3.0	28.57	10	13	3.0	30.00	11	13.5	2.5	22.73
99.9	*Dc*	11.36	14.37	3.01	26.50	11.51	14.53	3.02	26.24	10.88	13.82	2.94	27.02	11.56	14.59	3.03	26.21
	D	11.5	14.5	3.0	26.09	12	15	3.0	25.00	11	14	3.0	27.27	12	15	3.0	25.0

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.89	12.6	2.71	27.40	10.02	12.75	2.73	27.25	9.45	12.11	2.66	28.15	10.06	12.8	2.74	27.24
	D	10	13	3.0	30.00	10.5	13	2.5	23.81	9.5	12.5	3.0	31.58	10.5	13	2.5	23.81
90	*Dc*	10.23	12.99	2.76	26.98	10.36	13.14	2.78	26.83	9.78	12.48	2.70	27.61	10.41	13.19	2.78	26.71
	D	10.5	13	2.5	23.81	10.5	13.5	3.0	28.57	10	12.5	2.5	25.00	10.5	13.5	3.0	28.57
95	*Dc*	10.75	13.58	2.83	26.33	10.89	13.74	2.85	26.17	10.29	13.05	2.76	26.82	10.94	13.79	2.85	26.05
	D	11	14	3.0	27.27	11	14	3.0	27.27	10.5	13.5	3.0	28.57	11	14	3.0	27.27
99.9	*Dc*	11.79	14.76	2.97	25.19	11.94	14.92	2.98	24.96	11.29	14.19	2.90	25.69	11.99	14.98	2.99	24.94
	D	12	15	3.0	25.0	12	15	3.0	25.0	11.5	14.5	3.0	26.09	12	15	3.0	25.0

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.37	13.04	2.67	25.75	10.5	13.2	2.70	25.71	9.92	12.53	2.61	26.31	10.55	13.25	2.7	25.59
	D	10.5	13.5	3.0	28.57	11	13.5	2.5	22.73	10	13	3.0	30.00	11	13.5	2.5	22.73
90	*Dc*	10.72	13.44	2.72	25.37	10.86	13.6	2.74	25.23	10.26	12.92	2.66	25.93	10.91	13.65	2.74	25.11
	D	11	13.5	2.5	22.73	11	14	3.0	27.27	10.5	13	2.5	23.81	11	14	3.0	27.27
95	*Dc*	11.27	14.05	2.78	24.67	11.41	14.22	2.81	24.63	10.79	13.51	2.72	25.21	11.46	14.27	2.81	24.52
	D	11.5	14.5	3.0	26.09	11.5	14.5	3.0	26.09	11	14	3.0	27.27	11.5	14.5	3.0	26.09
99.9	*Dc*	-	-	-	-	-	-	-	-	11.83	14.69	2.86	24.18	-	-	-	-
	D	-	-	-	-	-	-	-	-	12	15	3.0	25.0	-	-	-	-

(e) Pt = 3.5

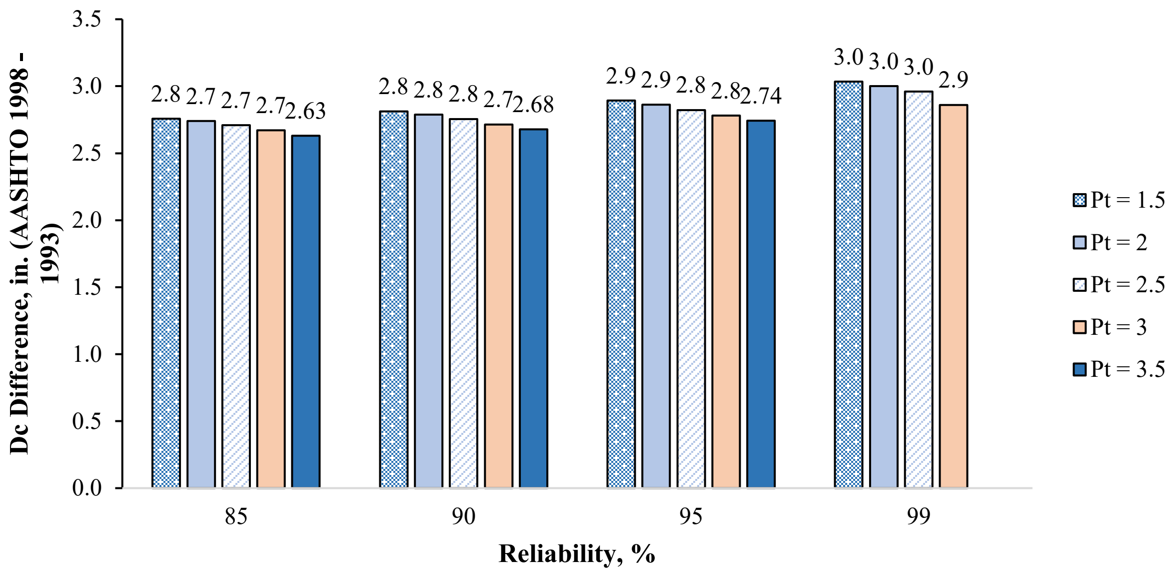
Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.07	13.7	2.63	23.76	11.21	13.86	2.65	23.64	10.59	13.17	2.58	24.36	11.26	13.92	2.66	23.62
	D	11.5	14	2.5	21.74	11.5	14	2.50	21.74	11	13.5	2.50	22.73	11.5	14	2.50	21.74
90	*Dc*	11.44	14.12	2.68	23.43	11.59	14.29	2.70	23.30	10.95	13.58	2.63	24.02	11.64	14.34	2.70	23.20
	D	11.5	14.5	3.0	26.09	12	14.5	2.50	20.83	11	14	3.00	27.27	12	14.5	2.50	20.83
95	*Dc*	12.02	14.77	2.75	22.88	12.17	14.94	2.77	22.76	11.51	14.2	2.69	23.37	12.23	14.99	2.76	22.57
	D	12.5	15	2.5	20.00	12.5	15	2.5	20.0	12	14.5	2.50	20.83	12.5	15	2.50	20.0
99.9	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note:

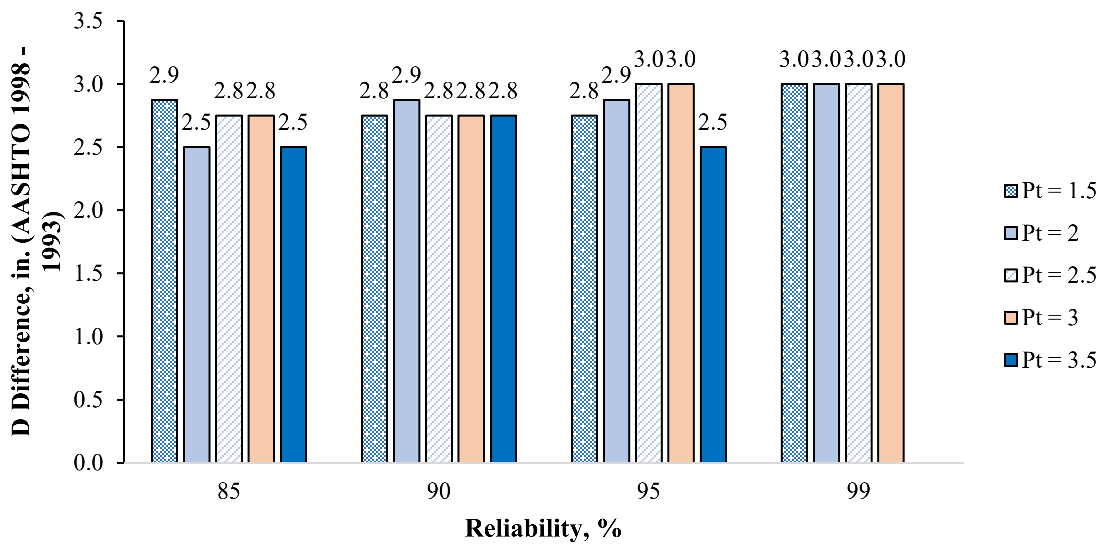
- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993

- $\% \text{ Diff.} = \frac{Thickness\ designed\ by AASHTO 1998 - Thickness\ designed\ by\ AASHTO\ 1993}{Thickness\ designed\ by\ AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 31(a) and **31(b)** illustrates the average differences in computed thickness and rounded designed thickness, respectively. At high traffic level, the AASHTO 1998 method consistently produces thicker JRCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, ***Dc*** is 2.8 inches thicker (26.53% increase), and ***D*** is 2.81 inches thicker (25.52% increase). These results indicate that AASHTO 1998 generally recommends thicker JRCP concrete for high traffic condition. The figures also show that the difference between the two methods is more pronounced at higher reliability levels.



(a)



(b)

Figure 31. JRCP concrete thickness differences between AASHTO 1998 and 1993 for high-traffic conditions: (a) computed; (b) designed.

5.2.2 Medium Traffic Condition

Table 15(a) to 15(e) present the JRCP concrete thickness for medium-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at medium traffic level, the AASHTO 1998 method yields a higher thickness than the AASHTO 1993 method.

Table 15. Comparison of JRCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for Medium Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.49	9.94	2.45	32.71	6.38	8.58	2.20	34.48	6.9	9.23	2.33	33.77	7.12	9.48	2.36	33.15
	D	7.5	10	2.5	33.33	6.5	9	2.5	38.46	7	9.5	2.5	35.71	7.5	9.5	2.0	26.67
90	*Dc*	7.76	10.26	2.50	32.22	6.61	8.86	2.25	34.04	7.15	9.53	2.38	33.29	7.37	9.79	2.42	32.84
	D	8	10.5	2.5	31.25	7	9	2.0	28.57	7.5	10	2.5	33.33	7.5	10	2.5	33.33
95	*Dc*	8.16	10.74	2.58	31.62	6.97	9.3	2.33	33.43	7.53	9.99	2.46	32.67	7.76	10.26	2.50	32.22
	D	8.5	11	2.5	29.41	7	9.5	2.5	35.71	8	10	2.0	25.00	8	10.5	2.5	31.25
99.9	*Dc*	8.98	11.7	2.72	30.29	7.68	10.17	2.49	32.42	8.29	10.9	2.61	31.48	8.54	11.19	2.65	31.03
	D	9	12	3.0	33.33	8	10.5	2.5	31.25	8.5	11	2.5	29.41	9	11.5	2.5	27.78

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.71	10.16	2.45	31.78	6.53	8.77	2.24	34.30	7.09	9.44	2.35	33.15	7.31	9.7	2.39	32.69
	D	8	10.5	2.5	31.25	7	9	2.0	28.57	7.5	9.5	2.0	26.67	7.5	10	2.5	33.33
90	*Dc*	7.99	10.49	2.50	31.29	6.78	9.07	2.29	33.78	7.35	9.75	2.40	32.65	7.58	10.01	2.43	32.06
	D	8	10.5	2.5	31.25	7	9.5	2.5	35.71	7.5	10	2.5	33.33	8	10.5	2.5	31.25
95	*Dc*	8.42	10.98	2.56	30.40	7.16	9.51	2.35	32.82	7.75	10.22	2.47	31.87	7.99	10.49	2.50	31.29
	D	8.5	11	2.5	29.41	7.5	10	2.5	33.33	8	10.5	2.5	31.25	8	10.5	2.5	31.25
99.9	*Dc*	9.26	11.97	2.71	29.27	7.91	10.4	2.49	31.48	8.55	11.14	2.59	30.29	8.81	11.44	2.63	29.85
	D	9.5	12	2.5	26.32	8	10.5	2.5	31.25	9	11.5	2.5	27.78	9	11.5	2.5	27.78

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8	10.44	2.44	30.50	6.73	9.01	2.28	33.88	7.34	9.7	2.36	32.15	7.57	9.97	2.40	31.70
	D	8	10.5	2.5	31.25	7	9.5	2.5	35.71	7.5	10	2.5	33.33	8	10	2.0	25.00
90	*Dc*	8.29	10.78	2.49	30.04	7	9.32	2.32	33.14	7.62	10.01	2.39	31.36	7.86	10.29	2.43	30.92
	D	8.5	11	2.5	29.41	7	9.5	2.5	35.71	8	10.5	2.5	31.25	8	10.5	2.5	31.25
95	*Dc*	8.73	11.29	2.56	29.32	7.41	9.78	2.37	31.98	8.04	10.5	2.46	30.60	8.29	10.78	2.49	30.04
	D	9	11.5	2.5	27.78	7.5	10	2.5	33.33	8.5	10.5	2.0	23.53	8.5	11	2.5	29.41
99.9	*Dc*	9.62	12.29	2.67	27.75	8.21	10.68	2.47	30.09	8.88	11.45	2.57	28.94	9.14	11.76	2.62	28.67
	D	10	12.5	2.5	25.00	8.5	11	2.5	29.41	9	11.5	2.5	27.78	9.5	12	2.5	26.32

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.38	10.82	2.44	29.12	7.02	9.34	2.32	33.05	7.68	10.05	2.37	30.86	7.94	10.33	2.39	30.10
	D	8.5	11	2.5	29.41	7.5	9.5	2.0	26.67	8	10.5	2.5	31.25	8	10.5	2.5	31.25
90	*Dc*	8.69	11.16	2.47	28.42	7.32	9.66	2.34	31.97	7.98	10.37	2.39	29.95	8.24	10.66	2.42	29.37
	D	9	11.5	2.5	27.78	7.5	10	2.5	33.33	8	10.5	2.5	31.25	8.5	11	2.5	29.41
95	*Dc*	9.16	11.69	2.53	27.62	7.76	10.13	2.37	30.54	8.43	10.87	2.44	28.94	8.7	11.17	2.47	28.39
	D	9.5	12	2.5	26.32	8	10.5	2.5	31.25	8.5	11	2.5	29.41	9	11.5	2.5	27.78
99.9	*Dc*	10.09	12.73	2.64	26.16	8.61	11.06	2.45	28.46	9.31	11.86	2.55	27.39	9.59	12.17	2.58	26.90
	D	10.5	13	2.5	23.81	9	11.5	2.5	27.78	9.5	12	2.5	26.32	10	12.5	2.5	25.00

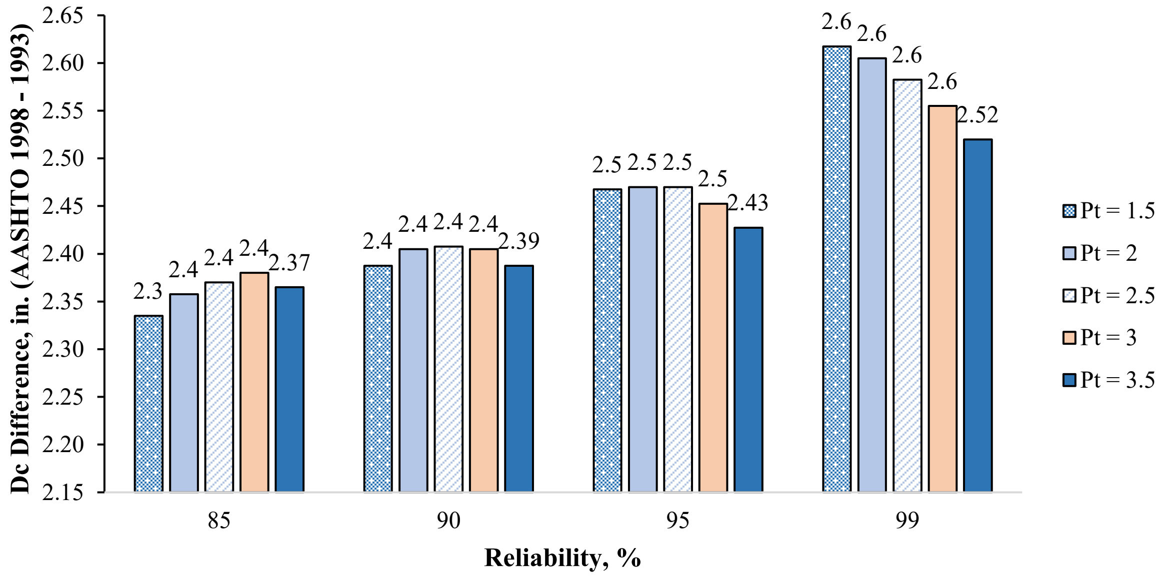
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.97	11.38	2.41	26.87	7.51	9.84	2.33	31.03	8.22	10.57	2.35	28.59	8.49	10.86	2.37	27.92
	D	9	11.5	2.5	27.78	8	10	2.0	25.00	8.5	11	2.5	29.41	8.5	11	2.5	29.41
90	*Dc*	9.29	11.74	2.45	26.37	7.83	10.16	2.33	29.76	8.54	10.91	2.37	27.75	8.81	11.21	2.40	27.24
	D	9.5	12	2.5	26.32	8	10.5	2.5	31.25	9	11	2.0	22.22	9	11.5	2.5	27.78
95	*Dc*	9.79	12.29	2.5	25.54	8.3	10.66	2.36	28.43	9.02	11.43	2.41	26.72	9.3	11.74	2.44	26.24
	D	10	12.5	2.5	25.00	8.5	11	2.5	29.41	9.5	11.5	2.0	21.05	9.5	12	2.5	26.32
99.9	*Dc*	10.77	13.37	2.60	24.14	9.2	11.63	2.43	26.41	9.95	12.46	2.51	25.23	10.25	12.79	2.54	24.78
	D	11	13.5	2.5	22.73	9.5	12	2.5	26.32	10	12.5	2.5	25.00	10.5	13	2.5	23.81

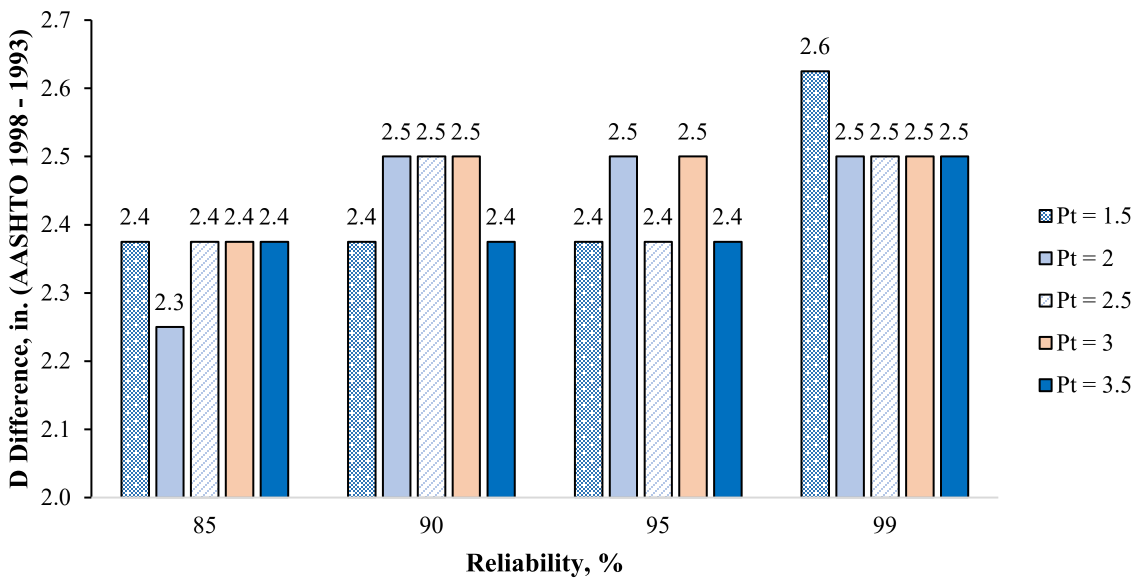
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{Thickness\ designed\ by AASHTO 1998 - Thickness\ designed\ by\ AASHTO\ 1993}{Thickness\ designed\ by\ AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 32(a) and **32(b)** illustrate the average differences in computed thickness and rounded designed thickness, respectively, for medium-traffic conditions. The AASHTO 1998 method consistently produces thicker JRCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, ***Dc*** is 2.45 inch thicker (30.27% increase), and ***D*** is 2.44 inch thicker (29.32% increase). These results are consistent with the observations for high-traffic conditions for JRCP pavements.



(a)



(b)

Figure 32. JRCP concrete thickness differences between AASHTO 1998 and 1993 for medium-traffic conditions: (a) computed; (b) designed.

5.2.3 Low Traffic Condition

Table 16(a) to 16(e) present the JRCP concrete thickness for low-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at low traffic level, the AASHTO 1998 method yields a higher JRCP thickness than the AASHTO 1993 method.

Table 16. Comparison of JRCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for Low Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	5.47	7.43	1.96	35.83	-	-	-	-
	D	-	-	-	-	-	-	-	-	5.5	7.5	2.00	36.36	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	5.67	7.69	2.02	35.63	-	-	-	-
	D	-	-	-	-	-	-	-	-	6	8	2.00	33.33	-	-	-	-
95	*Dc*	5.43	7.37	1.94	35.73	5.32	7.24	1.92	36.09	5.99	8.09	2.10	35.06	5.51	7.47	1.96	26.24
	D	5.5	8.5	3.00	54.55	5.5	7.5	2.00	36.36	6	8.5	2.50	41.67	6	7.5	1.50	20.00
99.9	*Dc*	6.01	8.12	2.11	35.11	5.89	7.97	2.08	35.31	6.62	8.88	2.26	34.14	6.1	8.23	2.13	25.88
	D	6.5	9.5	3.00	46.15	6	8	2.00	33.33	7	9	2.00	28.57	6.5	8.5	2.00	23.53

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	5.55	7.58	2.03	36.58	-	-	-	-
	D	-	-	-	-	-	-	-	-	6	8	2.00	33.33	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	5.77	7.86	2.09	36.22	5.28	7.23	1.95	36.93
	D	-	-	-	-	-	-	-	-	6	8	2.00	33.33	5.5	7.5	2.00	36.36
95	*Dc*	5.51	7.52	2.01	36.48	5.4	7.38	1.98	36.67	6.11	8.27	2.16	35.35	5.59	7.63	2.04	36.49
	D	6	8	2.00	33.33	5.5	7.5	2.00	36.36	6.5	8.5	2.00	30.77	6	8	2.00	33.33
99.9	*Dc*	6.13	8.3	2.17	35.40	6.01	8.15	2.14	35.61	6.79	9.08	2.29	33.73	6.23	8.41	2.18	34.99
	D	6.5	8.5	2.00	30.77	6.5	8.5	2.00	30.77	7	9.5	2.50	35.71	6.5	8.5	2.00	30.77

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	5.67	7.78	2.11	37.21	5.15	7.13	1.98	38.45
	D	-	-	-	-	-	-	-	-	6	8	2.00	33.33	5.5	7.5	2.00	36.36
90	*Dc*	5.28	7.3	2.02	38.26	5.17	7.16	1.99	38.49	5.9	8.07	2.17	36.78	5.37	7.41	2.04	37.99
	D	5.5	7.5	2.00	36.36	5.5	7.5	2.00	36.36	6	8.5	2.50	41.67	5.5	7.5	2.00	36.36
95	*Dc*	5.62	7.72	2.10	37.37	5.49	7.57	2.08	37.89	6.27	8.5	2.23	35.57	5.71	7.83	2.12	37.13
	D	6	8	2.00	33.33	5.5	8	2.50	45.45	6.5	8.5	2.00	30.77	6	8	2.00	33.33
99.9	*Dc*	6.3	8.52	2.22	35.24	6.17	8.37	2.20	35.66	7.01	9.33	2.32	33.10	6.4	8.64	2.24	35.00
	D	6.5	9	2.50	38.46	6.5	8.5	2.00	30.77	7.5	9.5	2.00	26.67	6.5	9	2.50	38.46

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	5.17	7.26	2.09	40.43	-	-	-	-	5.83	8.06	2.23	38.25	5.26	7.37	2.11	40.11
	D	5.5	7.5	2.00	36.36	-	-	-	-	6	8.5	2.50	41.67	5.5	7.5	2.00	36.36
90	*Dc*	5.4	7.56	2.16	40.00	5.28	7.4	2.12	40.15	6.01	8.36	2.35	39.10	5.49	7.67	2.18	39.71
	D	5.5	8	2.50	45.45	5.5	7.5	2.00	36.36	6.5	8.5	2.00	30.77	5.5	8	2.50	45.45
95	*Dc*	5.77	8	2.23	38.65	5.64	7.84	2.20	39.01	6.52	8.81	2.29	35.12	5.87	8.12	2.25	38.33
	D	6	8	2.00	33.33	6	8	2.00	33.33	7	9	2.00	28.57	6	8.5	2.50	41.67
99.9	*Dc*	6.54	8.83	2.29	35.02	6.39	8.68	2.29	35.84	7.33	9.67	2.34	31.92	6.66	8.95	2.29	34.38
	D	7	9	2.00	28.57	6.5	9	2.50	38.46	7.5	10	2.50	33.33	7	9	2.00	28.57

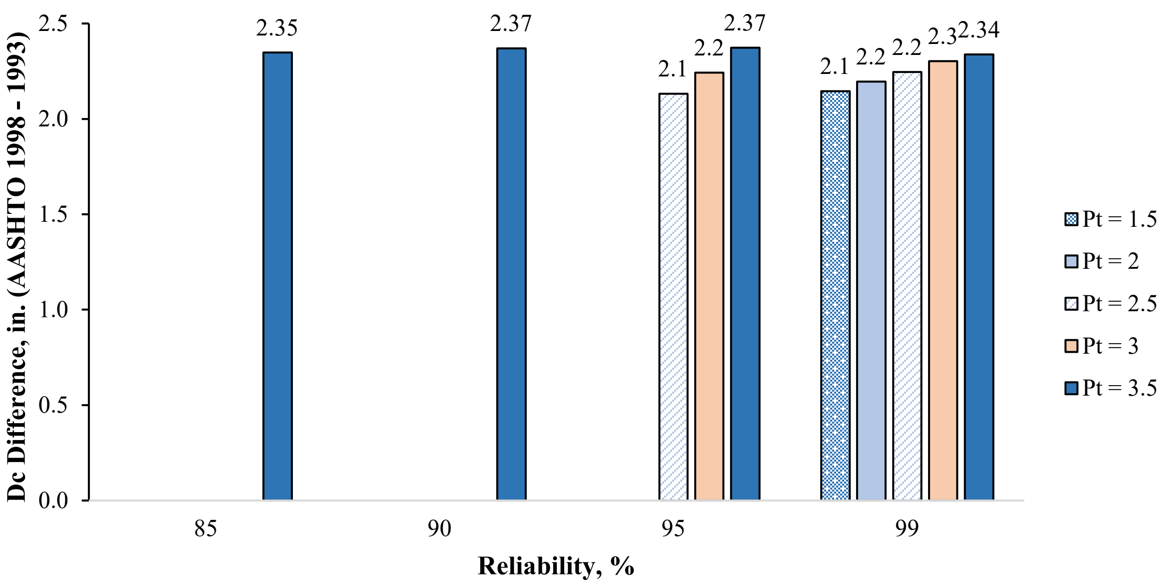
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	5.31	7.65	2.34	44.07	5.18	7.48	2.30	44.40	6.11	8.5	2.39	39.12	5.42	7.78	2.36	43.54
	D	5.5	8	2.50	45.45	5.5	7.5	2.00	36.36	6.5	8.5	2.00	30.77	5.5	8	2.50	45.45
90	*Dc*	5.59	7.97	2.38	42.58	5.44	7.8	2.36	43.38	6.45	8.81	2.36	36.59	5.71	8.09	2.38	41.68
	D	6	8	2.00	33.33	5.5	8	2.50	45.45	6.5	9	2.50	38.46	6	8.5	2.50	41.67
95	*Dc*	6.05	8.43	2.38	39.34	5.88	8.27	2.39	40.65	6.94	9.28	2.34	33.72	6.18	8.56	2.38	38.51
	D	6.5	8.5	2.00	30.77	6	8.5	2.50	41.67	7	9.5	2.50	35.71	6.5	9	2.50	38.46
99.9	*Dc*	6.97	9.31	2.34	33.57	6.8	9.14	2.34	34.41	7.84	10.18	2.34	29.85	7.1	9.43	2.33	32.82
	D	7	9.5	2.50	35.71	7	9.5	2.50	35.71	8	10.5	2.50	31.25	7.5	9.5	2.00	26.67

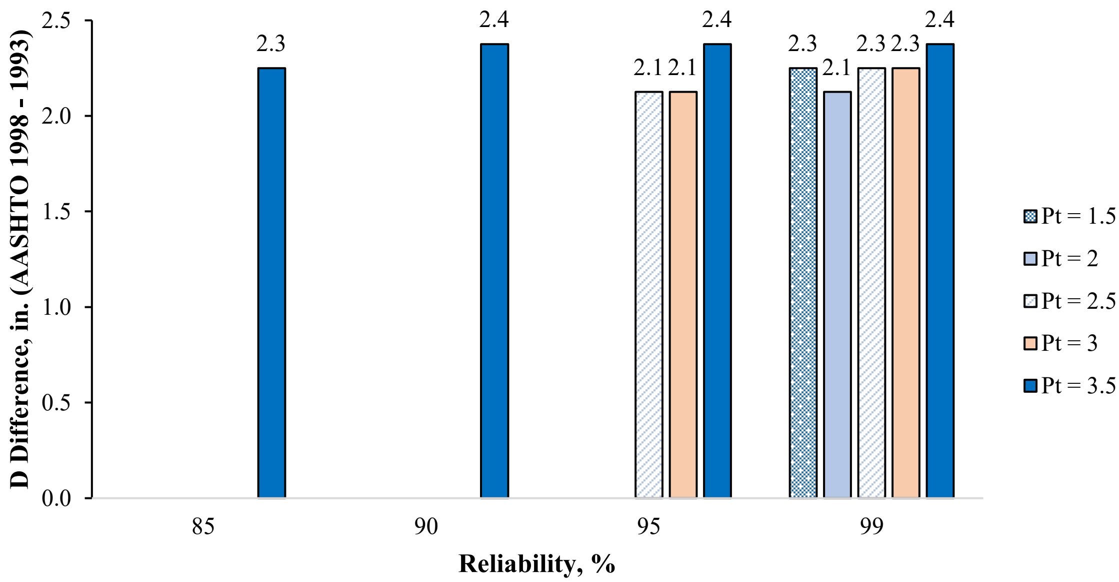
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{Thickness\ designed\ by AASHTO 1998 - Thickness\ designed\ by\ AASHTO\ 1993}{Thickness\ designed\ by\ AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 33(a) and **33(b)** illustrate the average differences in computed thickness and rounded designed thickness, respectively, for low-traffic conditions. The AASHTO 1998 method yields thicker JRCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. These results are consistent with the observations for medium- and high-traffic conditions. On average, the computed JRCP thickness is 2.16 inch higher (36.75% increase), and rounded designed value is 2.16 inch higher 35.43% increase).



(a)



(b)

Figure 33. JRCP concrete thickness differences between AASHTO 1998 and 1993 for low-traffic conditions: (a) computed; (b) designed.

5.3 CRCP Concrete Thickness Differences Between AASHTO 1998 and 1993

This section presents the design thickness of CRCP slabs under varying reliability and terminal serviceability conditions for four locations: Mobile, Montgomery, Birmingham, and Huntsville.

5.3.1 High Traffic Condition

Table 17(a) to 17(e) present the JRCP concrete thickness for high-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, the AASHTO 1998 method yields a higher CRCP thickness compared to the AASHTO 1993 method.

Table 17. Comparison of CRCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for High Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.23	10.5	1.27	13.76	9.35	10.5	1.15	12.30	8.83	9.79	0.96	10.87	9.39	10.44	1.05	11.18
	D	9.5	10.5	1	10.53	9.5	10.5	1	10.53	9	10	1	11.11	9.5	10.5	1	10.53
90	*Dc*	9.55	10.84	1.29	13.51	9.67	10.84	1.17	12.10	9.13	10.11	0.98	10.73	9.71	10.78	1.07	11.02
	D	10	11	1	10.00	10	11	1	10.00	9.5	10.5	1	10.53	10	11	1	10.00
95	*Dc*	10.03	11.37	1.34	13.36	10.16	11.37	1.21	11.91	9.6	10.6	1	10.42	10.21	11.31	1.1	10.77
	D	10.5	11.5	1	9.52	10.5	11.5	1	9.52	10	11	1	10.00	10.5	11.5	1	9.52
99.9	*Dc*	11.01	12.41	1.4	12.72	11.15	12.42	1.27	11.39	10.54	11.59	1.05	9.96	11.2	12.35	1.15	10.27
	D	11.5	12.5	1	8.70	11.5	12.5	1	8.70	11	12	1	9.09	11.5	12.5	1	8.70

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.52	10.77	1.25	13.13	9.65	10.78	1.13	11.71	9.11	10.04	0.93	10.21	9.69	10.72	1.03	10.63
	D	10	11	1	10.00	10	11	1	10.00	9.5	10.5	1	10.53	10	11	1	10.00
90	*Dc*	9.85	11.12	1.27	12.89	9.98	11.13	1.15	11.52	9.42	10.37	0.95	10.08	10.02	11.07	1.05	10.48
	D	10	11.5	1.5	15.00	10	11.5	1.5	15.00	9.5	10.5	1	10.53	10.5	11.5	1	9.52
95	*Dc*	10.35	11.66	1.31	12.66	10.49	11.67	1.18	11.25	9.91	10.88	0.97	9.79	10.53	11.61	1.08	10.26
	D	10.5	12	1.5	14.29	10.5	12	1.5	14.29	10	11	1	10.00	11	12	1	9.09
99.9	*Dc*	11.36	12.73	1.37	12.06	11.51	12.74	1.23	10.69	10.88	11.89	1.01	9.28	11.56	12.68	1.12	9.69
	D	11.5	13	1.5	13.04	12	13	1	8.33	11	12	1	9.09	12	13	1	8.33

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.89	11.11	1.22	12.34	10.02	11.12	1.1	10.98	9.45	10.37	0.92	9.74	10.06	11.07	1.01	10.04
	D	10	11.5	1.5	15.00	10.5	11.5	1	9.52	9.5	10.5	1	10.53	10.5	11.5	1	9.52
90	*Dc*	10.23	11.47	1.24	12.12	10.36	11.48	1.12	10.81	9.78	10.71	0.93	9.51	10.41	11.43	1.02	9.80
	D	10.5	11.5	1	9.52	10.5	11.5	1	9.52	10	11	1	10.00	10.5	11.5	1	9.52
95	*Dc*	10.75	12.03	1.28	11.91	10.89	12.04	1.15	10.56	10.29	11.24	0.95	9.23	10.94	11.98	1.04	9.51
	D	11	12.5	1.5	13.64	11	12.5	1.5	13.64	10.5	11.5	1	9.52	11	12	1	9.09
99.9	*Dc*	11.79	13.14	1.35	11.45	11.94	13.15	1.21	10.13	11.29	12.28	0.99	8.77	11.99	13.09	1.1	9.17
	D	12	13.5	1.5	12.50	12	13.5	1.5	12.50	11.5	12.5	1	8.70	12	13.5	1.5	12.50

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.37	11.57	1.2	11.57	10.5	11.59	1.09	10.38	9.92	10.81	0.89	8.97	10.55	11.53	0.98	9.29
	D	10.5	12	1.5	14.29	11	12	1	9.09	10	11	1	10.00	11	12	1	9.09
90	*Dc*	10.72	11.95	1.23	11.47	10.86	11.96	1.1	10.13	10.26	11.17	0.91	8.87	10.91	11.91	1	9.17
	D	11	12	1	9.09	11	12	1	9.09	10.5	11.5	1	9.52	11	12	1	9.09
95	*Dc*	11.27	12.53	1.26	11.18	11.41	12.54	1.13	9.90	10.79	11.71	0.92	8.53	11.46	12.49	1.03	8.99
	D	11.5	13	1.5	13.04	11.5	13	1.5	13.04	11	12	1	9.09	11.5	12.5	1	8.70
99.9	*Dc*	12.36	13.68	1.32	10.68	12.51	13.7	1.19	9.51	11.83	12.8	0.97	8.20	12.57	13.64	1.07	8.51
	D	12.5	14	1.5	12.00	13	14	1	7.69	12	13	1	8.33	13	14	1	7.69

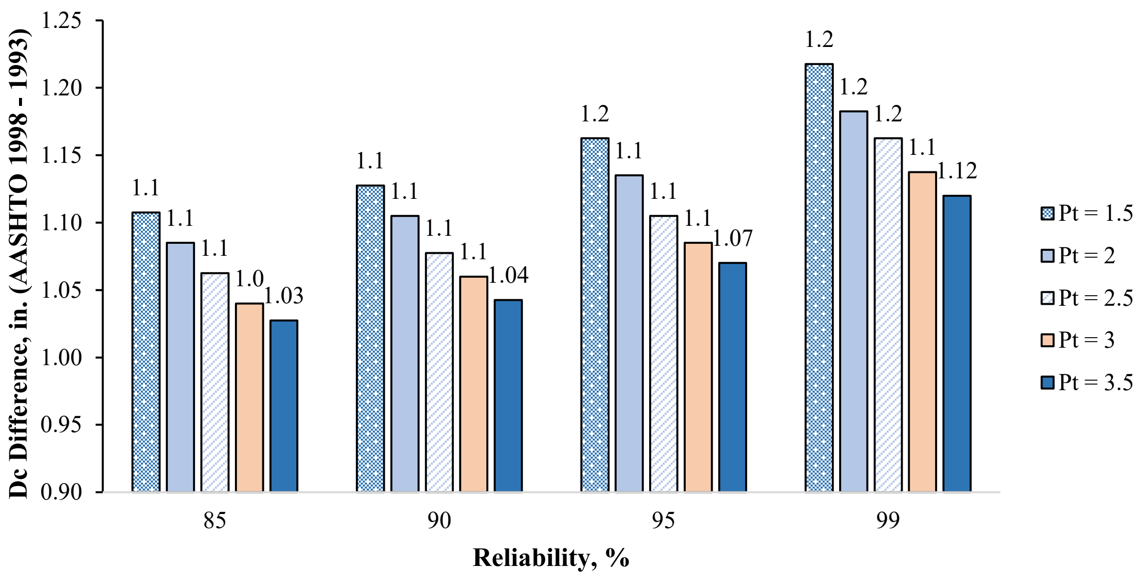
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.07	12.26	1.19	10.75	11.21	12.28	1.07	9.55	10.59	11.47	0.88	8.31	11.26	12.23	0.97	8.61
	D	11.5	12.5	1	8.70	11.5	12.5	1	8.70	11	11.5	0.5	4.55	11.5	12.5	1	8.70
90	*Dc*	11.44	12.65	1.21	10.58	11.59	12.68	1.09	9.40	10.95	11.84	0.89	8.13	11.64	12.62	0.98	8.42
	D	11.5	13	1.5	13.04	12	13	1	8.33	11	11	0	0.00	12	13	1	8.33
95	*Dc*	12.02	13.26	1.24	10.32	12.17	13.29	1.12	9.20	11.51	12.42	0.91	7.91	12.23	13.24	1.01	8.26
	D	12.5	13.5	1	8.00	12.5	13.5	1	8.00	12	12.5	0.5	4.17	12.5	13.5	1	8.00
99.9	*Dc*	13.17	14.48	1.31	9.95	13.34	14.51	1.17	8.77	12.62	13.57	0.95	7.53	13.4	14.45	1.05	7.84
	D	13.5	14.5	1	7.41	13.5	15	1.5	11.11	13	14	1	7.69	13.5	14.5	1	7.41

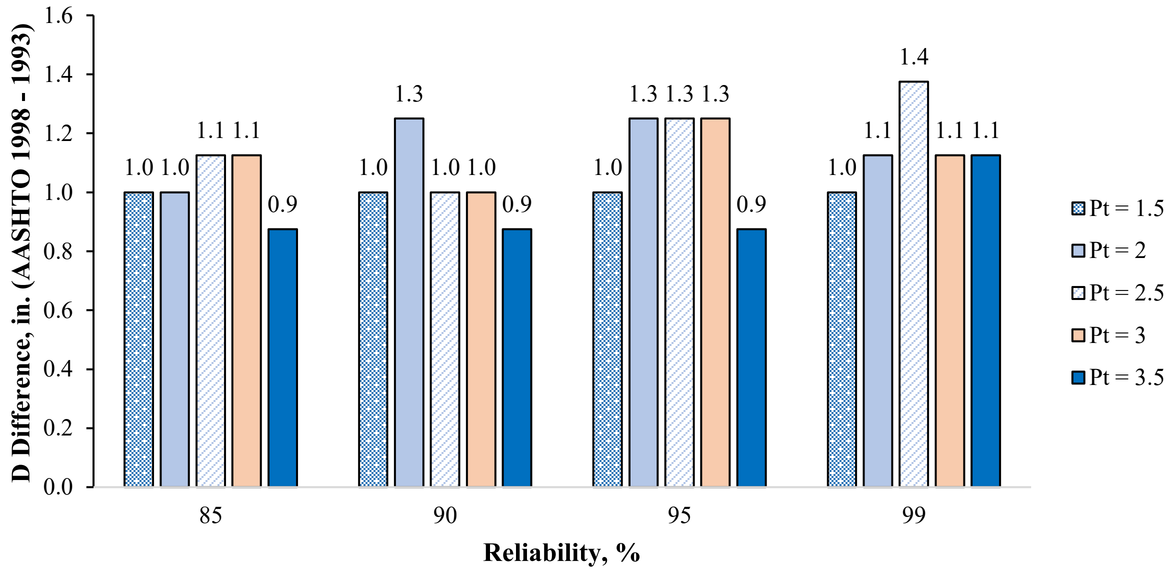
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{Thickness\ designed\ by AASHTO 1998 - Thickness\ designed\ by\ AASHTO\ 1993}{Thickness\ designed\ by\ AASHTO\ 1993} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 34(a) and **34(b)** illustrates the average differences in computed thickness and rounded designed thickness, respectively. At high traffic level, the AASHTO 1998 method consistently produces thicker CRCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, ***Dc*** is 1.11 inches thicker (10.34% increase), and ***D*** is 1.08 inches thicker (9.88% increase). These results indicate that AASHTO 1998 generally recommends thicker CRCP concrete for high traffic condition. The figures also show that the difference between the two methods is more pronounced at higher reliability levels.



(a)



(b)

Figure 34. CRCP concrete thickness differences between AASHTO 1998 and 1993 for high-traffic conditions: (a) computed; (b) designed.

5.3.2 Medium Traffic Condition

Table 18(a) to 18(e) present the CRCP concrete thickness for medium-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at medium traffic level, the AASHTO 1998 method yields a higher CRCP thickness than the AASHTO 1993 method.

Table 18. Comparison of CRCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for Medium Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.49	8.63	1.14	15.22	6.38	7.34	0.96	15.05	6.9	7.77	0.87	12.61	7.12	8.04	0.92	12.92
	D	7.5	9	1.5	20.00	6.5	7.5	1	15.38	7	8	1	14.29	7.5	8.5	1	13.33
90	*Dc*	7.76	8.92	1.16	14.95	6.61	7.59	0.98	14.83	7.15	8.02	0.87	12.17	7.37	8.31	0.94	12.75
	D	8	9	1	12.50	7	8	1	14.29	7.5	8.5	1	13.33	7.5	8.5	1	13.33
95	*Dc*	8.16	9.36	1.2	14.71	6.97	7.97	1	14.35	7.53	8.42	0.89	11.82	7.76	9.17	1.41	18.17
	D	8.5	9.5	1	11.76	7	8	1	14.29	8	8.5	0.5	6.25	8	9.5	1.5	18.75
99.9	*Dc*	8.98	10.23	1.25	13.92	7.68	8.73	1.05	13.67	8.29	9.23	0.94	11.34	8.54	10.03	1.49	17.45
	D	9	10.5	1.5	16.67	8	9	1	12.50	8.5	9.5	1	11.76	9	10.5	1.5	16.67

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.71	8.85	1.14	14.79	6.53	7.5	0.97	14.85	7.09	7.95	0.86	12.13	7.31	8.24	0.93	12.72
	D	8	9	1	12.50	7	7.5	0.5	7.14	7.5	8	0.5	6.67	7.5	8.5	1	13.33
90	*Dc*	7.99	9.14	1.15	14.39	6.78	7.76	0.98	14.45	7.35	8.22	0.87	11.84	7.58	8.51	0.93	12.27
	D	8	9.5	1.5	18.75	7	8	1	14.29	7.5	8.5	1	13.33	8	9	1	12.50
95	*Dc*	8.42	9.59	1.17	13.90	7.16	8.16	1	13.97	7.75	8.64	0.89	11.48	7.99	8.94	0.95	11.89
	D	8.5	10	1.5	17.65	7.5	8.5	1	13.33	8	9	1	12.50	8	9	1	12.50
99.9	*Dc*	9.26	10.49	1.23	13.28	7.91	8.95	1.04	13.15	8.55	9.46	0.91	10.64	8.81	9.79	0.98	11.12
	D	9.5	10.5	1	10.53	8	9	1	12.50	9	9.5	0.5	5.56	9	10	1	11.11

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8	9.12	1.12	14.00	6.73	7.72	0.99	14.71	7.34	8.2	0.86	11.72	7.57	8.49	0.92	12.15
	D	8	9.5	1.5	18.75	7	8	1	14.29	7.5	8.5	1	13.33	8	8.5	0.5	6.25
90	*Dc*	8.29	9.43	1.14	13.75	7	7.99	0.99	14.14	7.62	8.48	0.86	11.29	7.86	8.78	0.92	11.70
	D	8.5	9.5	1	11.76	7	8	1	14.29	8	8.5	0.5	6.25	8	9	1	12.50
95	*Dc*	8.73	9.9	1.17	13.40	7.41	8.41	1	13.50	8.04	8.91	0.87	10.82	8.29	9.23	0.94	11.34
	D	9	10	1	11.11	7.5	8.5	1	13.33	8.5	9	0.5	5.88	8.5	9.5	1	11.76
99.9	*Dc*	9.62	10.83	1.21	12.58	8.21	9.23	1.02	12.42	8.88	9.77	0.89	10.02	9.14	10.11	0.97	10.61
	D	10	11	1	10.00	8.5	9.5	1	11.76	9	10	1	11.11	9.5	10.5	1	10.53

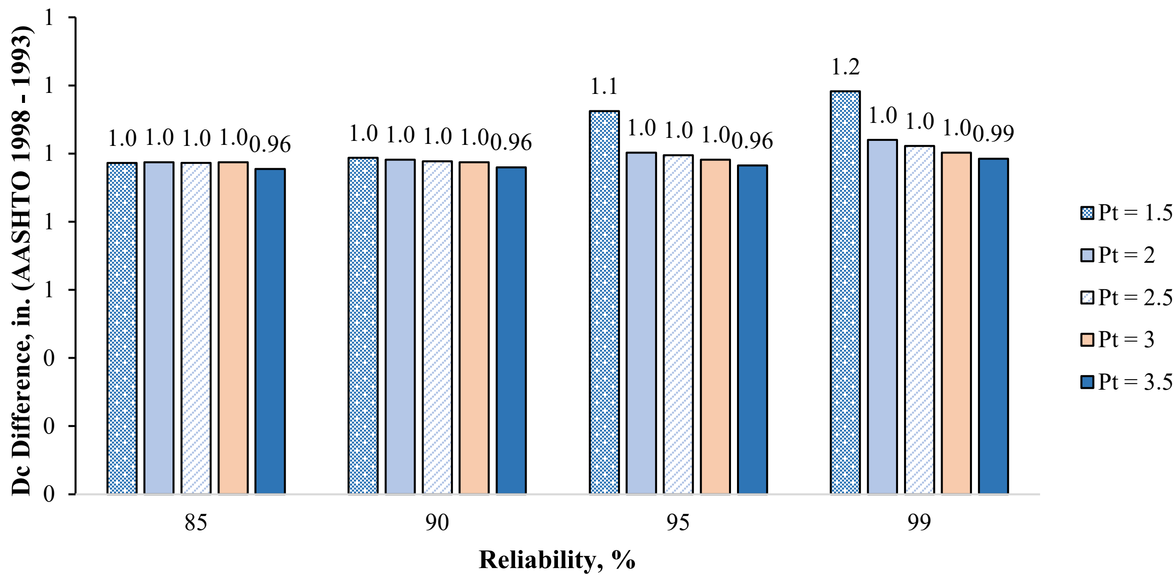
(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.38	9.5	1.12	13.37	7.02	8.03	1.01	14.39	7.68	8.54	0.86	11.20	7.94	8.85	0.91	11.46
	D	8.5	9.5	1	11.76	7.5	8.5	1	13.33	8	9	1	12.50	8	9	1	12.50
90	*Dc*	8.69	9.82	1.13	13.00	7.32	8.32	1	13.66	7.98	8.84	0.86	10.78	8.24	9.15	0.91	11.04
	D	9	10	1	11.11	7.5	8.5	1	13.33	8	9	1	12.50	8.5	9.5	1	11.76
95	*Dc*	9.16	10.31	1.15	12.55	7.76	8.76	1	12.89	8.43	9.29	0.86	10.20	8.7	9.62	0.92	10.57
	D	9.5	10.5	1	10.53	8	9	1	12.50	8.5	9.5	1	11.76	9	10	1	11.11
99.9	*Dc*	10.09	11.28	1.19	11.79	8.61	9.61	1	11.61	9.31	10.19	0.88	9.45	9.59	10.53	0.94	9.80
	D	10.5	11.5	1	9.52	9	10	1	11.11	9.5	10.5	1	10.53	10	11	1	10.00

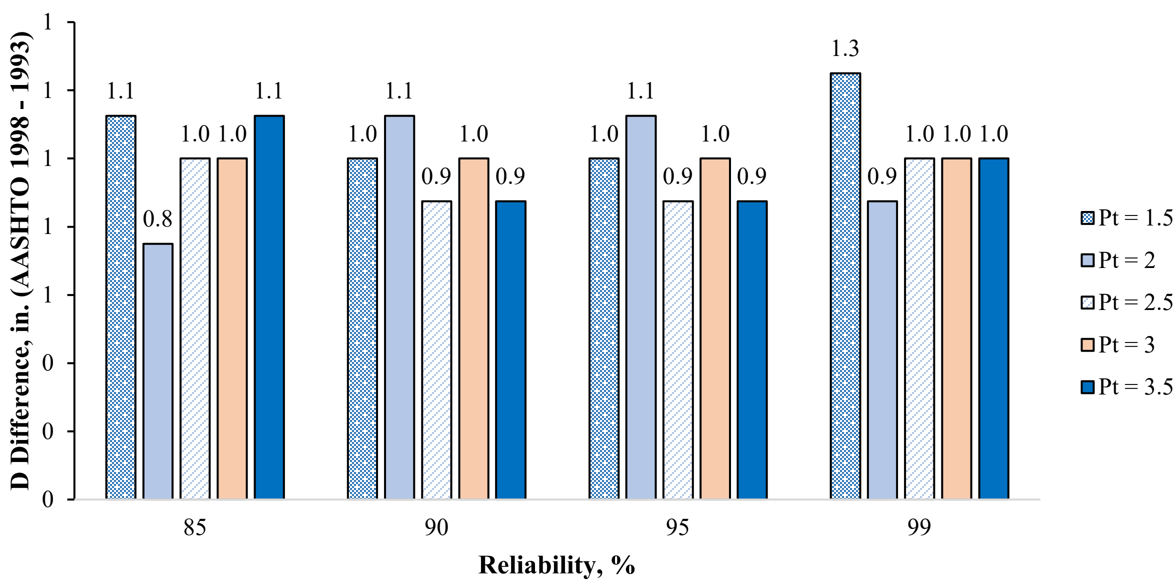
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.97	10.06	1.09	12.15	7.51	8.51	1	13.32	8.22	9.06	0.84	10.22	8.49	9.38	0.89	10.48
	D	9	10.5	1.5	16.67	8	9	1	12.50	8.5	9.5	1	11.76	8.5	9.5	1	11.76
90	*Dc*	9.29	10.4	1.11	11.95	7.83	8.82	0.99	12.64	8.54	9.38	0.84	9.84	8.81	9.71	0.9	10.22
	D	9.5	10.5	1	10.53	8	9	1	12.50	9	9.5	0.5	5.56	9	10	1	11.11
95	*Dc*	9.79	10.92	1.13	11.54	8.3	9.29	0.99	11.93	9.02	9.86	0.84	9.31	9.3	10.2	0.9	9.68
	D	10	11	1	10.00	8.5	9.5	1	11.76	9.5	10	0.5	5.26	9.5	10.5	1	10.53
99.9	*Dc*	10.77	11.94	1.17	10.86	9.2	10.19	0.99	10.76	9.95	10.81	0.86	8.64	10.25	11.17	0.92	8.98
	D	11	12	1	9.09	9.5	10.5	1	10.53	10	11	1	10.00	10.5	11.5	1	9.52

Figures 35(a) and **35(b)** illustrate the average differences in computed thickness and rounded designed thickness, respectively, for medium-traffic conditions. The AASHTO 1998 method consistently produces thicker CRCP pavements than AASHTO 1993 for both computed (***Dc***) and rounded designed (***D***) values. On average, ***Dc*** is 1.0 inch thicker (12.39% increase), and ***D*** is 0.99 inch thicker (11.96% increase).



(a)



(b)

Figure 35. CRCP concrete thickness differences between AASHTO 1998 and 1993 for medium-traffic conditions: (a) computed; (b) designed.

5.3.3 Low Traffic Condition

Table 19(a) to 19(e) present the CRCP concrete thickness for low-traffic condition across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. As observed, at low traffic level, the AASHTO 1998 method yields a higher CRCP thickness than the AASHTO 1993 method.

Table 19. Comparison of CRCP Concrete Thickness Between AASHTO 1998 and AASHTO 1993 for Low Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	6.01	7.04	1.03	17.14	-	-	-	-	6.62	7.47	0.85	12.84	-	-	-	-
	D	6.5	7.5	1	15.38	-	-	-	-	7	7.5	0.5	7.14	-	-	-	-

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	6.13	7.19	1.06	17.29	-	-	-	-	6.79	7.64	0.85	12.52	6.23	7.09	0.86	13.80
	D	6.5	7.5	1	15.38	-	-	-	-	7	8	1	14.29	6.5	7.5	1	15.38

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	6.27	7.13	0.86	13.72	-	-	-	-
	D	-	-	-	-	-	-	-	-	6.5	7.5	1	15.38	-	-	-	-
99.9	*Dc*	6.3	7.38	1.08	17.14	6.17	7.16	0.99	16.05	7.01	7.87	0.86	12.27	6.4	7.28	0.88	13.75
	D	6.5	7.5	1	15.38	6.5	7.5	1	15.38	7.5	8	0.5	6.67	6.5	7.5	1	15.38

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	6.52	7.4	0.88	13.50	-	-	-	-
	D	-	-		-	-	-	-	-	7	7.5	0.5	7.14	-	-	-	-
99.9	*Dc*	6.54	7.66	1.12	17.13	6.39	7.43	1.04	16.28	7.33	8.19	0.86	11.73	6.66	7.56	0.9	13.51
	D	7	8	1	14.29	6.5	7.5	1	15.38	7.5	8.5	1	13.33	7	8	1	14.29

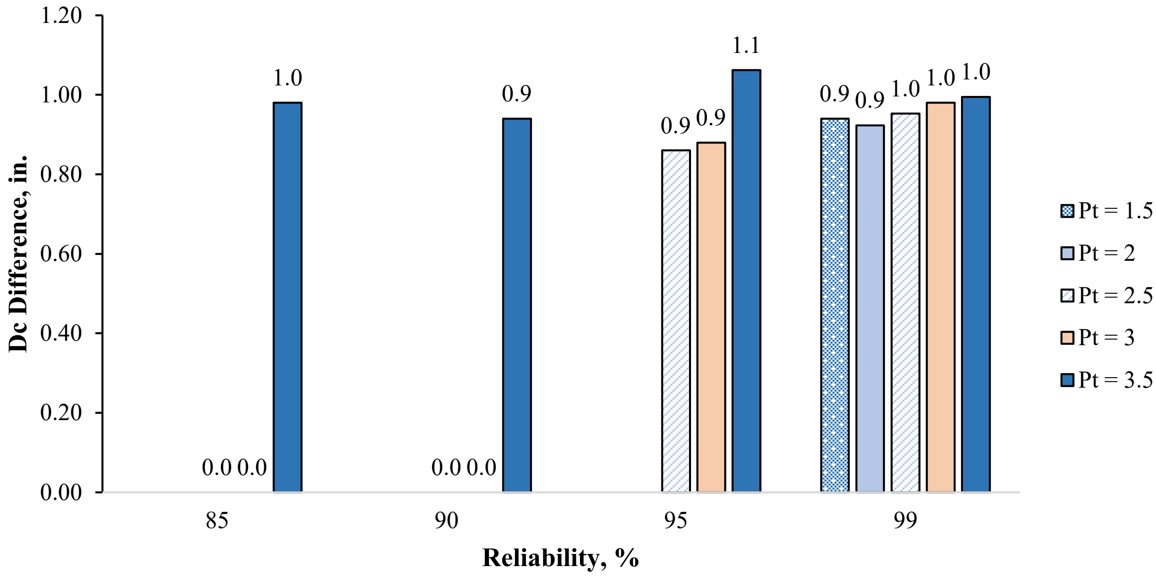
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.	1993 (in.)	1998 (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	6.11	7.09	0.98	16.04	-	-	-	-
	D	-	-	-	-	-	-	-	-	6.5	7.5	1	15.38	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	6.45	7.39	0.94	14.57	-	-	-	-
	D	-	-	-	-	-	-	-	-	6.5	7.5	1	15.38	-	-	-	-
95	*Dc*	6.05	7.27	1.22	20.17	5.88	7.02	1.14	19.39	6.94	7.84	0.9	12.97	6.18	7.17	0.99	16.02
	D	6.5	7.5	1	15.38	6	7.5	1.5	25.00	7	8	1	14.29	6.5	7.5	1	15.38
99.9	*Dc*	6.97	8.11	1.14	16.36	6.8	7.87	1.07	15.74	7.84	8.69	0.85	10.84	7.1	8.02	0.92	12.96
	D	7	8.5	1.5	21.43	7	8	1	14.29	8	9	1	12.50	7.5	8.5	1	13.33

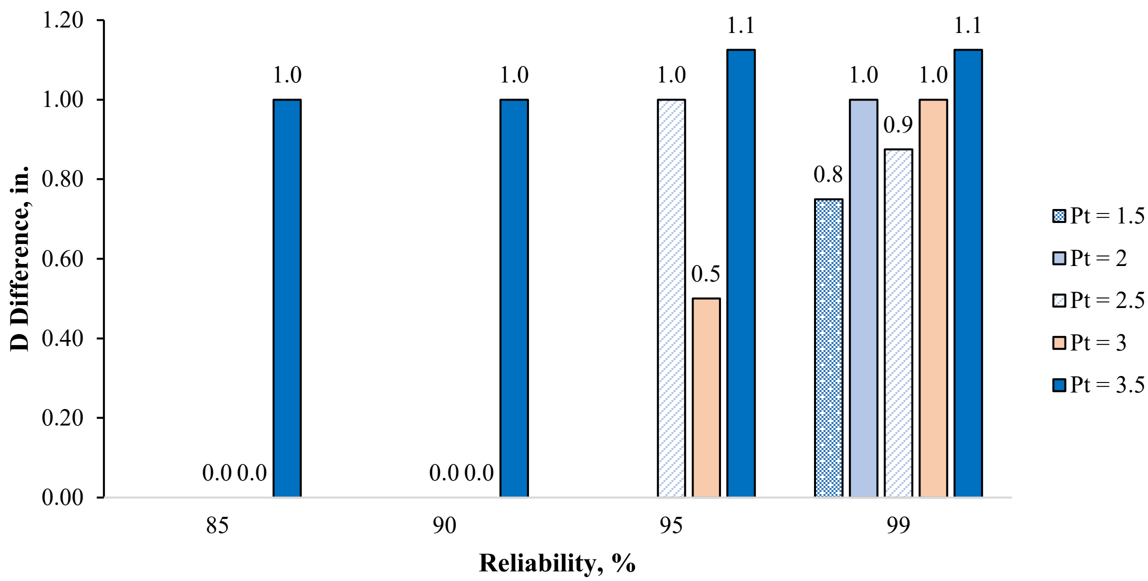
Note:

- Diff. = Thickness designed by AASHTO 1998 minus thickness designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{\text{Thickness designed by} AASHTO 1998 - \text{Thickness designed by } AASHTO \text{ 1993}}{\text{Thickness designed by } AASHTO \text{ 1993}} \times 100\%$
- D_c represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 36(a) and **36(b)** illustrate the average differences in computed thickness and rounded designed thickness, respectively, for low-traffic conditions. Based on the available data, the AASHTO 1998 method yields thicker CRCP pavements than AASHTO 1993 for both computed and rounded designed values. These results are consistent with the observations for medium- and high-traffic conditions. On average, the computed CRCP thickness is 0.95 inch higher (14.79 % increase), and rounded designed value is 0.94 inch higher 14% increase).



(a)



(b)

Figure 36. CRCP concrete thickness differences between AASHTO 1998 and 1993 for low-traffic conditions: (a) computed; (b) designed.

5.4 Chapter Summary

This chapter compared the AASHTO 1993 and AASHTO 1998 design methods across different reliability levels and terminal serviceability indices for JPCP, JRCP, and CRCP at four locations in Alabama: Mobile, Montgomery, Birmingham, and Huntsville.

An increase in reliability (from 85% to 99%) results in a thicker concrete pavement. Reliability represents the probability that the pavement will perform satisfactorily throughout its design life despite variations in materials, loads, and environmental factors. Higher reliability levels account for greater uncertainty and worst-case conditions, leading to thicker pavements for added safety.

The terminal serviceability index (Pt) represents the minimum acceptable level of serviceability (or ride quality) a pavement can reach before it is considered to have failed functionally and requires rehabilitation. It directly affects the designed thickness of a concrete pavement in the AASHTO design method. A higher terminal serviceability index (Pt) means the pavement must remain smoother and more functional at the end of its design life. In other words, it cannot deteriorate as much before being considered unacceptable. Because of this stricter performance requirement, the pavement must be stronger and more durable, which the AASHTO design method achieves by requiring a thicker concrete slab. As Pt increases, the design requires thicker concrete slabs to maintain smoother performance and serviceability over time. Lower Pt values permit more deterioration and therefore result in thinner designs.

The comparative analysis showed that AASHTO 1998 generally produces thicker concrete pavement designs than AASHTO 1993. On average, the AASHTO 1998 method yielded pavements that were approximately 1 inch thicker for JPCP, 2.5 inches thicker for JRCP, and 1 inch thicker for CRCP, about 10% to 37% thicker overall. The required slab thickness increased with higher reliability and lower terminal serviceability, with high-traffic roads typically requiring thicker slabs than low-traffic roads.

The results indicate that AASHTO 1998 provides more conservative and durable pavement designs but at the expense of higher construction costs. At lower traffic levels, the difference in thickness between AASHTO 1998 and 1993 is smaller and generally insignificant. AASHTO 1993 is based on empirical correlations from the AASHO Road Test, calibrated primarily for moderate traffic and environmental conditions. The reasons for the higher slab thickness in the AASHTO 1998 design method may include:

- **Increased number of design variables:** AASHTO 1998 requires determining additional parameters such as the Poisson's ratio of concrete, base properties, edge support factors, and the effective subgrade modulus for different seasons.
- **Explicit consideration of structural and environmental factors:** Even when using an identical foundation support (k), the AASHTO 1998 method produces thicker slabs because it explicitly accounts for joint spacing, edge support, base stiffness/friction, climate-driven temperature gradients, and includes joint performance checks.
- **Impact of climatic condition**s: Temperature differentials between the top and bottom of the slab influence slab thickness. Greater temperature differentials lead to increased slab thickness because the differential affects subgrade support, causing pavement curling and warping, which in turn contribute to cracking and faulting (Trujillo and Guerrero, 2019; Caliendo & Parisi, 2010; Padala et al., 2023).
- **Mid-slab tensile stress considerations:** Mid-slab tensile stress from applied loads and temperature changes necessitates thicker slabs to reduce stress and maintain slab rigidity. AASHTO 1998 explicitly analyzes mid-slab tensile stress and designs slab thickness to mitigate it, thereby resulting in thicker slabs to minimize the risk of cracking and pavement failure (Rufino and Roesler, 2005).

One contributing factor to the thicker pavement designs produced by the AASHTO 1998 method is the more detailed consideration of joint performance through the load transfer coefficient (J). The J factor represents the efficiency of load transfer across joints, directly influencing the calculated pavement thickness. A higher J value indicates reduced load transfer efficiency, leading to increased slab thickness to maintain structural adequacy. Conversely, optimizing joint design to achieve a lower J value, through the use of dowel bars, tied shoulders, or stabilized bases, can partially offset the thickness (and associated cost) increases observed with the AASHTO 1998 design method. Therefore, careful selection and calibration of the load transfer coefficient can serve as a practical approach to balancing pavement performance and cost-effectiveness when adopting the AASHTO 1998 methodology.

6. COMPARISON OF THICKNESS BETWEEN CONVENTIONAL 12' LANE WITH TIED SHOULDER VS WIDENED LANE WITH NON-TIED SHOULDER

This chapter presents a comparison between 12 ft conventional lanes with tied shoulders and 14 ft widened lanes with non-tied shoulders using the AASHTO 1998 design method to determine slab thickness. The comparison between the two lane types is conducted across reliability levels ranging from 85% to 99.9% and terminal serviceability indices from 1.5 to 3.5.

6.1 JPCP Concrete Thickness Differences Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder

The comparison is made for JPCP sections with tied shoulders and widened lanes, having a joint spacing of 15 ft. This section presents the design of JPCP slab thickness using the AASHTO 1998 design method for various levels of reliability and terminal serviceability in Mobile, Montgomery, Birmingham, and Huntsville. Traffic volume and climate data for each location, as described in the methodology chapter, are used in this comparative analysis.

6.1.1 High Traffic Condition

Table 20(a) to 20(e) present the JPCP concrete thickness designed for high-traffic condition across the four locations in Alabama, covering four reliability values (85%, 90%, 95%, and 99.9%) and five terminal serviceability values (1.5, 2.0, 2.5, 3.0 and 3.5). In these tables, **C** stands for "conventional lane with tied shoulder" and **W** stands "widened lane with non-tied shoulder". ***Dc*** in the tables represents the calculated thickness, obtained from AASHTO equations or software, and may include fractional values (e.g., 10.3 in.). ***D*** represents the recommended design thickness, rounded up to the nearest 0.5-inch increment (e.g., 10.5 in.). This rounding practice follows both the AASHTO 1993 and 1998 design procedures, as well as ALDOT standards.

As observed, at high traffic level, the JPCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders. The presence of tied shoulders provides additional edge support, which results in thicker pavement designs compared to widened lanes that achieve effective load distribution. However, for high reliability levels, the AASHTO 1998 design method does not provide thickness values above 15 inches, making it unsuitable for higher reliability applications.

Table 20. Comparison of JPCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for High Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.5	10.3	-0.2	-1.5	10.5	10.3	-0.2	-1.5	9.8	9.6	-0.2	-1.6	10.4	10.3	-0.2	-1.4
	D	10.5	10.5	0.0	0.0	10.5	10.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0
90	*Dc*	10.8	10.7	-0.2	-1.6	10.8	10.7	-0.2	-1.6	10.1	10.0	-0.2	-1.6	10.8	10.6	-0.2	-1.5
	D	11.0	11.0	0.0	0.0	11.0	11.0	0.0	0.0	10.5	10.0	-0.5	-4.8	11.0	11.0	0.0	0.0
95	*Dc*	11.4	11.2	-0.2	-1.6	11.4	11.2	-0.2	-1.6	10.6	10.4	-0.2	-1.6	11.3	11.1	-0.2	-1.5
	D	11.5	11.5	0.0	0.0	11.5	11.5	0.0	0.0	11.0	10.5	-0.5	-4.5	11.5	11.5	0.0	0.0
99.9	*Dc*	12.4	12.2	-0.2	-1.5	12.4	12.2	-0.2	-1.5	11.6	11.4	-0.2	-1.6	12.4	12.2	-0.2	-1.5
	D	12.5	12.5	0.0	0.0	12.5	12.5	0.0	0.0	12.0	11.5	-0.5	-4.2	12.5	12.5	0.0	0.0

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.8	10.6	-0.2	-1.5	10.8	10.6	-0.2	-1.6	10.0	10.0	-0.1	-0.6	10.7	10.6	-0.2	-1.5
	D	11.0	11.0	0.0	0.0	11.0	11.0	0.0	0.0	10.5	10.0	-0.5	-4.8	11.0	11.0	0.0	0.0
90	*Dc*	11.1	11.0	-0.2	-1.5	11.1	11.0	-0.2	-1.5	10.4	10.2	-0.1	-1.4	11.1	10.9	-0.2	-1.4
	D	11.5	11.0	-0.5	-4.3	11.5	11.0	-0.5	-4.3	10.5	10.5	0.0	0.0	11.5	11.0	-0.5	-4.3
95	*Dc*	11.7	11.5	-0.2	-1.5	11.7	11.5	-0.2	-1.5	10.9	10.7	-0.2	-1.5	11.6	11.4	-0.2	-1.5
	D	12.0	11.5	-0.5	-4.2	12.0	11.5	-0.5	-4.2	11.0	11.0	0.0	0.0	12.0	11.5	-0.5	-4.2
99.9	*Dc*	12.7	12.5	-0.2	-1.5	12.7	12.6	-0.2	-1.5	11.9	11.7	-0.2	-1.5	12.7	12.5	-0.2	-1.4
	D	13.0	13.0	0.0	0.0	13.0	13.0	0.0	0.0	12.0	12.0	0.0	0.0	13.0	12.5	-0.5	-3.8

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.1	11.0	-0.2	-1.4	11.1	11.0	-0.2	-1.5	10.4	10.2	-0.1	-1.4	11.1	10.9	-0.2	-1.4
	D	11.5	11.0	-0.5	-4.3	11.5	11.0	-0.5	-4.3	10.5	10.5	0.0	0.0	11.5	11.0	-0.5	-4.3
90	*Dc*	11.5	11.3	-0.2	-1.4	11.5	11.3	-0.2	-1.5	10.7	10.6	-0.2	-1.5	11.4	11.3	-0.2	-1.4
	D	11.5	11.5	0.0	0.0	11.5	11.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0
95	*Dc*	12.0	11.9	-0.2	-1.5	12.0	11.9	-0.2	-1.5	11.2	11.1	-0.2	-1.5	12.0	11.8	-0.2	-1.4
	D	12.5	12.0	-0.5	-4.0	12.5	12.0	-0.5	-4.0	11.5	11.5	0.0	0.0	12.0	12.0	0.0	0.0
99.9	*Dc*	13.1	13.0	-0.2	-1.4	13.2	13.0	-0.2	-1.4	12.3	12.1	-0.2	-1.5	13.1	12.9	-0.2	-1.4
	D	13.5	13.0	-0.5	-3.7	13.5	13.0	-0.5	-3.7	12.5	12.5	0.0	0.0	13.5	13.0	-0.5	-3.7

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.6	11.4	-0.2	-1.4	11.6	11.4	-0.2	-1.5	10.8	10.7	-0.2	-1.5	11.5	11.4	-0.2	-1.4
	D	12.0	11.5	-0.5	-4.2	12.0	11.5	-0.5	-4.2	11.0	11.0	0.0	0.0	12.0	11.5	-0.5	-4.2
90	*Dc*	12.0	11.8	-0.2	-1.4	12.0	11.8	-0.2	-1.4	11.2	11.0	-0.2	-1.5	11.9	11.8	-0.2	-1.3
	D	12.0	12.0	0.0	0.0	12.0	12.0	0.0	0.0	11.5	11.0	-0.5	-4.3	12.0	12.0	0.0	0.0
95	*Dc*	12.5	12.4	-0.2	-1.4	12.5	12.4	-0.2	-1.4	11.7	11.5	-0.2	-1.5	12.5	12.3	-0.2	-1.4
	D	13.0	12.5	-0.5	-3.8	13.0	12.5	-0.5	-3.8	12.0	12.0	0.0	0.0	12.5	12.5	0.0	0.0
99.9	*Dc*	13.7	13.5	-0.2	-1.5	13.7	13.5	-0.2	-1.5	12.8	12.6	-0.2	-1.4	13.6	13.5	-0.2	-1.4
	D	14.0	13.5	-0.5	-3.6	14.0	13.5	-0.5	-3.6	13.0	13.0	0.0	0.0	14.0	13.5	-0.5	-3.6

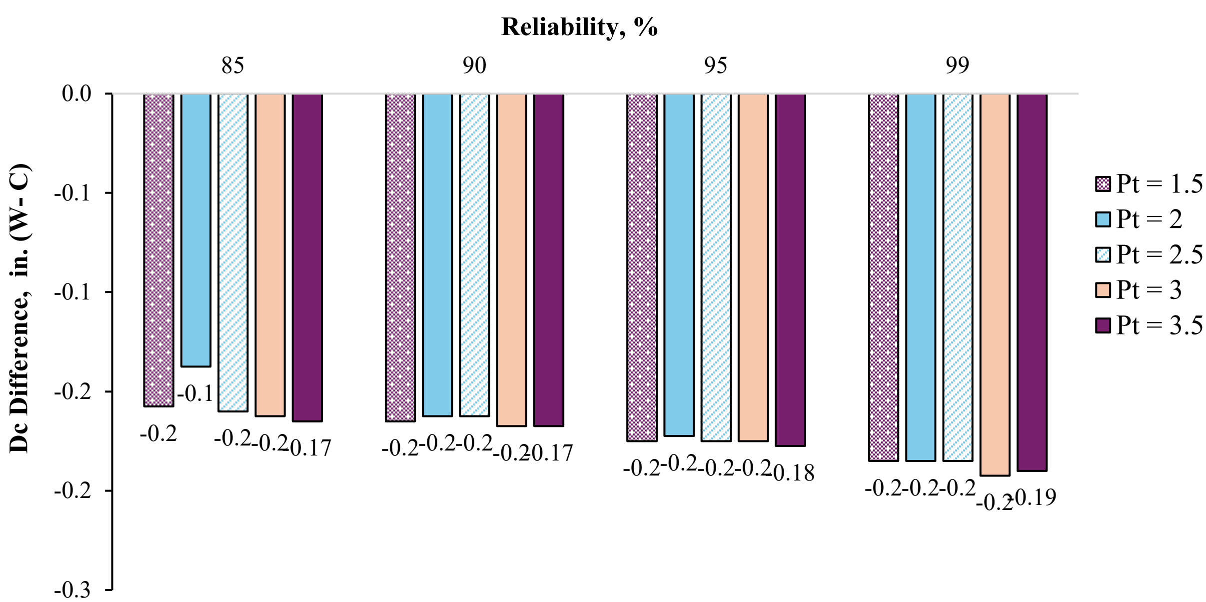
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	12.3	12.1	-0.2	-1.4	12.3	12.1	-0.2	-1.4	11.5	11.3	-0.2	-1.4	12.2	12.1	-0.2	-1.3
	D	12.5	12.5	0.0	0.0	12.5	12.5	0.0	0.0	11.5	11.5	0.0	0.0	12.5	12.5	0.0	0.0
90	*Dc*	12.7	12.5	-0.2	-1.3	12.7	12.5	-0.2	-1.4	11.8	11.7	-0.2	-1.4	12.6	12.5	-0.2	-1.3
	D	13.0	12.5	-0.5	-3.8	13.0	12.5	-0.5	-3.8	11.0	12.0	1.0	9.1	13.0	12.5	-0.5	-3.8
95	*Dc*	13.3	13.1	-0.2	-1.4	13.3	13.1	-0.2	-1.4	12.4	12.3	-0.2	-1.4	13.2	13.1	-0.2	-1.4
	D	13.5	13.5	0.0	0.0	13.5	13.5	0.0	0.0	12.5	12.5	0.0	0.0	13.5	13.5	0.0	0.0
99.9	*Dc*	14.5	14.3	-0.2	-1.4	14.5	14.3	-0.2	-1.4	13.6	13.4	-0.2	-1.3	14.5	14.3	-0.2	-1.2
	D	14.5	14.5	0.0	0.0	15.0	14.5	-0.5	-3.3	14.0	13.5	-0.5	-3.6	14.5	14.5	0.0	0.0

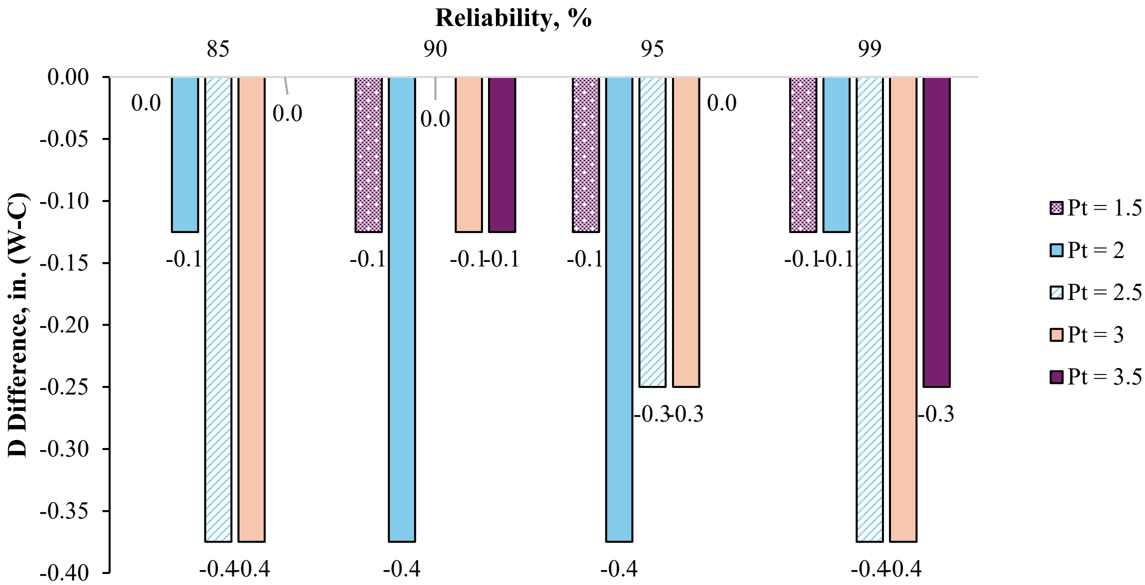
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 37(a) and **37(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. The widening lane without a tied-shoulder method consistently produces thinner JPCP pavements than the conventional lane without a tied-shoulder for both computed (***Dc***) and rounded design (***D***) values. On average, the computed thickness is 0.17 inches thinner (a 1.44% decrease), and design thickness is 0.19 inches thinner (a 1.55% decrease). At Pt = 3.5 and R = 85%, there is no difference in the design thickness. These results indicate that the widening lane without a tied-shoulder generally results in a thinner JPCP pavement design under high-traffic conditions. However, since all differences are less than 0.5 inches, the practical impact is negligible.



(a)



(b)

Figure 37. JPCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for high-traffic conditions: (a) computed; (b) designed.

6.1.2 Medium Traffic Condition

Table 21(a) to 22(e) present the JPCP concrete thickness designed for medium-traffic condition across the four locations in Alabama, covering four reliability values (85%, 90%, 95%, and 99.9%) and five terminal serviceability values (1.5, 2.0, 2.5, 3.0 and 3.5). As observed, at medium traffic level, the JPCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 21. Comparison of JPCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Medium Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.6	8.5	-0.1	-1.5	7.3	7.2	-0.1	-1.6	7.8	7.6	-0.1	-1.7	8.0	7.9	-0.1	-1.5
	D	9.0	8.5	-0.5	-5.6	7.5	7.5	0.0	0.0	8.0	8.0	0.0	0.0	8.5	8.0	-0.5	-5.9
90	*Dc*	8.9	8.8	-0.1	-1.6	7.6	7.5	-0.1	-1.6	8.0	7.9	-0.1	-1.5	8.3	8.2	-0.1	-1.6
	D	9.0	9.0	0.0	0.0	8.0	7.5	-0.5	-6.3	8.5	8.0	-0.5	-5.9	8.5	8.5	0.0	0.0
95	*Dc*	9.4	9.2	-0.1	-1.6	8.0	7.8	-0.1	-1.6	8.4	8.3	-0.1	-1.5	9.2	8.7	-0.4	-4.9
	D	9.5	9.5	0.0	0.0	9.0	8.0	-1.0	-11.1	8.5	8.5	0.0	0.0	9.5	9.0	-0.5	-5.3
99.9	*Dc*	10.2	10.1	-0.2	-1.6	8.7	8.6	-0.1	-1.6	9.2	9.1	-0.2	-1.6	10.0	9.5	-0.5	-4.9
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.5	10.0	-0.5	-4.8

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.9	8.7	-0.1	-1.6	7.5	7.4	-0.1	-1.6	8.0	7.8	-0.1	-1.6	8.2	8.1	-0.1	-1.6
	D	9.0	9.0	0.0	0.0	7.5	7.5	0.0	0.0	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0
90	*Dc*	9.1	9.0	-0.1	-1.5	7.8	7.6	-0.1	-1.5	8.2	8.1	-0.1	-1.6	8.5	8.4	-0.1	-1.4
	D	9.5	9.0	-0.5	-5.3	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	8.5	-0.5	-5.6
95	*Dc*	9.6	9.5	-0.1	-1.5	8.2	8.0	-0.1	-1.6	8.6	8.5	-0.1	-1.6	8.9	8.8	-0.1	-1.5
	D	10.0	9.5	-0.5	-5.0	8.5	8.5	0.0	0.0	9.0	8.5	-0.5	-5.6	9.0	9.0	0.0	0.0
99.9	*Dc*	10.5	10.3	-0.2	-1.4	9.0	8.8	-0.1	-1.6	9.5	9.3	-0.1	-1.5	9.8	9.7	-0.1	-1.4
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.1	8.9	-0.2	-2.5	7.7	7.6	-0.1	-1.7	8.2	8.1	-0.1	-1.7	8.5	8.4	-0.1	-1.4
	D	9.5	9.0	-0.5	-5.3	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0	8.5	8.5	0.0	0.0
90	*Dc*	9.4	9.3	-0.1	-1.5	8.0	7.9	-0.1	-1.5	8.5	8.4	-0.1	-1.5	8.8	8.7	-0.1	-1.5
	D	9.5	9.5	0.0	0.0	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	9.0	0.0	0.0
95	*Dc*	9.9	9.8	-0.2	-1.5	8.4	8.3	-0.1	-1.5	8.9	8.8	-0.1	-1.5	9.2	9.1	-0.1	-1.5
	D	10.0	10.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0
99.9	*Dc*	10.8	10.7	-0.2	-1.5	9.2	9.1	-0.1	-1.5	9.8	9.6	-0.2	-1.5	10.1	10.0	-0.1	-1.5
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.0	-0.5	-4.8

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.5	9.4	-0.1	-1.5	8.0	7.9	-0.1	-1.6	8.5	8.4	-0.1	-1.6	8.9	8.7	-0.1	-1.5
	D	9.5	9.5	0.0	0.0	8.5	8.0	-0.5	-5.9	9.0	8.5	-0.5	-5.6	9.0	9.0	0.0	0.0
90	*Dc*	9.8	9.7	-0.2	-1.5	8.3	8.2	-0.1	-1.6	8.8	8.7	-0.1	-1.6	9.2	9.0	-0.1	-1.4
	D	10.0	10.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0
95	*Dc*	10.3	10.2	-0.2	-1.5	8.8	8.6	-0.1	-1.6	9.3	9.2	-0.1	-1.5	9.6	9.5	-0.1	-1.5
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	9.5	-0.5	-5.0
99.9	*Dc*	11.3	11.1	-0.2	-1.5	9.6	9.5	-0.1	-1.5	10.2	10.0	-0.2	-1.5	10.5	10.4	-0.1	-1.2
	D	11.5	11.5	0.0	0.0	10.0	9.5	-0.5	-5.0	10.5	10.5	0.0	0.0	11.0	10.5	-0.5	-4.5

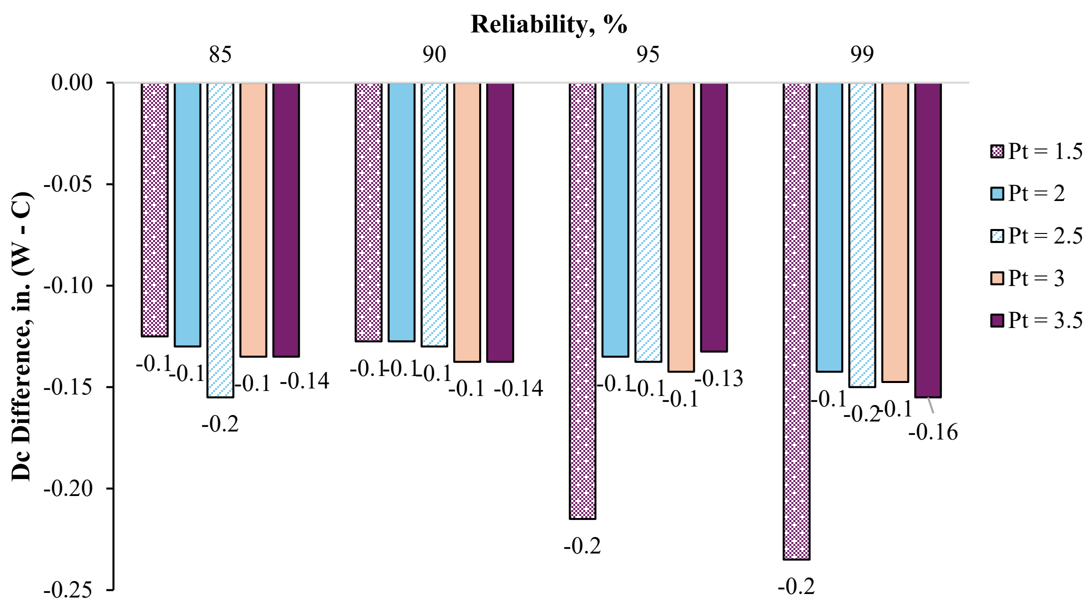
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.1	9.9	-0.1	-1.4	8.5	8.4	-0.1	-1.5	9.1	8.9	-0.1	-1.5	9.4	9.3	-0.1	-1.4
	D	10.5	10.0	-0.5	-4.8	9.0	8.5	-0.5	-5.6	9.5	9.0	-0.5	-5.3	9.5	9.5	0.0	0.0
90	*Dc*	10.4	10.3	-0.1	-1.3	8.8	8.7	-0.1	-1.5	9.4	9.2	-0.1	-1.5	9.7	9.6	-0.1	-1.4
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0
95	*Dc*	10.9	10.8	-0.2	-1.4	9.3	9.2	-0.1	-1.5	9.9	9.7	-0.1	-1.4	10.2	10.1	-0.1	-1.0
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0
99.9	*Dc*	11.9	11.8	-0.2	-1.3	10.2	10.1	-0.1	-1.4	10.8	10.7	-0.2	-1.4	11.2	11.0	-0.2	-1.5
	D	12.0	12.0	0.0	0.0	10.5	10.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0

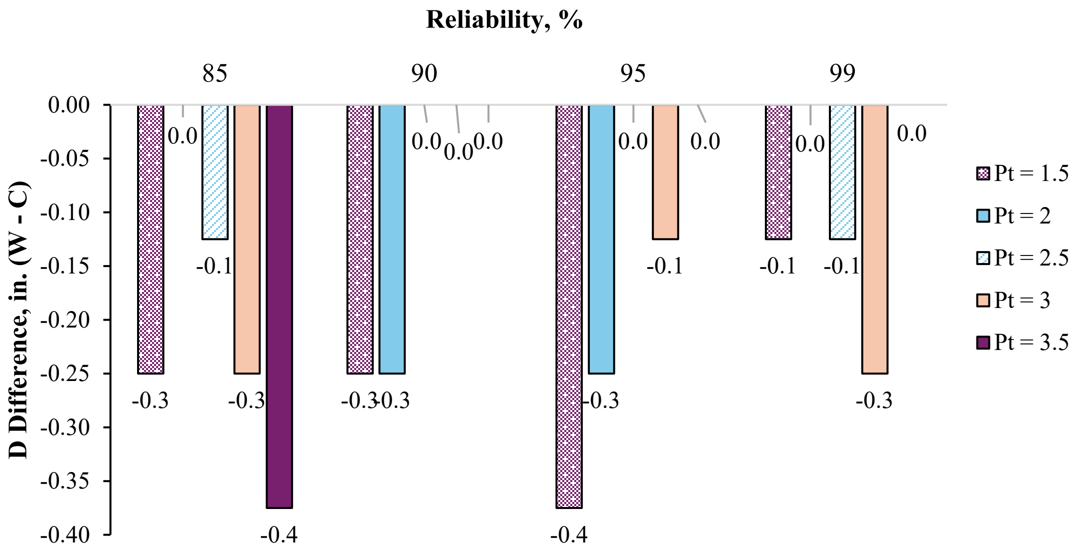
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 38(a) and **38(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At medium traffic level, the widening lane without a tied-shoulder method consistently produces thinner JPCP pavements than the conventional lane without a tied-shoulder for both computed (***Dc***) and rounded design (***D***) values. On average, the computed thickness is 0.15 inches thinner (a 1.6% decrease), and design thickness is 0.14 inches thinner (a 1.47% decrease). These results indicate that the widening lane without a tied-shoulder generally results in a thinner JPCP pavement design under medium-traffic conditions. Since all differences are less than 0.5 inches, the practical impact is negligible.



(a)



(b)

Figure 38. JPCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for medium-traffic conditions: (a) computed; (b) designed.

6.1.3 Low Traffic Condition

Table 22(a) to 22(e) present the JPCP concrete thickness designed for low-traffic condition across the four locations in Alabama, covering four reliability values and five terminal serviceability values. As observed, at low traffic level, the JPCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders. It should be noted that the AASHTO 1998 Excel-based design tool utilized for pavement thickness calculations provides output values only within the range of 7 to 15 inches. Under low-traffic conditions, certain computed thicknesses were less than 7 inches; therefore, corresponding cells in the table are left blank.

Table 22. Comparison of JPCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Low Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	-	-	-	-	-	-	-	-	7.5	7.4	-0.1	-1.6	-	-	-	-
	D	-	-	-	-	-	-	-	-	7.5	7.5	0.0	0.0	-	-	-	-

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	7.2	7.1	-0.1	-1.7	-	-	-	-	7.6	7.5	-0.1	-1.6	-	-	-	-
	D	7.5	7.5	0.0	0.0	-	-	-	-	8.0	8.0	0.0	0.0	-	-	-	-

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	7.1	7.0	-0.1	-1.7	-	-	-	-
	D	-	-	-	-	-	-	-	-	7.5	7.5	0.0	0.0	-	-	-	-
99.9	*Dc*	7.4	7.3	-0.1	-1.6	7.2	7.0	-0.1	-1.7	7.9	7.7	-0.1	-1.7	7.3	7.2	-0.1	-1.5
	D	7.5	7.5	0.0	0.0	7.5	7.5	0.0	0.0	8.0	8.0	0.0	0.0	7.5	7.5	0.0	0.0

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	7	7	0	-2	-	-	-	-
	D	-	-	-	-	-	-	-	-	8	8	0	0	-	-	-	-
99.9	*Dc*	7.7	7.5	-0.1	-1.7	7.4	7.3	-0.1	-1.6	8.2	8.1	-0.1	-1.6	7.6	7.4	-0.1	-1.6
	D	8.0	8.0	0.0	0.0	7.5	7.5	0.0	0.0	8.5	8.5	0.0	0.0	8.0	7.5	-0.5	-6.3

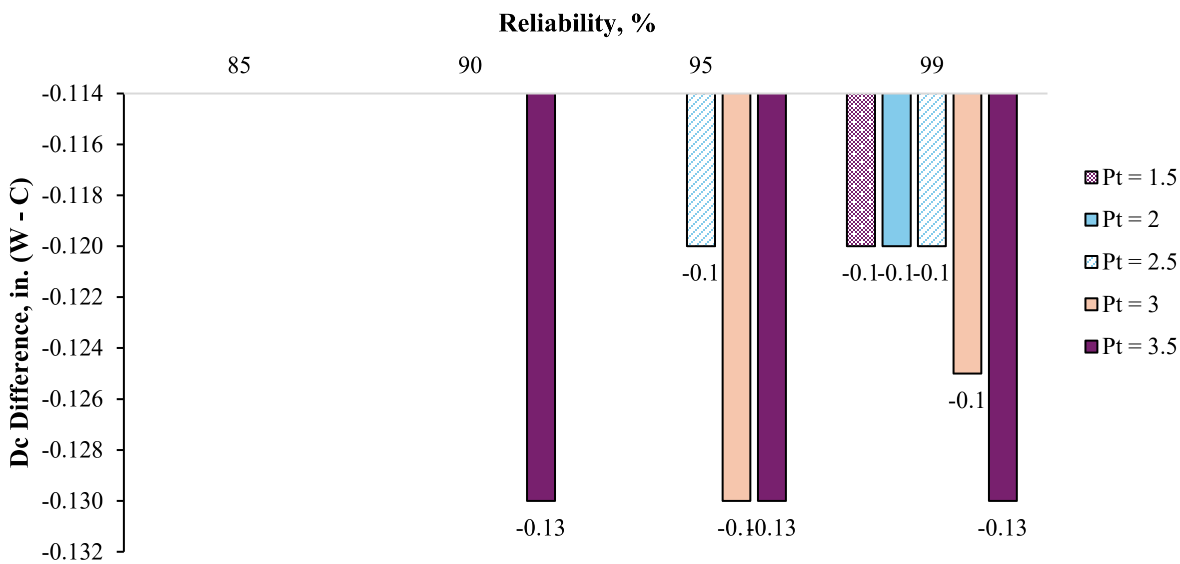
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	7.4	7.3	-0.1	-1.8	-	-	-	-
	D	-	-	-	-	-	-	-	-	7.5	7.5	0.0	0.0	-	-	-	-
95	*Dc*	7.3	7.1	-0.1	-1.8	-	-	-	-	7.8	7.7	-0.1	-1.7	-	-	-	-
	D	7.5	7.5	0.0	0.0	-	-	-	-	8.0	8.0	0.0	0.0	-	-	-	-
99.9	*Dc*	8.1	8.0	-0.1	-1.6	7.9	7.7	-0.1	-1.7	8.7	8.6	-0.1	-1.5	8.0	7.9	-0.1	-1.6
	D	8.5	8.0	-0.5	-5.9	8.0	8.0	0.0	0.0	9.0	9.0	0.0	0.0	8.5	8.0	-0.5	-5.9

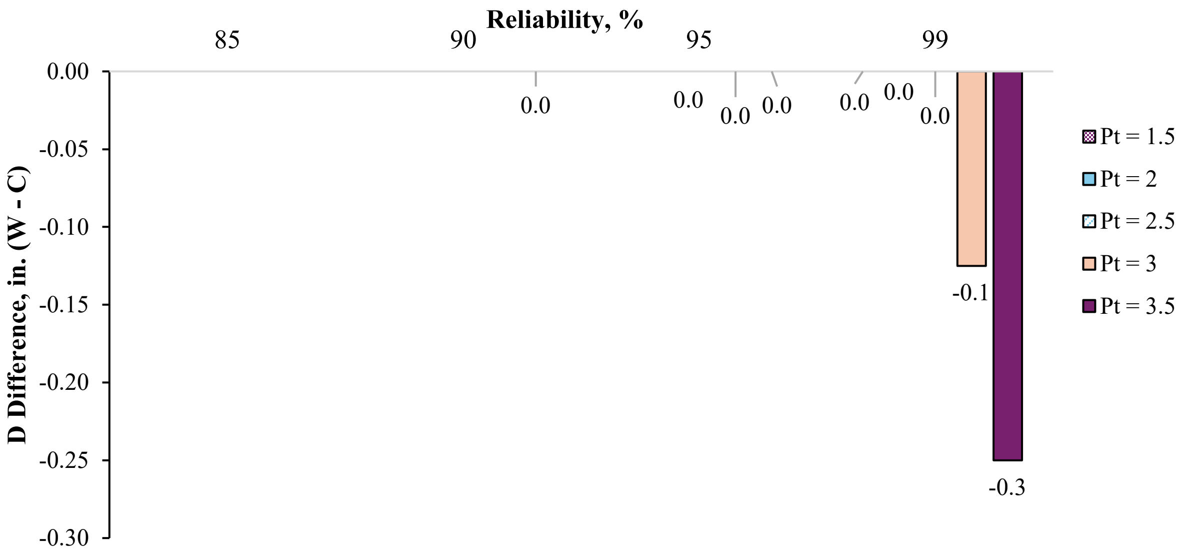
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 39(a) and **39(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At low traffic level, the widening lane without a tied-shoulder method consistently produces thinner JPCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.13 inches thinner (a 1.66% decrease), and the design thickness is 0.04 inches thinner (a 0.5% decrease). After rounding, the difference becomes insignificant. These results indicate that the widening lane without a tied-shoulder generally results in a thinner JPCP pavement design under low-traffic conditions.



(a)



(b)

Figure 39. JPCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for low-traffic conditions: (a) computed; (b) designed.

6.2 JRCP Concrete Thickness Differences Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder

This section presents the design of JRCP slab thickness using the AASHTO 1998 design method for various levels of reliability and terminal serviceability for four locations.

6.2.1 High Traffic Condition

Table 23(a) to 23(e) present the JRCP concrete thickness designed for high-traffic condition across the four locations in Alabama, covering four reliability values (85%, 90%, 95%, and 99.9%) and five terminal serviceability values (1.5, 2.0, 2.5, 3.0 and 3.5). At high traffic level, the JRCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 23. Comparison of JRCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for High Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	12.0	11.8	-0.2	-1.4	12.1	12.0	-0.2	-1.5	11.5	11.4	-0.2	-1.5	12.2	12.0	-0.2	-1.5
	D	12.0	12.0	0.0	0.0	12.5	12.0	-0.5	-4.0	12.0	11.5	-0.5	-4.2	12.5	12.0	-0.5	-4.0
90	*Dc*	12.4	12.2	-0.2	-1.5	12.5	12.3	-0.2	-1.4	11.9	11.7	-0.2	-1.4	12.6	12.4	-0.2	-1.4
	D	12.5	12.5	0.0	0.0	13.0	12.5	-0.5	-3.8	12.0	12.0	0.0	0.0	13.0	12.5	-0.5	-3.8
95	*Dc*	12.9	12.7	-0.2	-1.5	13.1	12.9	-0.2	-1.5	12.4	12.3	-0.2	-1.4	13.1	12.9	-0.2	-1.4
	D	13.0	13.0	0.0	0.0	13.5	13.0	-0.5	-3.7	12.5	12.5	0.0	0.0	13.5	13.0	-0.5	-3.7
99.9	*Dc*	14.1	13.9	-0.2	-1.4	14.2	14.0	-0.2	-1.4	13.5	13.3	-0.2	-1.4	14.3	14.1	-0.2	-1.5
	D	14.5	14.0	-0.5	-3.4	14.5	14.5	0.0	0.0	14.0	13.5	-0.5	-3.6	14.5	14.5	0.0	0.0

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	12.3	12.1	-0.2	-1.5	12.4	12.2	-0.2	-1.5	11.8	11.6	-0.2	-1.5	12.5	12.3	-0.2	-1.4
	D	12.5	12.5	0.0	0.0	12.5	12.5	0.0	0.0	12.0	12.0	0.0	0.0	12.5	12.5	0.0	0.0
90	*Dc*	12.6	12.5	-0.2	-1.4	12.8	12.6	-0.2	-1.4	12.2	12.0	-0.2	-1.5	12.8	12.7	-0.2	-1.4
	D	13.0	12.5	-0.5	-3.8	13.0	13.0	0.0	0.0	12.5	12.0	-0.5	-4.0	13.0	13.0	0.0	0.0
95	*Dc*	13.2	13.0	-0.2	-1.4	13.4	13.2	-0.2	-1.4	12.7	12.5	-0.2	-1.4	13.4	13.2	-0.2	-1.4
	D	13.5	13.5	0.0	0.0	13.5	13.5	0.0	0.0	13.0	13.0	0.0	0.0	13.5	13.5	0.0	0.0
99.9	*Dc*	14.4	14.2	-0.2	-1.5	14.5	14.3	-0.2	-1.4	13.8	13.6	-0.2	-1.4	14.6	14.4	-0.2	-1.4
	D	14.5	14.5	0.0	0.0	15.0	14.5	-0.5	-3.3	14.0	14.0	0.0	0.0	15.0	14.5	-0.5	-3.3

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	12.6	12.4	-0.2	-1.4	12.8	12.6	-0.2	-1.4	12.1	11.9	-0.2	-1.4	12.8	12.6	-0.2	-1.4
	D	13.0	12.5	-0.5	-3.8	13.0	13.0	0.0	0.0	12.5	12.0	-0.5	-4.0	13.0	13.0	0.0	0.0
90	*Dc*	13.0	12.8	-0.2	-1.4	13.1	13.0	-0.2	-1.4	12.5	12.3	-0.2	-1.4	13.2	13.0	-0.2	-1.4
	D	13.0	13.0	0.0	0.0	13.5	13.0	-0.5	-3.7	12.5	12.5	0.0	0.0	13.5	13.5	0.0	0.0
95	*Dc*	13.6	13.4	-0.2	-1.4	13.7	13.6	-0.2	-1.4	13.1	12.9	-0.2	-1.4	13.8	13.6	-0.2	-1.4
	D	14.0	13.5	-0.5	-3.6	14.0	14.0	0.0	0.0	13.5	13.0	-0.5	-3.7	14.0	14.0	0.0	0.0
99.9	*Dc*	14.8	14.6	-0.2	-1.4	14.9	14.7	-0.2	-1.3	14.2	14.0	-0.2	-1.4	15.0	14.8	-0.2	-1.3
	D	15.0	15.0	0.0	0.0	15.0	15.0	0.0	0.0	14.5	14.0	-0.5	-3.4	15.0	15.0	0.0	0.0

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	13.0	12.9	-0.2	-1.3	13.2	13.0	-0.2	-1.4	12.5	12.4	-0.2	-1.4	13.3	13.1	-0.2	-1.4
	D	13.5	13.0	-0.5	-3.7	13.5	13.5	0.0	0.0	13.0	12.5	-0.5	-3.8	13.5	13.5	0.0	0.0
90	*Dc*	13.4	13.3	-0.2	-1.3	13.6	13.4	-0.2	-1.3	12.9	12.8	-0.2	-1.3	13.7	13.5	-0.2	-1.3
	D	13.5	13.5	0.0	0.0	14.0	13.5	-0.5	-3.6	13.0	13.0	0.0	0.0	14.0	13.5	-0.5	-3.6
95	*Dc*	14.1	13.9	-0.2	-1.3	14.2	14.0	-0.2	-1.3	13.5	13.3	-0.2	-1.3	14.3	14.1	-0.2	-1.3
	D	14.5	14.0	-0.5	-3.4	14.5	14.5	0.0	0.0	14.0	13.5	-0.5	-3.6	14.5	14.5	0.0	0.0
99.9	*Dc*	-	-	-	-	-	-	-	-	14.7	14.5	-0.2	-1.4	-	-	-	-
	D	-	-	-	-	-	-	-	-	15.0	14.5	-0.5	-3.3	-	-	-	-

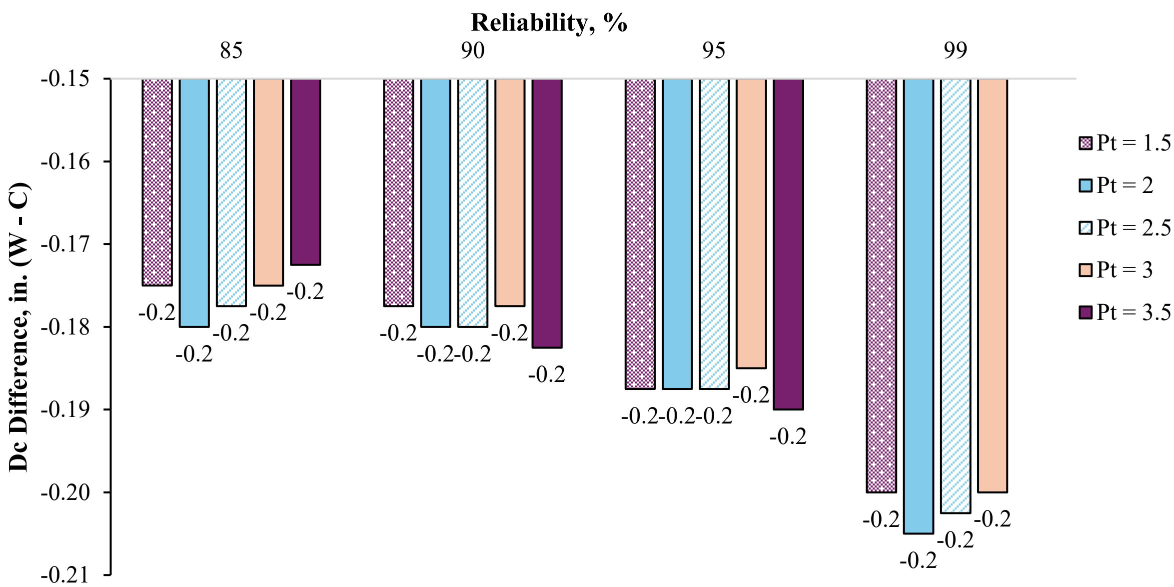
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	13.7	13.5	-0.2	-1.2	13.9	13.7	-0.2	-1.2	13.2	13.0	-0.2	-1.3	13.9	13.7	-0.2	-1.3
	D	14.0	14.0	0.0	0.0	14.0	14.0	0.0	0.0	13.5	13.0	-0.5	-3.7	14.0	14.0	0.0	0.0
90	*Dc*	14.1	13.9	-0.2	-1.3	14.3	14.1	-0.2	-1.3	13.6	13.4	-0.2	-1.3	14.3	14.2	-0.2	-1.3
	D	14.5	14.0	-0.5	-3.4	14.5	14.5	0.0	0.0	14.0	13.5	-0.5	-3.6	14.5	14.5	0.0	0.0
95	*Dc*	14.8	14.6	-0.2	-1.3	14.9	14.8	-0.2	-1.3	14.2	14.0	-0.2	-1.3	15.0	14.8	-0.2	-1.3
	D	15.0	15.0	0.0	0.0	15.0	15.0	0.0	0.0	14.5	14.5	0.0	0.0	15.0	15.0	0.0	0.0
99.9	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

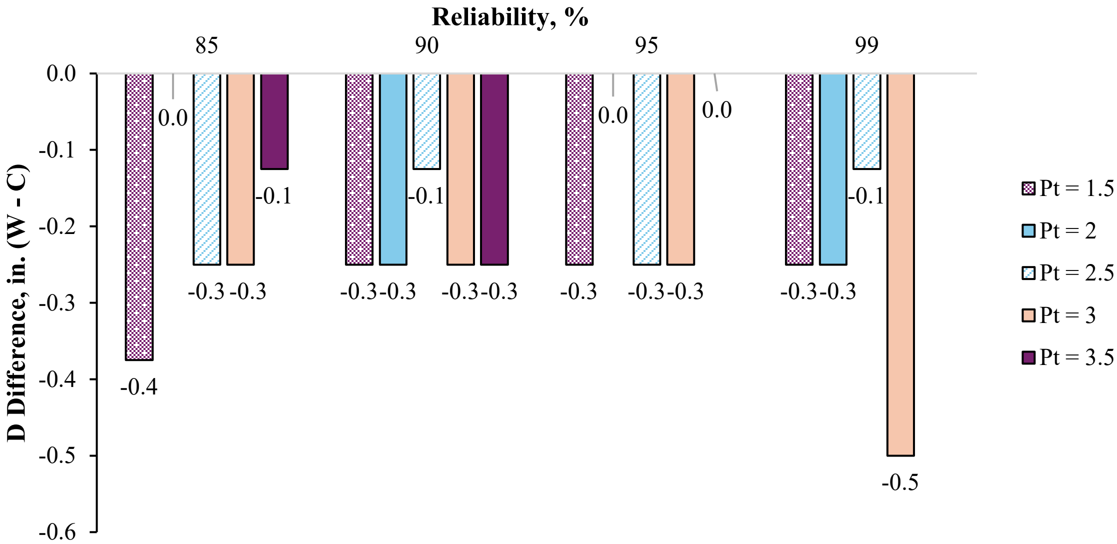
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 40(a) and **40(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At high traffic level, the widening lane without a tied-shoulder method consistently produces thinner JRCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.19 inches thinner (a 1.38% decrease), and design thickness is 0.21 inches thinner (a 1.54% decrease). These results indicate that the widening lane without a tied-shoulder generally results in a thinner JRCP pavement design under high-traffic conditions.



(a)



(b)

Figure 40. JRCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for high-traffic conditions: (a) computed; (b) designed.

6.2.2 Medium Traffic Condition

Table 24(a) to 24(e) present the JRCP concrete thickness designed for medium-traffic condition across the four locations in Alabama, covering four reliability values and five terminal serviceability values. As observed, at the medium-level traffic, the JRCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 24. Comparison of JRCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Medium Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.9	9.8	-0.2	-1.6	8.6	8.4	-0.1	-1.6	9.2	9.1	-0.2	-1.6	9.5	9.3	-0.1	-1.5
	D	10.0	10.0	0.0	0.0	9.0	8.5	-0.5	-5.6	9.5	9.5	0.0	0.0	9.5	9.5	0.0	0.0
90	*Dc*	10.3	10.1	-0.2	-1.6	8.9	8.7	-0.1	-1.6	9.5	9.4	-0.1	-1.6	9.8	9.6	-0.1	-1.5
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	10.0	9.5	-0.5	-5.0	10.0	10.0	0.0	0.0
95	*Dc*	10.7	10.6	-0.2	-1.5	9.3	9.2	-0.1	-1.5	10.0	9.8	-0.2	-1.5	10.3	10.1	-0.2	-1.6
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0
99.9	*Dc*	11.7	11.5	-0.2	-1.5	10.2	10.0	-0.2	-1.6	10.9	10.7	-0.2	-1.6	11.2	11.0	-0.2	-1.5
	D	12.0	12.0	0.0	0.0	10.5	10.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.2	10.0	-0.2	-1.5	8.8	8.6	-0.1	-1.6	9.4	9.3	-0.2	-1.6	9.7	9.6	-0.1	-1.5
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0
90	*Dc*	10.5	10.3	-0.2	-1.5	9.1	8.9	-0.2	-1.7	9.8	9.6	-0.2	-1.5	10.0	9.9	-0.2	-1.5
	D	10.5	10.5	0.0	0.0	9.5	9.0	-0.5	-5.3	10.0	10.0	0.0	0.0	10.5	10.0	-0.5	-4.8
95	*Dc*	11.0	10.8	-0.2	-1.5	9.5	9.4	-0.1	-1.5	10.2	10.1	-0.2	-1.6	10.5	10.3	-0.2	-1.4
	D	11.0	11.0	0.0	0.0	10.0	9.5	-0.5	-5.0	10.5	10.5	0.0	0.0	10.5	10.5	0.0	0.0
99.9	*Dc*	12.0	11.8	-0.2	-1.5	10.4	10.2	-0.2	-1.5	11.1	11.0	-0.2	-1.4	11.4	11.3	-0.2	-1.5
	D	12.0	12.0	0.0	0.0	10.5	10.5	0.0	0.0	11.5	11.0	-0.5	-4.3	11.5	11.5	0.0	0.0

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.4	10.3	-0.2	-1.4	9.0	8.9	-0.1	-1.6	9.7	9.6	-0.1	-1.5	10.0	9.8	-0.2	-1.5
	D	10.5	10.5	0.0	0.0	9.5	9.0	-0.5	-5.3	10.0	10.0	0.0	0.0	10.0	10.0	0.0	0.0
90	*Dc*	10.8	10.6	-0.2	-1.5	9.3	9.2	-0.1	-1.5	10.0	9.9	-0.1	-1.4	10.3	10.1	-0.1	-1.5
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.5	10.0	-0.5	-4.8	10.5	10.5	0.0	0.0
95	*Dc*	11.3	11.1	-0.2	-1.4	9.8	9.6	-0.1	-1.5	10.5	10.4	-0.2	-1.4	10.8	10.6	-0.1	-1.4
	D	11.5	11.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0	11.0	11.0	0.0	0.0
99.9	*Dc*	12.3	12.1	-0.2	-1.4	10.7	10.5	-0.2	-1.4	11.5	11.3	-0.2	-1.4	11.8	11.6	-0.2	-1.4
	D	12.5	12.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0	12.0	12.0	0.0	0.0

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.8	10.7	-0.2	-1.4	9.3	9.2	-0.1	-1.5	10.1	9.9	-0.2	-1.5	10.3	10.2	-0.2	-1.5
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.5	10.0	-0.5	-4.8	10.5	10.5	0.0	0.0
90	*Dc*	11.2	11.0	-0.2	-1.4	9.7	9.5	-0.2	-1.6	10.4	10.2	-0.1	-1.4	10.7	10.5	-0.2	-1.4
	D	11.5	11.0	-0.5	-4.3	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0	11.0	11.0	0.0	0.0
95	*Dc*	11.7	11.5	-0.2	-1.4	10.1	10.0	-0.2	-1.5	10.9	10.7	-0.1	-1.4	11.2	11.0	-0.2	-1.4
	D	12.0	12.0	0.0	0.0	10.5	10.0	-0.5	-4.8	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0
99.9	*Dc*	12.7	12.6	-0.2	-1.4	11.1	10.9	-0.2	-1.4	11.9	11.7	-0.2	-1.4	12.2	12.0	-0.2	-1.4
	D	13.0	13.0	0.0	0.0	11.5	11.0	-0.5	-4.3	12.0	12.0	0.0	0.0	12.5	12.0	-0.5	-4.0

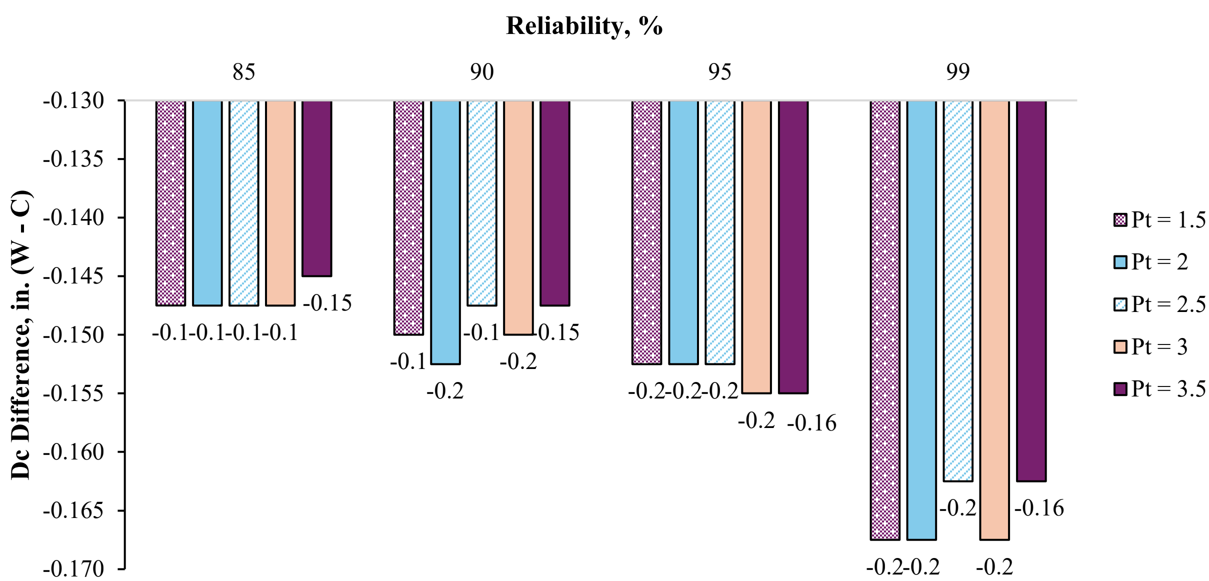
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.4	11.2	-0.2	-1.4	9.8	9.7	-0.1	-1.4	10.6	10.4	-0.1	-1.3	10.9	10.7	-0.1	-1.3
	D	11.5	11.5	0.0	0.0	10.0	10.0	0.0	0.0	11.0	10.5	-0.5	-4.5	11.0	11.0	0.0	0.0
90	*Dc*	11.7	11.6	-0.2	-1.4	10.2	10.0	-0.1	-1.4	10.9	10.8	-0.1	-1.3	11.2	11.1	-0.2	-1.3
	D	12.0	12.0	0.0	0.0	10.5	10.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0
95	*Dc*	12.3	12.1	-0.2	-1.4	10.7	10.5	-0.2	-1.4	11.4	11.3	-0.2	-1.3	11.7	11.6	-0.2	-1.3
	D	12.5	12.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0	12.0	12.0	0.0	0.0
99.9	*Dc*	13.4	13.2	-0.2	-1.3	11.6	11.5	-0.2	-1.3	12.5	12.3	-0.2	-1.3	12.8	12.6	-0.2	-1.3
	D	13.5	13.5	0.0	0.0	12.0	11.5	-0.5	-4.2	12.5	12.5	0.0	0.0	13.0	13.0	0.0	0.0

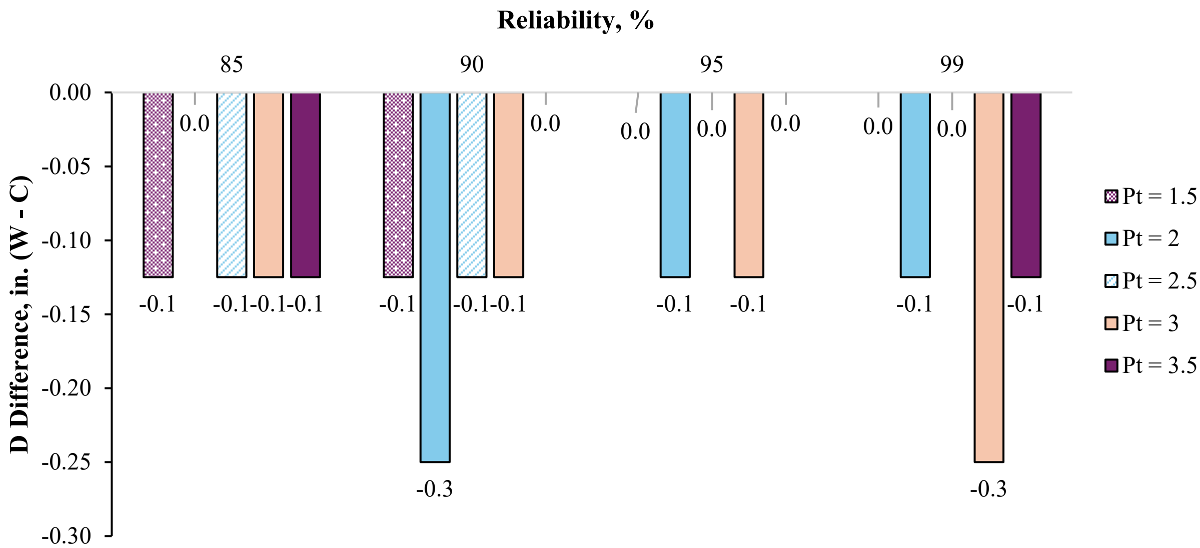
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 41(a) and **41(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At medium traffic level, the widening lane without a tied-shoulder method consistently produces slight thinner JRCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.15 inches thinner (a 1.46% decrease), and design thickness is 0.09 inches thinner (a 0.94% decrease). These results indicate that the widening lane without a tied-shoulder generally results in a slight thinner JRCP pavement design under medium-traffic conditions.



(a)



(b)

Figure 41. JRCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for medium-traffic conditions: (a) computed; (b) designed.

6.2.3 Low Traffic Condition

Table 25(a) to 25(e) present the JRCP concrete thickness designed for low-traffic condition across the four locations in Alabama, covering four reliability values and five terminal serviceability values. As observed, at the low-level traffic, the JRCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 25. Comparison of JRCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Low Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	7.4	7.3	-0.1	-1.7	-	-	-	-
	D	-	-	-	-	-	-	-	-	7.5	7.5	0.0	0.0	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	7.7	7.6	-0.1	-1.7	-	-	-	-
	D	-	-	-	-	-	-	-	-	8.0	8.0	0.0	0.0	-	-	-	-
95	*Dc*	7.4	7.3	-0.1	-1.6	7.2	7.1	-0.1	-1.8	8.1	8.0	-0.1	-1.6	7.5	7.4	-0.1	-1.6
	D	8.5	7.5	-1.0	-11.8	7.5	7.5	0.0	0.0	8.5	8.0	-0.5	-5.9	7.5	7.5	0.0	0.0
99.9	*Dc*	8.1	8.0	-0.1	-1.7	8.0	7.8	-0.1	-1.6	8.9	8.7	-0.1	-1.6	8.2	8.1	-0.1	-1.7
	D	9.5	8.0	-1.5	-15.8	8.0	8.0	0.0	0.0	9.0	9.0	0.0	0.0	8.5	8.5	0.0	0.0

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	7.6	7.5	-0.1	-1.7	-	-	-	-
	D	-	-	-	-	-	-	-	-	8.0	7.5	-0.5	-6.3	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	7.9	7.7	-0.1	-1.8	7.2	7.1	-0.1	-1.8
	D	-	-	-	-	-	-	-	-	8.0	8.0	0.0	0.0	7.5	7.5	0.0	0.0
95	*Dc*	7.5	7.4	-0.1	-1.7	7.4	7.3	-0.1	-1.6	8.3	8.1	-0.1	-1.6	7.6	7.5	-0.1	-1.7
	D	8.0	7.5	-0.5	-6.3	7.5	7.5	0.0	0.0	8.5	8.5	0.0	0.0	8.0	7.5	-0.5	-6.3
99.9	*Dc*	8.3	8.2	-0.1	-1.7	8.2	8.0	-0.1	-1.7	9.1	8.9	-0.1	-1.5	8.4	8.3	-0.1	-1.7
	D	8.5	8.5	0.0	0.0	8.5	8.5	0.0	0.0	9.5	9.0	-0.5	-5.3	8.5	8.5	0.0	0.0

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	7.8	7.7	-0.1	-1.7	7.1	7.0	-0.1	-1.8
	D	-	-	-	-	-	-	-	-	8.0	8.0	0.0	0.0	7.5	7.0	-0.5	-6.7
90	*Dc*	7.3	7.2	-0.1	-1.8	7.2	7.0	-0.1	-2.0	8.1	7.9	-0.1	-1.7	7.4	7.3	-0.1	-1.8
	D	7.5	7.5	0.0	0.0	7.5	7.5	0.0	0.0	8.5	8.0	-0.5	-5.9	7.5	7.5	0.0	0.0
95	*Dc*	7.7	7.6	-0.1	-1.7	7.6	7.4	-0.1	-1.7	8.5	8.4	-0.1	-1.6	7.8	7.7	-0.1	-1.7
	D	8.0	8.0	0.0	0.0	8.0	7.5	-0.5	-6.3	8.5	8.5	0.0	0.0	8.0	8.0	0.0	0.0
99.9	*Dc*	8.5	8.4	-0.1	-1.5	8.4	8.2	-0.1	-1.6	9.3	9.2	-0.1	-1.5	8.6	8.5	-0.1	-1.6
	D	9.0	8.5	-0.5	-5.6	8.5	8.5	0.0	0.0	9.5	9.5	0.0	0.0	9.0	8.5	-0.5	-5.6

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.3	7.1	-0.1	-1.9	-	-	-	-	8.1	7.9	-0.1	-1.6	7.4	7.2	-0.1	-1.8
	D	7.5	7.5	0.0	0.0	-	-	-	-	8.5	8.0	-0.5	-5.9	7.5	7.5	0.0	0.0
90	*Dc*	7.6	7.4	-0.1	-1.9	7.4	7.3	-0.1	-1.9	8.4	8.2	-0.1	-1.7	7.7	7.5	-0.1	-1.7
	D	8.0	7.5	-0.5	-6.3	7.5	7.5	0.0	0.0	8.5	8.5	0.0	0.0	8.0	8.0	0.0	0.0
95	*Dc*	8.0	7.9	-0.1	-1.8	7.8	7.7	-0.1	-1.7	8.8	8.7	-0.1	-1.6	8.1	8.0	-0.1	-1.7
	D	8.0	8.0	0.0	0.0	8.0	8.0	0.0	0.0	9.0	9.0	0.0	0.0	8.5	8.0	-0.5	-5.9
99.9	*Dc*	8.8	8.7	-0.1	-1.5	8.7	8.5	-0.1	-1.6	9.7	9.5	-0.1	-1.4	9.0	8.8	-0.1	-1.5
	D	9.0	9.0	0.0	0.0	9.0	9.0	0.0	0.0	10.0	10.0	0.0	0.0	9.0	9.0	0.0	0.0

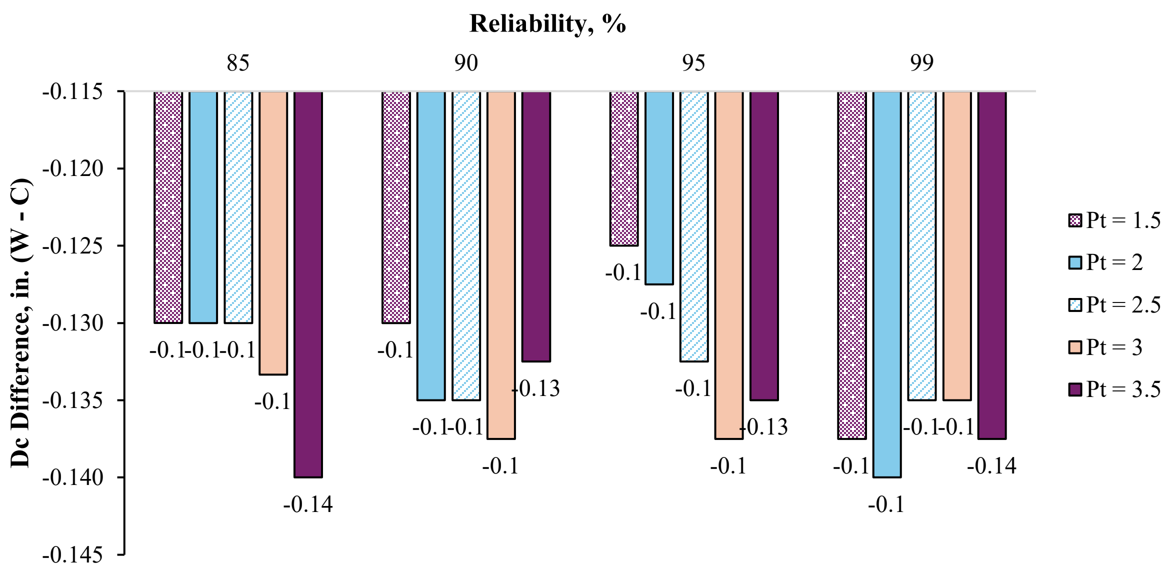
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	7.7	7.5	-0.1	-1.8	7.5	7.3	-0.1	-1.9	8.5	8.4	-0.1	-1.6	7.8	7.6	-0.1	-1.8
	D	8.0	8.0	0.0	0.0	7.5	7.5	0.0	0.0	8.5	8.5	0.0	0.0	8.0	8.0	0.0	0.0
90	*Dc*	8.0	7.8	-0.1	-1.8	7.8	7.7	-0.1	-1.7	8.8	8.7	-0.1	-1.5	8.1	8.0	-0.1	-1.6
	D	8.0	8.0	0.0	0.0	8.0	8.0	0.0	0.0	9.0	9.0	0.0	0.0	8.5	8.0	-0.5	-5.9
95	*Dc*	8.4	8.3	-0.1	-1.5	8.3	8.1	-0.1	-1.6	9.3	9.1	-0.1	-1.5	8.6	8.4	-0.1	-1.6
	D	8.5	8.5	0.0	0.0	8.5	8.5	0.0	0.0	9.5	9.5	0.0	0.0	9.0	8.5	-0.5	-5.6
99.9	*Dc*	9.3	9.2	-0.1	-1.5	9.1	9.0	-0.1	-1.4	10.2	10.0	-0.2	-1.5	9.4	9.3	-0.1	-1.4
	D	9.5	9.5	0.0	0.0	9.5	9.5	0.0	0.0	10.5	10.5	0.0	0.0	9.5	9.5	0.0	0.0

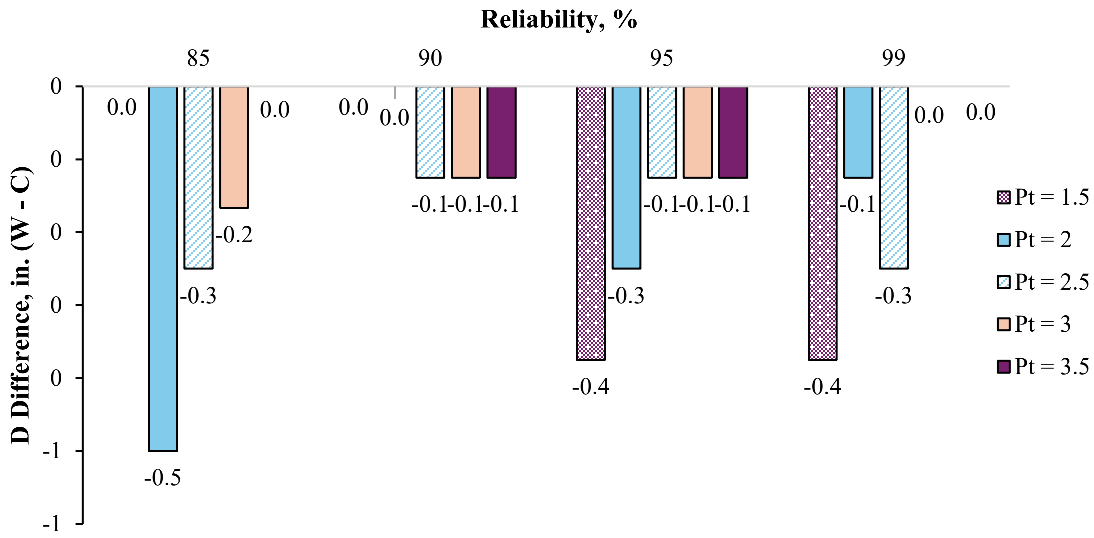
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 42(a) and **42(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At low traffic level, the widening lane without a tied-shoulder method consistently produces thinner JRCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.13 inches thinner (a 1.67% decrease), and the design thickness is 0.15 inches thinner (a 1.8% decrease). After rounding, the difference becomes insignificant. These results indicate that the widening lane without a tied-shoulder generally results in a thinner JRCP pavement design under low-traffic conditions.



(a)



(b)

Figure 42. JRCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for low-traffic conditions: (a) computed; (b) designed.

6.3 CRCP Concrete Thickness Differences Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder

This section presents the design of JRCP slab thickness using the AASHTO 1998 design method for various levels of reliability and terminal serviceability for four locations.

6.3.1 High Traffic Condition

Table 26(a) to 26(e) present the CRCP concrete thickness designed for high-traffic condition across the four locations in Alabama, covering four reliability values (85%, 90%, 95%, and 99.9%) and five terminal serviceability values (1.5, 2.0, 2.5, 3.0 and 3.5). At high traffic level, the CRCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 26. Comparison of CRCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for High Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.5	10.3	-0.2	-1.5	10.5	10.3	-0.2	-1.5	9.8	9.6	-0.2	-1.6	10.4	10.3	-0.1	-1.3
	D	10.5	10.5	0.0	0.0	10.5	10.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0
90	*Dc*	10.8	10.7	-0.2	-1.6	10.8	10.7	-0.2	-1.6	10.1	10.0	-0.2	-1.6	10.8	10.6	-0.2	-1.7
	D	11.0	11.0	0.0	0.0	11.0	11.0	0.0	0.0	10.5	10.0	-0.5	-4.8	11.0	11.0	0.0	0.0
95	*Dc*	11.4	11.2	-0.2	-1.6	11.4	11.2	-0.2	-1.6	10.6	10.4	-0.2	-1.6	11.3	11.1	-0.2	-1.9
	D	11.5	11.5	0.0	0.0	11.5	11.5	0.0	0.0	11.0	10.5	-0.5	-4.5	11.5	11.5	0.0	0.0
99.9	*Dc*	12.4	12.2	-0.2	-1.5	12.4	12.2	-0.2	-1.5	11.6	11.4	-0.2	-1.6	12.4	12.2	-0.2	-1.2
	D	12.5	12.5	0.0	0.0	12.5	12.5	0.0	0.0	12.0	11.5	-0.5	-4.2	12.5	12.5	0.0	0.0

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.8	10.6	-0.2	-1.5	10.8	10.6	-0.2	-1.6	10.4	9.9	-0.5	-4.9	10.7	10.6	-0.1	-1.1
	D	11.0	11.0	0.0	0.0	11.0	11.0	0.0	0.0	10.5	10.0	-0.5	-4.8	11.0	11.0	0.0	0.0
90	*Dc*	11.1	11.0	-0.2	-1.5	11.1	11.0	-0.2	-1.5	10.4	10.2	-0.1	-1.4	11.1	10.9	-0.2	-1.5
	D	11.5	11.0	-0.5	-4.3	11.5	11.0	-0.5	-4.3	10.5	10.5	0.0	0.0	11.5	11.0	-0.5	-4.3
95	*Dc*	11.7	11.5	-0.2	-1.5	11.7	11.5	-0.2	-1.5	10.9	10.7	-0.2	-1.5	11.6	11.4	-0.2	-1.8
	D	12.0	11.5	-0.5	-4.2	12.0	11.5	-0.5	-4.2	11.0	11.0	0.0	0.0	12.0	11.5	-0.5	-4.2
99.9	*Dc*	12.7	12.5	-0.2	-1.5	12.7	12.6	-0.2	-1.5	11.9	11.7	-0.2	-1.5	12.7	12.5	-0.2	-1.4
	D	13.0	13.0	0.0	0.0	13.0	13.0	0.0	0.0	12.0	12.0	0.0	0.0	13.0	12.5	-0.5	-3.8

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.1	11.0	-0.2	-1.4	11.1	11.0	-0.2	-1.5	10.4	10.2	-0.1	-1.4	11.1	10.9	-0.2	-1.5
	D	11.5	11.0	-0.5	-4.3	11.5	11.0	-0.5	-4.3	10.5	10.5	0.0	0.0	11.5	11.0	-0.5	-4.3
90	*Dc*	11.5	11.3	-0.2	-1.4	11.5	11.3	-0.2	-1.5	10.7	10.6	-0.2	-1.5	11.4	11.3	-0.1	-1.1
	D	11.5	11.5	0.0	0.0	11.5	11.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0
95	*Dc*	12.0	11.9	-0.2	-1.5	12.0	11.9	-0.2	-1.5	11.2	11.7	0.5	4.1	12.0	11.8	-0.2	-1.5
	D	12.5	12.0	-0.5	-4.0	12.5	12.0	-0.5	-4.0	11.5	12.0	0.5	4.3	12.0	12.0	0.0	0.0
99.9	*Dc*	13.1	13.0	-0.2	-1.4	13.2	13.0	-0.2	-1.4	12.3	12.1	-0.2	-1.5	13.1	12.9	-0.2	-1.5
	D	13.5	13.0	-0.5	-3.7	13.5	13.0	-0.5	-3.7	12.5	12.5	0.0	0.0	13.5	13.0	-0.5	-3.7

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	11.6	11.4	-0.2	-1.4	11.6	11.4	-0.2	-1.5	10.8	10.7	-0.2	-1.5	11.5	11.4	-0.1	-1.1
	D	12.0	11.5	-0.5	-4.2	12.0	11.5	-0.5	-4.2	11.0	11.0	0.0	0.0	12.0	11.5	-0.5	-4.2
90	*Dc*	12.0	11.8	-0.2	-1.4	12.0	11.8	-0.2	-1.4	11.2	11.0	-0.2	-1.5	11.9	11.8	-0.1	-0.9
	D	12.0	12.0	0.0	0.0	12.0	12.0	0.0	0.0	11.5	11.0	-0.5	-4.3	12.0	12.0	0.0	0.0
95	*Dc*	12.5	12.4	-0.2	-1.4	12.5	12.4	-0.2	-1.4	11.7	11.5	-0.2	-1.5	12.5	12.3	-0.2	-1.5
	D	13.0	12.5	-0.5	-3.8	13.0	12.5	-0.5	-3.8	12.0	12.0	0.0	0.0	12.5	12.5	0.0	0.0
99.9	*Dc*	13.7	13.5	-0.2	-1.5	13.7	13.5	-0.2	-1.5	12.8	12.6	-0.2	-1.4	13.6	13.5	-0.1	-1.0
	D	14.0	13.5	-0.5	-3.6	14.0	14.0	0.0	0.0	13.0	13.0	0.0	0.0	14.0	13.5	-0.5	-3.6

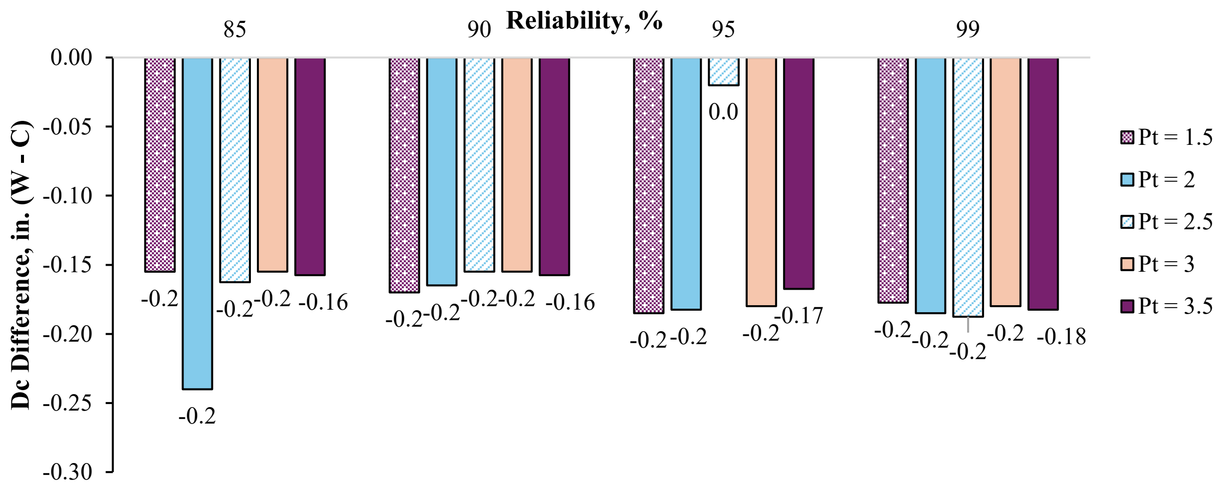
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	12.3	12.1	-0.2	-1.4	12.3	12.1	-0.2	-1.4	11.5	11.3	-0.2	-1.4	12.2	12.1	-0.1	-1.1
	D	12.5	12.5	0.0	0.0	12.5	12.5	0.0	0.0	11.5	11.5	0.0	0.0	12.5	12.5	0.0	0.0
90	*Dc*	12.7	12.5	-0.2	-1.3	12.7	12.5	-0.2	-1.4	11.8	11.7	-0.2	-1.4	12.6	12.5	-0.1	-1.0
	D	13.0	12.5	-0.5	-3.8	13.0	12.5	-0.5	-3.8	12.0	12.0	0.0	0.0	13.0	12.5	-0.5	-3.8
95	*Dc*	13.3	13.1	-0.2	-1.4	13.3	13.1	-0.2	-1.4	12.4	12.3	-0.2	-1.4	13.2	13.1	-0.1	-1.1
	D	13.5	13.5	0.0	0.0	13.5	13.5	0.0	0.0	12.5	12.5	0.0	0.0	13.5	13.5	0.0	0.0
99.9	*Dc*	14.5	14.3	-0.2	-1.4	14.5	14.3	-0.2	-1.4	13.6	13.4	-0.2	-1.3	14.5	14.3	-0.1	-1.0
	D	14.5	14.5	0.0	0.0	15.0	14.5	-0.5	-3.3	14.0	12.5	-1.5	-10.7	15.0	14.5	-0.5	-3.3

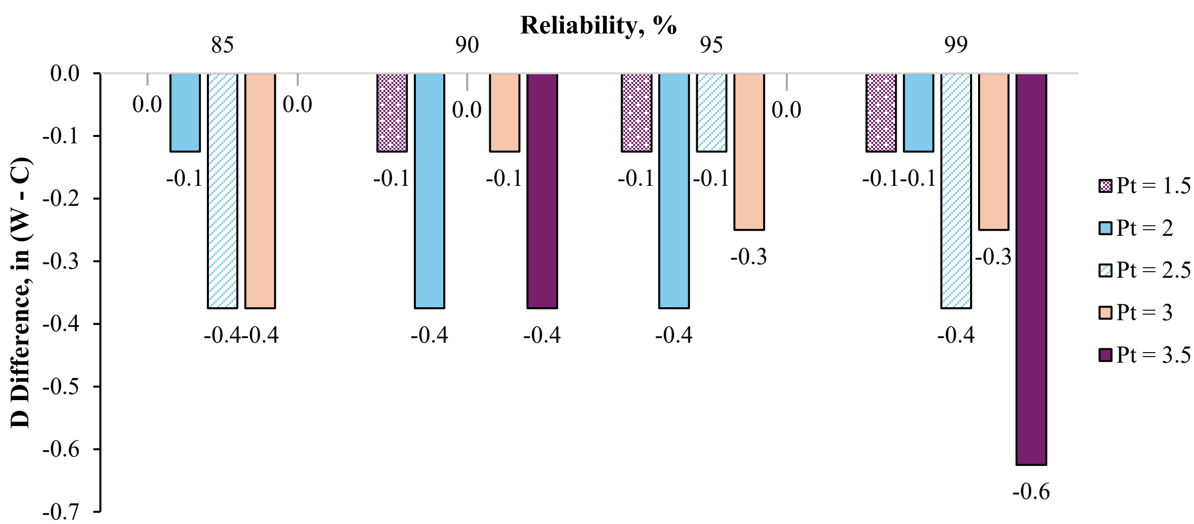
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$

Figures 43(a) and **43(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At high traffic level, the widening lane without a tied-shoulder method consistently produces thinner CRCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.17 inches thinner (a 1.41% decrease), and design thickness is 0.21 inches thinner (a 1.7% decrease). These results indicate that the widening lane without a tied-shoulder generally results in a thinner CRCP pavement design under high-traffic conditions.



(a)



(b)

Figure 43. CRCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for high-traffic conditions: (a) computed; (b) designed.

6.3.2 Medium Traffic Condition

Table 27(a) to 27(e) present the CRCP concrete thickness designed for medium-traffic condition across the four locations in Alabama, covering four reliability values (85%, 90%, 95%, and 99.9%) and five terminal serviceability values (1.5, 2.0, 2.5, 3.0 and 3.5). At medium traffic level, the CRCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 27. Comparison of CRCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Medium Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.6	8.5	-0.1	-1.5	7.3	7.2	-0.1	-1.6	7.8	7.6	-0.1	-1.7	8.0	7.9	-0.1	-1.5
	D	9.0	8.5	-0.5	-5.6	7.5	7.5	0.0	0.0	8.0	8.0	0.0	0.0	8.5	8.0	-0.5	-5.9
90	*Dc*	8.9	8.8	-0.1	-1.6	7.6	7.5	-0.1	-1.6	8.0	7.9	-0.1	-1.5	8.3	8.2	-0.1	-1.6
	D	9.0	9.0	0.0	0.0	8.0	7.5	-0.5	-6.3	8.5	8.0	-0.5	-5.9	8.5	8.5	0.0	0.0
95	*Dc*	9.4	9.2	-0.1	-1.6	8.0	7.8	-0.1	-1.6	8.4	8.3	-0.1	-1.5	9.2	8.7	-0.4	-4.9
	D	9.5	9.5	0.0	0.0	9.0	8.0	-1.0	-11.1	8.5	8.5	0.0	0.0	9.5	9.0	-0.5	-5.3
99.9	*Dc*	10.2	10.1	-0.2	-1.6	8.7	8.6	-0.1	-1.6	9.2	9.1	-0.2	-1.6	10.0	9.5	-0.5	-4.9
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.5	10.0	-0.5	-4.8

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	8.9	8.7	-0.1	-1.6	7.5	7.4	-0.1	-1.6	8.0	7.8	-0.1	-1.6	8.2	8.1	-0.1	-1.6
	D	9.0	9.0	0.0	0.0	7.5	7.5	0.0	0.0	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0
90	*Dc*	9.1	9.0	-0.1	-1.5	7.8	7.6	-0.1	-1.5	8.2	8.1	-0.1	-1.6	8.5	8.4	-0.1	-1.4
	D	9.5	9.0	-0.5	-5.3	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	8.5	-0.5	-5.6
95	*Dc*	9.6	9.5	-0.1	-1.5	8.2	8.0	-0.1	-1.6	8.6	8.5	-0.1	-1.6	8.9	8.8	-0.1	-1.5
	D	10.0	9.5	-0.5	-5.0	8.5	8.5	0.0	0.0	9.0	8.5	-0.5	-5.6	9.0	9.0	0.0	0.0
99.9	*Dc*	10.5	10.3	-0.2	-1.4	9.0	8.8	-0.1	-1.6	9.5	9.3	-0.1	-1.5	9.8	9.7	-0.1	-1.4
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.1	8.9	-0.2	-2.5	7.7	7.6	-0.1	-1.7	8.2	8.1	-0.1	-1.7	8.5	8.4	-0.1	-1.4
	D	9.5	9.0	-0.5	-5.3	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0	8.5	8.5	0.0	0.0
90	*Dc*	9.4	9.3	-0.1	-1.5	8.0	7.9	-0.1	-1.5	8.5	8.4	-0.1	-1.5	8.8	8.7	-0.1	-1.5
	D	9.5	9.5	0.0	0.0	8.0	8.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	9.0	0.0	0.0
95	*Dc*	9.9	9.8	-0.2	-1.5	8.4	8.3	-0.1	-1.5	8.9	8.8	-0.1	-1.5	9.2	9.1	-0.1	-1.5
	D	10.0	10.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0
99.9	*Dc*	10.8	10.7	-0.2	-1.5	9.2	9.1	-0.1	-1.5	9.8	9.6	-0.2	-1.5	10.1	10.0	-0.1	-1.5
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.0	-0.5	-4.8

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	9.5	9.4	-0.1	-1.5	8.0	7.9	-0.1	-1.6	8.5	8.4	-0.1	-1.6	8.9	8.7	-0.1	-1.5
	D	9.5	9.5	0.0	0.0	8.5	8.0	-0.5	-5.9	9.0	8.5	-0.5	-5.6	9.0	9.0	0.0	0.0
90	*Dc*	9.8	9.7	-0.2	-1.5	8.3	8.2	-0.1	-1.6	8.8	8.7	-0.1	-1.6	9.2	9.0	-0.1	-1.4
	D	10.0	10.0	0.0	0.0	8.5	8.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0
95	*Dc*	10.3	10.2	-0.2	-1.5	8.8	8.6	-0.1	-1.6	9.3	9.2	-0.1	-1.5	9.6	9.5	-0.1	-1.5
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	9.5	-0.5	-5.0
99.9	*Dc*	11.3	11.1	-0.2	-1.5	9.6	9.5	-0.1	-1.5	10.2	10.0	-0.2	-1.5	10.5	10.4	-0.1	-1.2
	D	11.5	11.5	0.0	0.0	10.0	9.5	-0.5	-5.0	10.5	10.5	0.0	0.0	11.0	10.5	-0.5	-4.5

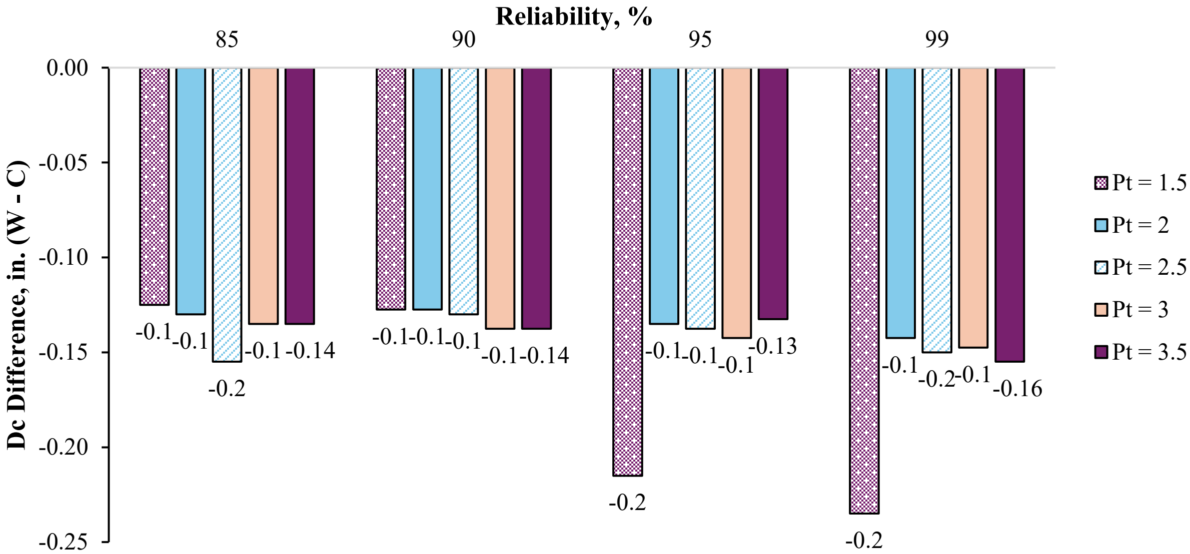
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	10.1	9.9	-0.1	-1.4	8.5	8.4	-0.1	-1.5	9.1	8.9	-0.1	-1.5	9.4	9.3	-0.1	-1.4
	D	10.5	10.0	-0.5	-4.8	9.0	8.5	-0.5	-5.6	9.5	9.0	-0.5	-5.3	9.5	9.5	0.0	0.0
90	*Dc*	10.4	10.3	-0.1	-1.3	8.8	8.7	-0.1	-1.5	9.4	9.2	-0.1	-1.5	9.7	9.6	-0.1	-1.4
	D	10.5	10.5	0.0	0.0	9.0	9.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0
95	*Dc*	10.9	10.8	-0.2	-1.4	9.3	9.2	-0.1	-1.5	9.9	9.7	-0.1	-1.4	10.2	10.1	-0.1	-1.0
	D	11.0	11.0	0.0	0.0	9.5	9.5	0.0	0.0	10.0	10.0	0.0	0.0	10.5	10.5	0.0	0.0
99.9	*Dc*	11.9	11.8	-0.2	-1.3	10.2	10.1	-0.1	-1.4	10.8	10.7	-0.2	-1.4	11.2	11.0	-0.2	-1.5
	D	12.0	12.0	0.0	0.0	10.5	10.5	0.0	0.0	11.0	11.0	0.0	0.0	11.5	11.5	0.0	0.0

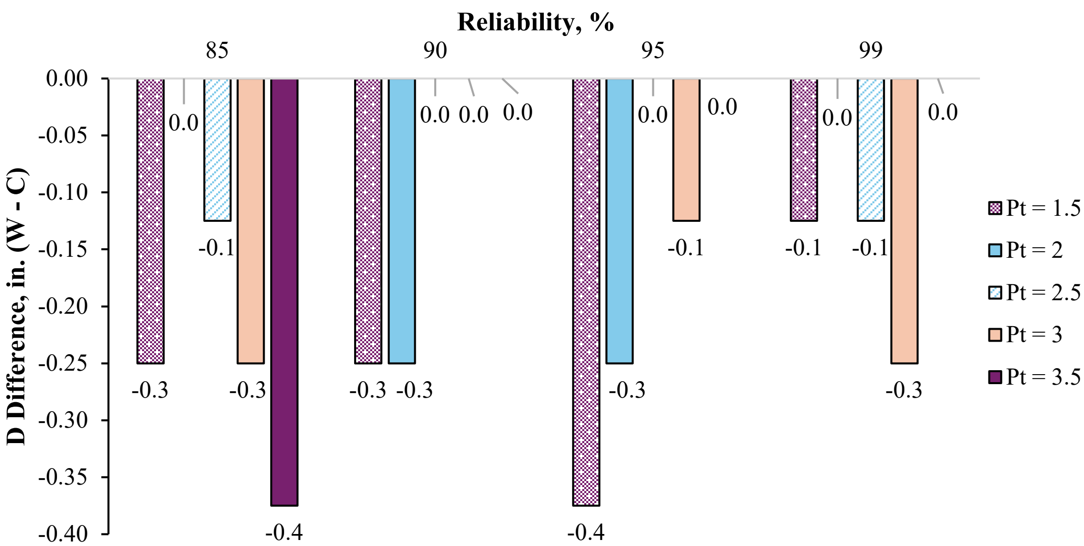
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 44(a) and **44(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At medium traffic level, the widening lane without a tied-shoulder method consistently produces slight thinner CRCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.15 inches thinner (a 1.6% decrease), and design thickness is 0.14 inches thinner (a 1.47% decrease). These results indicate that the widening lane without a tied-shoulder generally results in a slight thinner CRCP pavement design under medium-traffic conditions.



(a)



(b)

Figure 44. CRCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for medium-traffic conditions: (a) computed; (b) designed.

6.3.3 Low Traffic Condition

Table 28(a) to 28(e) present the CRCP concrete thickness designed for low-traffic condition across the four locations in Alabama, covering four reliability values and five terminal serviceability values. At low traffic level, the CRCP thickness designed for widened lanes with non-tied shoulders is smaller than that for conventional lanes with tied shoulders.

Table 28. Comparison of CRCP Concrete Thickness Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Low Traffic Condition

(a) Pt = 1.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	-	-	-	-	-	-	-	-	7.5	7.4	-0.1	-1.6	-	-	-	-
	D	9.5	8.0	-1.5	-15.8	8.0	8.0	0.0	0.0	9.0	9.0	0.0	0.0	8.5	8.5	0.0	0.0

(b) Pt = 2.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	*Dc*	7.2	7.1	-0.1	-1.7	-	-	-	-	7.6	7.5	-0.1	-1.6	-	-	-	-
	D	7.5	7.5	0.0	0.0	-	-	-	-	8.0	8.0	0.0	0.0	-	-	-	-

(c) Pt = 2.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	7.1	7.0	-0.1	-1.7	-	-	-	-
	D	-	-	-	-	-	-	-	-	7.5	7.5	0.0	0.0	-	-	-	-
99.9	*Dc*	7.4	7.3	-0.1	-1.6	7.2	7.0	-0.1	-1.7	7.9	7.7	-0.1	-1.7	7.3	7.2	-0.1	-1.5
	D	7.5	7.5	0.0	0.0	7.5	7.5	0.0	0.0	8.0	8.0	0.0	0.0	7.5	7.5	0.0	0.0

(d) Pt = 3.0

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	*Dc*	-	-	-	-	-	-	-	-	7	7	0	-2	-	-	-	-
	D	-	-	-	-	-	-	-	-	8	8	0	0	-	-	-	-
99.9	*Dc*	7.7	7.5	-0.1	-1.7	7.4	7.3	-0.1	-1.6	8.2	8.1	-0.1	-1.6	7.6	7.4	-0.1	-1.6
	D	8.0	8.0	0.0	0.0	7.5	7.5	0.0	0.0	8.5	8.5	0.0	0.0	8.0	7.5	-0.5	-6.3

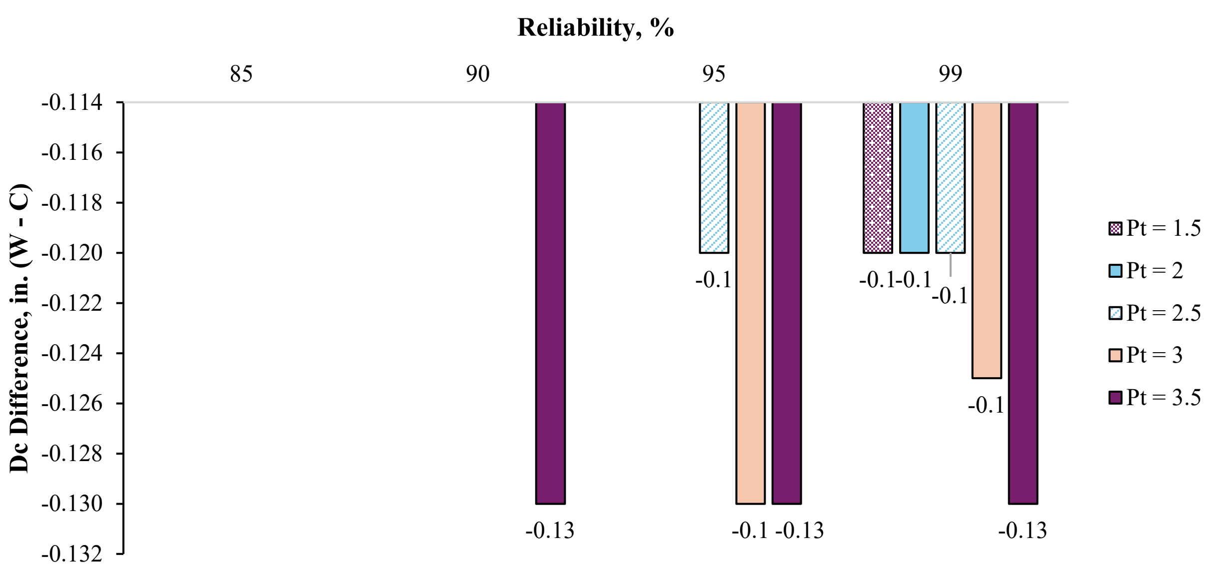
(e) Pt = 3.5

Location		Mobile				Montgomery				Birmingham				Huntsville			
R, %	Value	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.	C (in.)	W (in.)	Diff. (in.)	% Diff.
85	*Dc*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Dc*	-	-	-	-	-	-	-	-	7.4	7.3	-0.1	-1.8	-	-	-	-
	D	-	-	-	-	-	-	-	-	7.5	7.5	0.0	0.0	-	-	-	-
95	*Dc*	7.3	7.1	-0.1	-1.8	-	-	-	-	7.8	7.7	-0.1	-1.7	-	-	-	-
	D	7.5	7.5	0.0	0.0	-	-	-	-	8.0	8.0	0.0	0.0	-	-	-	-
99.9	*Dc*	8.1	8.0	-0.1	-1.6	7.9	7.7	-0.1	-1.7	8.7	8.6	-0.1	-1.5	8.0	7.9	-0.1	-1.6
	D	8.5	8.0	-0.5	-5.9	8.0	8.0	0.0	0.0	9.0	9.0	0.0	0.0	8.5	8.0	-0.5	-5.9

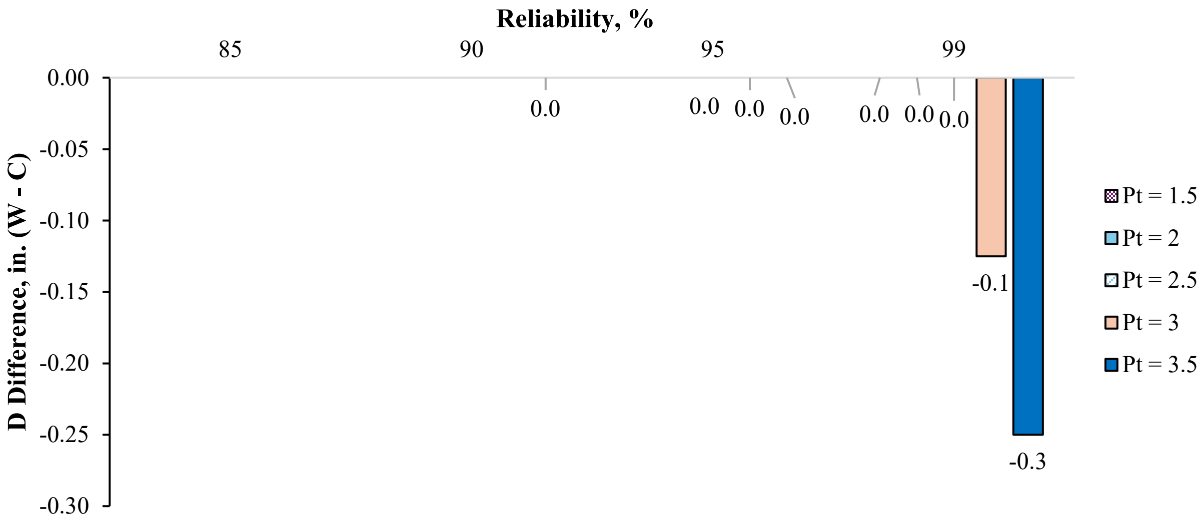
Note:

- Diff. = Thickness designed for widened lane with non-tied shoulder (W) – thickness designed for conventional lane with tied shoulder (C)
- $\% \text{ Diff.} = \frac{W - C}{C} \times 100\%$
- ***Dc*** represents the calculated thickness obtained from equations or software;
- ***D*** represents the designed thickness (rounded to 0.5 inches).

Figures 45(a) and **45(b)** illustrate the average differences in computed and rounded design thicknesses, respectively. At low traffic level, the widening lane without a tied-shoulder method consistently produces thinner CRCP pavements than the conventional lane without a tied-shoulder for both computed and rounded design values. On average, the computed thickness is 0.13 inches thinner (a 1.67% decrease), and the design thickness is 0.04 inches thinner (a 0.5% decrease). After rounding, the difference becomes insignificant. These results indicate that the widening lane without a tied-shoulder generally results in a thinner CRCP pavement design under low-traffic conditions.



(a)



(b)

Figure 45. CRCP concrete thickness differences between conventional lane with tied shoulder and widened lane with non-tied shoulder for low-traffic conditions: (a) computed; (b) designed.

6.4 Chapter Summary

This chapter presented a comparative analysis of pavement thickness for conventional lanes with tied shoulders and widened lanes without tied shoulders for JPCP, JRCP, and CRCP under varying traffic levels, reliability levels, and terminal serviceability indices. Across all pavement types and traffic conditions, the widening lane without a tied-shoulder generally resulted in slightly thinner pavements compared to conventional lanes.

For JPCP, the computed thickness reductions ranged from 0.13 to 0.17 inches, with design thickness reductions between 0.04 and 0.19 inches. These differences correspond to approximately 0.5% to 1.6% decreases and were largely negligible after rounding.

For JRCP, the computed thickness was reduced by 0.13 to 0.19 inches, and design thickness reductions ranged from 0.09 to 0.21 inches, corresponding to decreases of about 0.94% to 1.8%. Differences after rounding were generally insignificant under low-traffic conditions.

For CRCP, computed thickness reductions ranged from 0.13 to 0.17 inches, and design thickness reductions ranged from 0.04 to 0.21 inches, representing decreases of approximately 0.5% to 1.7%. Rounding further minimized practical differences.

Overall, while widening lanes without tied shoulders consistently leads to thinner pavement designs for all pavement types and traffic levels, the differences are small (less than 0.5 inches), indicating minimal practical impact on pavement performance. These findings suggest that lane widening without tied shoulders can achieve slightly more economical designs without significantly affecting pavement thickness or structural adequacy.

In conventional lanes with tied shoulders, the shoulder is considered to provide additional lateral support to the slab. This reduces slab bending at the edges but increases stresses transferred to the pavement. To accommodate the expected stresses, the design often results in slightly thicker slabs. In contrast, non-tied shoulders are assumed to provide minimal or no edge support, so the slab is considered to act more independently. The design accounts for this by slightly reducing the slab thickness, as the stress distribution is more uniform across the widened lane. In addition, widened lanes distribute wheel loads over a larger pavement width. This effectively reduces the stress per unit width in the concrete slab because the wheel load is shared across a wider area. Lower stresses mean the design does not require as much thickness to achieve the same performance level.

The difference is typically less than 0.5 inches (approximately 1-2%), indicating that although the widened lanes are technically thinner, the practical effect on structural performance is negligible. This confirms that the thinner design is due to better load-sharing rather than under-design.

The reasons for the thicker design of conventional lanes with tied shoulders may include:

(a) Lateral restraint effects: Tied shoulders reduce deflection and stress concentrations, but they also provide lateral restraint to the pavement. This can contribute to fatigue and structural failure under repeated traffic loads, necessitating a thicker pavement (NCHRP, 2008).

(b) Maintenance reduction: Thicker slabs with tied shoulders are better able to resist environmental wear and traffic loads, reducing maintenance needs (FHWA, 2016).

(c) Thermal expansion control: Tied shoulders help control thermal expansion, which requires a thicker slab to distribute stresses effectively and prevent joint openings (FHWA, 2016).

7. COMPARATIVE COST ANALYSIS OF CONCRETE PAVEMENT DESIGN BETWEEN AASHTO 1993 AND AASHTO 1998

This chapter presents a comparative cost analysis of concrete pavements designed using the AASHTO 1993 and AASHTO 1998 methods for JPCP, JRCP, and CRCP. The comparison is conducted across reliability levels ranging from 85% to 99.9% and terminal serviceability indices from 1.5 to 3.5 for four locations in Alabama.

7.1 JPCP Concrete Cost Differences Between AASHTO 1998 and 1993

The comparison between the two design methods was conducted for JPCP with a joint spacing of 15 feet. This section presents the design thickness of JPCP slabs under varying reliability and terminal serviceability conditions for four locations: Mobile, Montgomery, Birmingham, and Huntsville. Traffic volume and climate data for these locations, as described in Chapter 3, were used in this comparative analysis. This cost analysis covers the estimate of pavement materials only; all other construction costs are assumed equal for both design methods.

7.1.1 High Traffic Condition

Table 29(a) to 29(e) present the 1-mile JPCP concrete costs under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. The costs in the tables are calculated based on the designed slab thickness, rounded up to the nearest 0.5-inch increment, which reflects standard design practice.

As observed, the cost of JPCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 31% to 35%, with an average increase of $233,188 (approximately 32%).

Table 29. Comparison of JPCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for High Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	428,276	634,341	206,065	32	428,276	634,341	206,065	32	406,285	605,019	198,735	33	428,276	634,341	206,065	32
90	450,267	663,663	213,396	32	450,267	663,663	213,396	32	428,276	634,341	206,065	32	450,267	663,663	213,396	32
95	472,258	692,984	220,726	32	472,258	692,984	220,726	32	450,267	663,663	213,396	32	472,258	692,984	220,726	32
99	516,241	751,627	235,387	31	516,241	751,627	235,387	31	494,249	663,663	169,413	26	516,241	751,627	235,387	31

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	450,267	663,663	213,396	32	450,267	663,663	213,396	32	428,276	634,341	206,065	32	450,267	663,663	213,396	32
90	450,267	692,984	242,717	35	450,267	692,984	242,717	35	428,276	634,341	206,065	32	472,258	692,984	220,726	32
95	472,258	722,306	250,048	35	472,258	722,306	250,048	35	450,267	663,663	213,396	32	494,249	722,306	228,056	32
99.9	516,241	780,949	264,708	34	538,232	780,949	242,717	31	494,249	722,306	228,056	32	538,232	780,949	242,717	31

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	450,267	692,984	242,717	35	472,258	692,984	220,726	32	428,276	634,341	206,065	32	472,258	692,984	220,726	32
90	472,258	692,984	220,726	32	472,258	692,984	220,726	32	450,267	663,663	213,396	32	472,258	692,984	220,726	32
95	494,249	751,627	257,378	34	494,249	751,627	257,378	34	472,258	692,984	220,726	32	494,249	722,306	228,056	32
99.9	538,232	810,271	272,039	34	538,232	810,271	272,039	34	516,241	751,627	235,387	31	538,232	810,271	272,039	34

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	472,258	722,306	250,048	35	494,249	722,306	228,056	32	450,267	663,663	213,396	32	494,249	722,306	228,056	32
90	494,249	722,306	228,056	32	494,249	722,306	228,056	32	472,258	692,984	220,726	32	494,249	722,306	228,056	32
95	516,241	780,949	264,708	34	516,241	780,949	264,708	34	494,249	722,306	228,056	32	516,241	751,627	235,387	31
99.9	560,223	839,592	279,369	33	582,214	839,592	257,378	31	538,232	780,949	242,717	31	582,214	839,592	257,378	31

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	516,241	751,627	235,387	31	516,241	751,627	235,387	31	494,249	692,984	198,735	29	516,241	751,627	235,387	31
90	516,241	780,949	264,708	34	538,232	780,949	242,717	31	494,249	722,306	228,056	32	538,232	780,949	242,717	31
95	560,223	810,271	250,048	31	560,223	810,271	250,048	31	538,232	751,627	213,396	28	560,223	810,271	250,048	31
99.9	604,205	868,914	264,708	30	604,205	898,235	294,030	33	582,214	839,592	257,378	31	604,205	868,914	264,708	30

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- % Diff. $= \frac{Cost\ designed\ by AASHTO 1998 - Cost\ designed\ by\ AASHTO\ 1993}{Cost\ designed\ by\ AASHTO\ 1993} \times 100\%$

7.1.2 Medium Traffic Condition

Table 30(a) to 30(e) present the JPCP concrete cost for medium-traffic condition across the four locations. The JPCP cost estimated by AASHTO 1998 is consistently higher than that by AASHTO 1993 across all reliability levels, Pt values, and locations, showing an average increase of $189,572 (33%), ranging from 32% to 38%.

Table 30. Comparison of JPCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for Medium Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	340,311	546,376	206,065	38	296,329	458,411	162,083	35	318,320	487,733	169,413	35	340,311	517,055	176,744	34
90	362,302	546,376	184,074	34	318,320	487,733	169,413	35	340,311	517,055	176,744	34	340,311	517,055	176,744	34
95	384,293	575,698	191,404	33	318,320	487,733	169,413	35	362,302	517,055	154,752	30	362,302	575,698	213,396	37
99.9	406,285	634,341	228,056	36	362,302	546,376	184,074	34	384,293	575,698	191,404	33	406,285	634,341	228,056	36

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	362,302	546,376	184,074	34	318,320	458,411	140,092	31	340,311	487,733	147,422	30	340,311	517,055	176,744	34
90	362,302	575,698	213,396	37	318,320	487,733	169,413	35	340,311	517,055	176,744	34	362,302	546,376	184,074	34
95	384,293	605,019	220,726	36	340,311	517,055	176,744	34	362,302	546,376	184,074	34	362,302	546,376	184,074	34
99.9	428,276	634,341	206,065	32	362,302	546,376	184,074	34	406,285	575,698	169,413	29	406,285	605,019	198,735	33

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	362,302	575,698	213,396	37	318,320	487,733	169,413	35	340,311	517,055	176,744	34	362,302	517,055	154,752	30
90	384,293	575,698	191,404	33	318,320	487,733	169,413	35	362,302	517,055	154,752	30	362,302	546,376	184,074	34
95	406,285	605,019	198,735	33	340,311	517,055	176,744	34	384,293	546,376	162,083	30	384,293	575,698	191,404	33
99.9	450,267	663,663	213,396	32	384,293	575,698	191,404	33	406,285	605,019	198,735	33	428,276	634,341	206,065	32

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	384,293	575,698	191,404	33	340,311	517,055	176,744	34	362,302	546,376	184,074	34	362,302	546,376	184,074	34
90	406,285	605,019	198,735	33	340,311	517,055	176,744	34	362,302	546,376	184,074	34	384,293	575,698	191,404	33
95	428,276	634,341	206,065	32	362,302	546,376	184,074	34	384,293	575,698	191,404	33	406,285	605,019	198,735	33
99.9	472,258	692,984	220,726	32	406,285	605,019	198,735	33	428,276	634,341	206,065	32	450,267	663,663	213,396	32

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	406,285	634,341	228,056	36	362,302	546,376	184,074	34	384,293	575,698	191,404	33	384,293	575,698	191,404	33
90	428,276	634,341	206,065	32	362,302	546,376	184,074	34	406,285	575,698	169,413	29	406,285	605,019	198,735	33
95	450,267	663,663	213,396	32	384,293	575,698	191,404	33	428,276	605,019	176,744	29	428,276	634,341	206,065	32
99.9	494,249	722,306	228,056	32	428,276	634,341	206,065	32	450,267	663,663	213,396	32	472,258	692,984	220,726	32

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{Cost\ designed\ by AASHTO 1998 - Cost\ designed\ by\ AASHTO\ 1993}{Cost\ designed\ by\ AASHTO\ 1993} \times 100\%$

7.1.3 Low Traffic Condition

Table 31(a) to 31(e) present the JPCP concrete cost for low-traffic condition across the four locations, covering reliability values and terminal serviceability values. As observed, the cost of JPCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 30% to 40%, with an average increase of $158,723 (approximately 34%).

Table 31. Comparison of JPCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for Low Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	296,329	458,411	162,083	35	-	-	-	-	318,320	458,411	140,092	31	-	-	-	-

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	296,329	458,411	162,083	35	-	-	-	-	318,320	487,733	169,413	35	296,329	399,768	103,440	26

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	296,329	458,411	162,083	35	-	-	-	-
99.9	296,329	458,411	162,083	35	296,329	458,411	162,083	35	340,311	487,733	147,422	30	296,329	458,411	162,083	35

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-		-	-	-	-	-	318,320	458,411	140,092	31	-	-	-	-
99.9	318,320	487,733	169,413	35	296,329	458,411	162,083	35	340,311	517,055	176,744	34	318,320	487,733	169,413	35

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	296,329	458,411	162,083	35	-	-	-	-
90	-	-	-	-	-	-	-	-	296,329	458,411	162,083	35	-	-	-	-
95	296,329	458,411	162,083	35	274,337	458,411	184,074	40	318,320	487,733	169,413	35	296,329	399,768	103,440	26
99.9	318,320	517,055	198,735	38	318,320	487,733	169,413	35	362,302	546,376	184,074	34	340,311	517,055	176,744	34

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{Cost\ designed\ by AASHTO 1998 - Cost\ designed\ by\ AASHTO\ 1993}{Cost\ designed\ by\ AASHTO\ 1993} \times 100\%$

7.2 JRCP Concrete Cost Differences Between AASHTO 1998 and 1993

Similarly, this section presents a cost comparison for JRCP concrete pavements between the AASHTO 1998 and AASHTO 1993 methods. It consistently shows that the costs calculated using the AASHTO 1998 method are higher than those calculated using the AASHTO 1993 method, as presented through the following analysis.

7.2.1 High Traffic Condition

Table 32(a) to 32(e) present the 1-mile JRCP concrete costs under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values. As observed, the cost of JRCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 20% to 30%, with an average increase of $222,218 (approximately 26%).

Table 32. Comparison of JRCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for High Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	767,764	971,587	203,823	27	767,764	971,587	203,823	27	720,637	971,587	250,950	35	767,764	1,000,908	233,145	30
90	797,085	1,000,908	203,823	26	797,085	1,000,908	203,823	26	767,764	971,587	203,823	27	797,085	1,048,035	250,950	31
95	844,213	1,048,035	203,822	24	844,213	1,048,035	203,822	24	797,085	1,000,908	203,823	26	844,213	1,077,356	233,143	28
99.9	920,661	1,153,806	233,145	25	920,661	1,153,806	233,145	25	873,535	1,124,484	250,950	29	920,661	1,153,806	233,145	25

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	797,085	1,000,908	203,823	26	797,085	1,000,908	203,823	26	767,764	971,587	203,823	27	797,085	1,000,908	203,823	26
90	797,085	1,048,035	250,950	31	797,085	1,048,035	250,950	31	767,764	1,000,908	233,145	30	844,213	1,048,035	203,822	24
95	844,213	1,077,356	233,143	28	844,213	1,077,356	233,143	28	797,085	1,048,035	250,950	31	873,535	1,077,356	203,822	23
99.9	920,661	1,153,806	233,145	25	967,789	1,153,806	186,017	19	873,535	1,124,484	250,950	29	967,789	1,200,933	233,143	24

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	797,085	1,048,035	250,950	31	844,213	1,048,035	203,822	24	767,764	1,000,908	233,145	30	844,213	1,048,035	203,822	24
90	844,213	1,048,035	203,822	24	844,213	1,048,035	203,822	24	797,085	1,000,908	203,823	26	844,213	1,077,356	233,143	28
95	873,535	1,124,484	250,950	29	873,535	1,124,484	250,950	29	844,213	1,077,356	233,143	28	873,535	1,124,484	250,950	29
99.9	967,789	1,200,933	233,143	24	967,789	1,200,933	233,143	24	920,661	1,153,806	233,145	25	967,789	1,200,933	233,143	24

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	844,213	1,077,356	233,143	28	873,535	1,077,356	203,822	23	797,085	1,048,035	250,950	31	873,535	1,077,356	203,822	23
90	873,535	1,077,356	203,822	23	873,535	1,077,356	203,822	23	844,213	1,048,035	203,822	24	873,535	1,124,484	250,950	29
95	920,661	1,153,806	233,145	25	920,661	1,153,806	233,145	25	873,535	1,124,484	250,950	29	920,661	1,153,806	233,145	25
99	997,111	1,230,254	233,143	23	-	-	-	-	967,789	1,200,933	233,143	24	-	-	-	-

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	920,661	1,124,484	203,823	22	920,661	1,124,484	203,823	22	873,535	1,077,356	203,822	23	920,661	1,124,484	203,823	22
90	920,661	1,153,806	233,145	25	967,789	1,153,806	186,017	19	873,535	1,124,484	250,950	29	967,789	1,153,806	186,017	19
95	997,111	1,200,933	203,822	20	997,111	1,200,933	203,822	20	967,789	1,153,806	186,017	19	997,111	1,200,933	203,822	20
99.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- % Diff. $= \frac{Cost\ designed\ by AASHTO 1998 - Cost\ designed\ by\ AASHTO\ 1993}{Cost\ designed\ by\ AASHTO\ 1993} \times 100\%$

7.2.2 Medium Traffic Condition

Table 33(a) to 33(e) present the JRCP concrete cost for medium-traffic condition across the four locations. The JPCP cost estimated by AASHTO 1998 is consistently higher than that by AASHTO 1993 across all reliability levels, Pt values, and locations, showing an average increase of $193,035 (approximately 29%), ranging from 25% to 32%.

Table 33. Comparison of JRCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for Medium Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	614,866	800,883	186,017	30	538,418	724,434	186,017	35	567,739	771,561	203,822	36	614,866	771,561	156,695	25
90	644,187	848,010	203,823	32	567,739	724,434	156,695	28	614,866	800,883	186,017	30	614,866	800,883	186,017	30
95	691,315	877,332	186,017	27	567,739	771,561	203,822	36	644,187	800,883	156,695	24	644,187	848,010	203,823	32
99.9	720,637	971,587	250,950	35	644,187	848,010	203,823	32	691,315	877,332	186,017	27	720,637	924,459	203,822	28

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	644,187	848,010	203,823	32	567,739	724,434	156,695	28	614,866	771,561	156,695	25	614,866	800,883	186,017	30
90	644,187	848,010	203,823	32	567,739	771,561	203,822	36	614,866	800,883	186,017	30	644,187	848,010	203,823	32
95	691,315	877,332	186,017	27	614,866	800,883	186,017	30	644,187	848,010	203,823	32	644,187	848,010	203,823	32
99.9	767,764	971,587	203,823	27	644,187	848,010	203,823	32	720,637	924,459	203,822	28	720,637	924,459	203,822	28

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	644,187	848,010	203,823	32	567,739	771,561	203,822	36	614,866	800,883	186,017	30	644,187	800,883	156,695	24
90	691,315	877,332	186,017	27	567,739	771,561	203,822	36	644,187	848,010	203,823	32	644,187	848,010	203,823	32
95	720,637	924,459	203,822	28	614,866	800,883	186,017	30	691,315	848,010	156,695	23	691,315	877,332	186,017	27
99.9	797,085	1,000,908	203,823	26	691,315	877,332	186,017	27	720,637	924,459	203,822	28	767,764	971,587	203,823	27

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	691,315	877,332	186,017	27	614,866	771,561	156,695	25	644,187	848,010	203,823	32	644,187	848,010	203,823	32
90	720,637	924,459	203,822	28	614,866	800,883	186,017	30	644,187	848,010	203,823	32	691,315	877,332	186,017	27
95	767,764	971,587	203,823	27	644,187	848,010	203,823	32	691,315	877,332	186,017	27	720,637	924,459	203,822	28
99.9	844,213	1,048,035	203,822	24	720,637	924,459	203,822	28	767,764	971,587	203,823	27	797,085	1,000,908	203,823	26

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	720,637	924,459	203,822	28	644,187	800,883	156,695	24	691,315	877,332	186,017	27	691,315	877,332	186,017	27
90	767,764	971,587	203,823	27	644,187	848,010	203,823	32	720,637	877,332	156,695	22	720,637	924,459	203,822	28
95	797,085	1,000,908	203,823	26	691,315	877,332	186,017	27	767,764	924,459	156,695	20	767,764	971,587	203,823	27
99.9	873,535	1,077,356	203,822	23	767,764	971,587	203,823	27	797,085	1,000,908	203,823	26	844,213	1,048,035	203,822	24

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{\text{Cost designed byAASHTO1998} - \text{Cost designed by AASHTO 1993}}{\text{Cost designed by AASHTO 1993}} \times 100\%$

7.2.3 Low Traffic Condition

Table 34(a) to 34(e) present the JRCP concrete cost for low-traffic condition across the four locations, covering reliability values and terminal serviceability values. As observed, the cost of JRCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 21% to 46%, with an average increase of $170,319 (approximately 34 %).

Table 34. Comparison of JRCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for Low Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	444,163	618,663	174,500	39	-	-	-	-
90	-	-	-	-	-	-	-	-	491,290	647,985	156,695	32	-	-	-	-
95	-	-	-	-	444,163	618,663	174,500	39	491,290	695,113	203,823	41	491,290	618,663	127,374	21
99.9	538,418	695,113	156,695	29	491,290	647,985	156,695	32	567,739	724,434	156,695	28	538,418	695,113	156,695	23

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	491,290	647,985	156,695	32	-	-	-	-
90	-	-	-	-	-	-	-	-	491,290	647,985	156,695	32	444,163	618,663	174,500	39
95	491,290	647,985	156,695	32	444,163	618,663	174,500	39	538,418	695,113	156,695	29	491,290	647,985	156,695	32
99.9	538,418	695,113	156,695	29	538,418	695,113	156,695	29	567,739	771,561	203,822	36	538,418	695,113	156,695	29

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	491,290	647,985	156,695	32	444,163	618,663	174,500	39
90	444,163	618,663	174,500	39	444,163	618,663	174,500	39	491,290	695,113	203,823	41	444,163	618,663	174,500	39
95	491,290	647,985	156,695	32	444,163	647,985	203,822	46	538,418	695,113	156,695	29	491,290	647,985	156,695	32
99.9	538,418	724,434	186,017	35	538,418	695,113	156,695	29	614,866	771,561	156,695	25	538,418	724,434	186,017	35

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	444,163	618,663	174,500	39	-	-	-	-	491,290	695,113	203,823	41	444,163	618,663	174,500	39
90	444,163	647,985	203,822	46	444,163	618,663	174,500	39	538,418	695,113	156,695	29	444,163	647,985	203,822	46
95	491,290	647,985	156,695	32	491,290	647,985	156,695	32	567,739	724,434	156,695	28	491,290	695,113	203,823	41
99.9	567,739	724,434	156,695	28	538,418	724,434	186,017	35	614,866	800,883	186,017	30	567,739	724,434	156,695	28

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	444,163	647,985	203,822	46	444,163	618,663	174,500	39	538,418	647,985	109,567	20	444,163	647,985	203,822	46
90	491,290	647,985	156,695	32	444,163	647,985	203,822	46	538,418	695,113	156,695	29	491,290	695,113	203,823	41
95	538,418	695,113	156,695	29	491,290	695,113	203,823	41	567,739	724,434	156,695	28	538,418	724,434	186,017	35
99.9	567,739	771,561	203,822	36	567,739	771,561	203,822	36	644,187	771,561	127,374	20	614,866	771,561	156,695	25

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{\text{Cost designed by} AASHTO 1998 - \text{Cost designed by } AASHTO\ 1993}{\text{Cost designed by } AASHTO\ 1993} \times 100\%$

7.3 CRCP Concrete Cost Differences Between AASHTO 1998 and 1993

Similarly, this section presents a cost comparison for CRCP concrete pavements between the AASHTO 1998 and AASHTO 1993 methods. It consistently shows that the costs calculated using the AASHTO 1998 method are higher than those calculated using the AASHTO 1993 method, as presented through the following analysis.

7.3.1 High Traffic Condition

Table 35(a) to 35(e) present the 1-mile CRCP concrete costs under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values. As observed, the cost of CRCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 7% to 12%, with an average increase of $ 86,992 (approximately 10%).

Table 35. Comparison of CRCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for High Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	759,299	841,683	82,384	11	759,299	841,683	82,384	11	722,064	804,448	82,384	11	759,299	841,683	82,384	11
90	804,448	878,918	74,470	9	804,448	878,918	74,470	9	759,299	841,683	82,384	11	804,448	878,918	74,470	9
95	841,683	924,067	82,384	10	841,683	924,067	82,384	10	804,448	878,918	74,470	9	841,683	924,067	82,384	10
99.9	924,067	998,537	74,470	8	924,067	998,537	74,470	8	878,918	961,302	82,384	9	924,067	998,537	74,470	8

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	804,448	878,918	74,470	9	804,448	878,918	74,470	9	759,299	841,683	82,384	11	804,448	878,918	74,470	9
90	804,448	924,067	119,619	15	804,448	924,067	119,619	15	759,299	841,683	82,384	11	841,683	924,067	82,384	10
95	841,683	961,302	119,619	14	841,683	961,302	119,619	14	804,448	878,918	74,470	9	878,918	961,302	82,384	9
99.9	924,067	1,043,687	119,620	13	961,302	1,043,687	82,384	9	878,918	961,302	82,384	9	961,302	1,043,687	82,384	9

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	804,448	924,067	119,619	15	841,683	924,067	82,384	10	759,299	841,683	82,384	11	841,683	924,067	82,384	10
90	841,683	924,067	82,384	10	841,683	924,067	82,384	10	804,448	878,918	74,470	9	841,683	924,067	82,384	10
95	878,918	998,537	119,619	14	878,918	998,537	119,619	14	841,683	924,067	82,384	10	878,918	961,302	82,384	9
99.9	961,302	1,080,922	119,619	12	961,302	1,080,922	119,619	12	924,067	998,537	74,470	8	961,302	1,080,922	119,619	12

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	841,683	961,302	119,619	14	878,918	961,302	82,384	9	804,448	878,918	74,470	9	878,918	961,302	82,384	9
90	878,918	961,302	82,384	9	878,918	961,302	82,384	9	841,683	924,067	82,384	10	878,918	961,302	82,384	9
95	924,067	1,043,687	119,620	13	924,067	1,043,687	119,620	13	878,918	961,302	82,384	9	924,067	998,537	74,470	8
99.9	998,537	1,118,157	119,620	12	1,043,687	1,118,157	74,470	7	961,302	1,043,687	82,384	9	1,043,687	1,118,157	74,470	7

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	924,067	998,537	74,470	8	924,067	998,537	74,470	8	878,918	924,067	45,149	5	924,067	998,537	74,470	8
90	924,067	1,043,687	119,620	13	961,302	1,043,687	82,384	9	878,918	961,302	82,384	9	961,302	1,043,687	82,384	9
95	998,537	1,080,922	82,384	8	998,537	1,080,922	82,384	8	961,302	998,537	37,235	4	998,537	1,080,922	82,384	8
99.9	1,080,922	1,155,392	74,470	7	1,080,922	1,200,541	119,619	11	1,043,687	1,118,157	74,470	7	1,080,922	1,155,392	74,470	7

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{\text{Cost designed by} AASHTO 1998 - \text{Cost designed by } AASHTO \text{ } 1993}{\text{Cost designed by } AASHTO \text{ } 1993} \times 100\%$

7.3.2 Medium Traffic Condition

Table 36(a) to 36(e) present the CRCP concrete cost for medium-traffic condition across the four locations. As observed, the cost of CRCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 9% to 15%, with an average increase of $79,248 (approximately 12%).

Table 36. Comparison of CRCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for Medium Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	602,444	722,064	119,619	20	527,974	602,444	74,470	14	565,209	639,679	74,470	13	602,444	684,828	82,384	14
90	639,679	722,064	82,384	13	565,209	639,679	74,470	13	602,444	684,828	82,384	14	602,444	684,828	82,384	14
95	684,828	759,299	74,470	11	565,209	639,679	74,470	13	639,679	684,828	45,149	7	639,679	759,299	119,619	19
99.9	722,064	841,683	119,619	17	639,679	722,064	82,384	13	684,828	759,299	74,470	11	722,064	841,683	119,619	17

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	639,679	722,064	82,384	13	565,209	602,444	37,236	7	602,444	639,679	37,235	6	602,444	684,828	82,384	14
90	639,679	759,299	119,619	19	565,209	639,679	74,470	13	602,444	684,828	82,384	14	639,679	722,064	82,384	13
95	684,828	804,448	119,619	17	602,444	684,828	82,384	14	639,679	722,064	82,384	13	639,679	722,064	82,384	13
99.9	759,299	841,683	82,384	11	639,679	722,064	82,384	13	722,064	759,299	37,235	5	722,064	804,448	82,384	11

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	639,679	759,299	119,619	19	565,209	639,679	74,470	13	602,444	684,828	82,384	14	639,679	684,828	45,149	7
90	684,828	759,299	74,470	11	565,209	639,679	74,470	13	639,679	684,828	45,149	7	639,679	722,064	82,384	13
95	722,064	804,448	82,384	11	602,444	684,828	82,384	14	684,828	722,064	37,236	5	684,828	759,299	74,470	11
99.9	804,448	878,918	74,470	9	684,828	759,299	74,470	11	722,064	804,448	82,384	11	759,299	841,683	82,384	11

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	684,828	759,299	74,470	11	602,444	684,828	82,384	14	639,679	722,064	82,384	13	639,679	722,064	82,384	13
90	722,064	804,448	82,384	11	602,444	684,828	82,384	14	639,679	722,064	82,384	13	684,828	759,299	74,470	11
95	759,299	841,683	82,384	11	639,679	722,064	82,384	13	684,828	759,299	74,470	11	722,064	804,448	82,384	11
99.9	841,683	924,067	82,384	10	722,064	804,448	82,384	11	759,299	841,683	82,384	11	804,448	878,918	74,470	9

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	722,064	841,683	119,619	17	639,679	722,064	82,384	13	684,828	759,299	74,470	11	684,828	759,299	74,470	11
90	759,299	841,683	82,384	11	639,679	722,064	82,384	13	722,064	759,299	37,235	5	722,064	804,448	82,384	11
95	804,448	878,918	74,470	9	684,828	759,299	74,470	11	759,299	804,448	45,149	6	759,299	841,683	82,384	11
99.9	878,918	961,302	82,384	9	759,299	841,683	82,384	11	804,448	878,918	74,470	9	841,683	924,067	82,384	10

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- % Diff. $= \frac{Cost\ designed\ by AASHTO 1998 - Cost\ designed\ by\ AASHTO\ 1993}{Cost\ designed\ by\ AASHTO\ 1993} \times 100\%$

7.3.3 Low Traffic Condition

Table 37(a) to 37(e) present the CRCP concrete cost for low-traffic condition across the four locations, covering reliability values and terminal serviceability values. As observed, the cost of

CRCP designed using the AASHTO 1998 method is consistently higher than that designed using the AASHTO 1993 method across all reliability levels, terminal serviceability indices, and locations. The cost increase ranges from 7% to 17%, with an average increase of $70,805 (approximately 13%).

Table 37. Comparison of CRCP Concrete Cost Between AASHTO 1998 and AASHTO 1993 for Low Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	527,974	602,444	74,470	14	-	-	-	-	565,209	602,444	37,236	7	-	-	-	-

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	527,974	602,444	74,470	14	-	-	-	-	565,209	639,679	74,470	13	527,974	602,444	74,470	14

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95.9	-	-	-	-	-	-	-	-	527,974	602,444	74,470	14	-	-	-	-
99.9	527,974	602,444	74,470	14	527,974	602,444	74,470	14	602,444	639,679	37,235	6	527,974	602,444	74,470	14

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-		-	-	-	-	-	565,209	602,444	37,236	7	-	-	-	-
99.9	565,209	639,679	74,470	13	527,974	602,444	74,470	14	602,444	684,828	82,384	14	565,209	639,679	74,470	13

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.	1993 ($)	1998 ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	527,974	602,444	74,470	14	-	-	-	-
90									527,974	602,444	74,470	14				
95	527,974	602,444	74,470	14	482,825	602,444	119,619	25	565,209	639,679	74,470	13	527,974	602,444	74,470	14
99.9	565,209	684,828	119,619	21	565,209	639,679	74,470	13	639,679	722,064	82,384	13	602,444	684,828	82,384	14

Note:

- Diff. = Cost designed by AASHTO 1998 minus cost designed by AASHTO 1993
- $\% \text{ Diff.} = \frac{Cost\ designed\ by AASHTO 1998 - Cost\ designed\ by\ AASHTO\ 1993}{Cost\ designed\ by\ AASHTO\ 1993} \times 100\%$

7.4 Chapter Summary

This chapter presented a comprehensive cost comparison between concrete pavement designs developed using the AASHTO 1993 and AASHTO 1998 methods for JPCP, JRCP, and CRCP under varying traffic levels, reliability levels, and terminal serviceability indices across four Alabama locations.

For JPCP, the results indicate that designs generated using the AASHTO 1998 method consistently yield higher construction costs compared to those designed using the AASHTO 1993 method across all scenarios. At high traffic levels, the cost increase ranged from 31% to 35%, with an average increase of approximately $233,188 (32%). At medium traffic levels, the cost increase ranged from 32% to 38%, averaging $189,572 (33%). At low traffic levels, the cost increase ranged from 30% to 40%, averaging $158,723 (34%).

For JRCP, a similar trend was observed, with the AASHTO 1998 designs producing higher costs across all conditions. The cost increase at high traffic levels ranged from 20% to 30%, with an average of $222,218 (26%). At medium traffic levels, the cost increase ranged from 25% to 32%, averaging $193,035 (29%). At low traffic levels, the cost increase ranged from 21% to 46%, averaging $170,319 (34%).

For CRCP, the cost differences between the two methods were less pronounced but remained consistent, with the AASHTO 1998 method producing higher costs in all cases. At high traffic levels, the cost increase ranged from 7% to 12%, averaging $86,992 (10%). At medium traffic levels, the increase ranged from 9% to 15%, averaging $79,248 (12%), while at low traffic levels, the increase ranged from 7% to 17%, averaging $70,805 (13%).

Overall, the AASHTO 1998 design method consistently results in higher pavement construction costs than the AASHTO 1993 method for all pavement types and traffic levels. The cost differences are most substantial for JPCP and JRCP and comparatively smaller for CRCP. These findings suggest that while the AASHTO 1998 method incorporates more refined mechanistic-empirical considerations leading to thicker and potentially more durable designs, this improvement comes with increased construction cost implications. Although the slabs designed using the AASHTO 1993 method are more economical, further studies are needed to evaluate their long-term performance and durability through LCCA.

8. COMPARATIVE COST ANALYSIS OF CONVENTIONAL 12' LANE WITH TIED SHOULDERS VERSUS WIDENED LANE WITH NON-TIED SHOULDERS

This chapter presents the comparison of cost between conventional 12' lane with tied shoulders and widened lane with non-tied shoulders for JPCP, JRCP, and CRCP.

8.1 JPCP Concrete Cost Differences Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder

This section presents the cost comparison between conventional 12' lane with tied shoulders and widened lane with non-tied shoulders for JPCP, in terms of high traffic, medium, and low traffic conditions, respectively.

8.1.1 High Traffic Condition

Table 38(a) to 38(e) present the 1-mile JPCP costs for conventional lane with tied shoulder and widened lane with non-tied shoulder under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. The costs in the tables are calculated based on the designed slab thickness, rounded up to the nearest 0.5-inch increment, which reflects standard design practice.

As observed for JPCP under high traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 12% to 16%. On average, the reduced cost is $100,584, representing approximately a 14% decrease.

Table 38. Comparison of JPCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for High Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	634,341	555,473	-78868	-12	634,341	555,473	-78868	-12	605,019	529,817	-75202	-12	634,341	555,473	-78868	-12
90	663,663	581,130	-82533	-12	663,663	581,130	-82533	-12	634,341	529,817	-104524	-16	663,663	581,130	-82533	-12
95	692,984	606,786	-86198	-12	692,984	606,786	-86198	-12	663,663	555,473	-108189	-16	692,984	606,786	-86198	-12
99.9	751,627	658,099	-93528	-12	751,627	658,099	-93528	-12	663,663	606,786	-56876	-9	751,627	658,099	-93528	-12

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	663,663	581,130	-82533	-12	663,663	581,130	-82533	-12	634,341	529,817	-104524	-16	663,663	581,130	-82533	-12
90	692,984	581,130	-111854	-16	692,984	581,130	-111854	-16	634,341	555,473	-78868	-12	692,984	581,130	-111854	-16
95	722,306	606,786	-115520	-16	722,306	606,786	-115520	-16	663,663	581,130	-82533	-12	722,306	606,786	-115520	-16
99.9	780,949	683,755	-97194	-12	780,949	683,755	-97194	-12	722,306	632,442	-89863	-12	780,949	658,099	-122850	-16

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	692,984	581,130	-111854	-16	692,984	581,130	-111854	-16	634,341	555,473	-78868	-12	692,984	581,130	-111854	-16
90	692,984	606,786	-86198	-12	692,984	606,786	-86198	-12	663,663	581,130	-82533	-12	692,984	606,786	-86198	-12
95	751,627	632,442	-119185	-16	751,627	632,442	-119185	-16	692,984	606,786	-86198	-12	722,306	632,442	-89863	-12
99.9	810,271	683,755	-126515	-16	810,271	683,755	-126515	-16	751,627	658,099	-93528	-12	810,271	683,755	-126515	-16

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	722,306	606,786	-115520	-16	722,306	606,786	-115520	-16	663,663	581,130	-82533	-12	722,306	606,786	-115520	-16
90	722,306	632,442	-89863	-12	722,306	632,442	-89863	-12	692,984	581,130	-111854	-16	722,306	632,442	-89863	-12
95	780,949	658,099	-122850	-16	780,949	658,099	-122850	-16	722,306	632,442	-89863	-12	751,627	658,099	-93528	-12
99.9	839,592	709,412	-130180	-16	839,592	709,412	-130180	-16	780,949	683,755	-97194	-12	839,592	709,412	-130180	-16

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	751,627	658,099	-93528	-12	751,627	658,099	-93528	-12	692,984	606,786	-86198	-12	751,627	658,099	-93528	-12
90	780,949	658,099	-122850	-16	780,949	658,099	-122850	-16	722,306	632,442	-89863	-12	780,949	658,099	-122850	-16
95	810,271	709,412	-100859	-12	810,271	709,412	-100859	-12	751,627	658,099	-93528	-12	810,271	709,412	-100859	-12
99.9	868,914	760,724	-108189	-12	898,235	760,724	-137511	-15	839,592	709,412	-130180	-16	868,914	760,724	-108189	-12

Note:

- Diff. = Cost of widened lane with non-tied shoulder minus cost of conventional lane with tied shoulder
- $\% \text{ Diff.} = \frac{Cost\ widened\ lane\ with\ non{-}tied\ shoulder - Cost\ of\ \text{conventional lane with tied shoulder}}{Cost\ of\ conventional\ lane\ with\ tied\ shoulder} \times 100\%$

8.1.2 Medium Traffic Condition

Table 39(a) to 39(e) present the 1-mile JPCP concrete costs for conventional lane with tied should and widened lane with non-tied shoulder under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values.

As observed for JPCP under medium traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 12% to 18%. On average, the reduced cost is $77,172, representing approximately a 14% decrease.

Table 39. Comparison of JPCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Medium Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	546,376	452,848	-93528	-17	458,411	401,535	-56876	-12	487,733	427,191	-60542	-12	517,055	427,191	-89863	-17
90	546,376	478,504	-67872	-12	487,733	401,535	-86198	-18	517,055	427,191	-89863	-17	517,055	452,848	-64207	-12
95	575,698	504,160	-71537	-12	487,733	427,191	-60542	-12	517,055	452,848	-64207	-12	575,698	478,504	-97194	-17
99.9	634,341	555,473	-78868	-12	546,376	478,504	-67872	-12	575,698	504,160	-71537	-12	634,341	529,817	-104524	-16

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	546,376	478,504	-67872	-12	458,411	401,535	-56876	-12	487,733	427,191	-60542	-12	517,055	452,848	-64207	-12
90	575,698	478,504	-97194	-17	487,733	427,191	-60542	-12	517,055	452,848	-64207	-12	546,376	452,848	-93528	-17
95	605,019	504,160	-100859	-17	517,055	452,848	-64207	-12	546,376	452,848	-93528	-17	546,376	478,504	-67872	-12
99.9	634,341	555,473	-78868	-12	546,376	478,504	-67872	-12	575,698	504,160	-71537	-12	605,019	529,817	-75202	-12

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	575,698	478,504	-97194	-17	487,733	427,191	-60542	-12	517,055	452,848	-64207	-12	517,055	452,848	-64207	-12
90	575,698	504,160	-71537	-12	487,733	427,191	-60542	-12	517,055	452,848	-64207	-12	546,376	478,504	-67872	-12
95	605,019	529,817	-75202	-12	517,055	452,848	-64207	-12	546,376	478,504	-67872	-12	575,698	504,160	-71537	-12
99.9	663,663	581,130	-82533	-12	575,698	504,160	-71537	-12	605,019	529,817	-75202	-12	634,341	529,817	-104524	-16

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	575,698	504,160	-71537	-12	517,055	427,191	-89863	-17	546,376	452,848	-93528	-17	546,376	478,504	-67872	-12
90	605,019	529,817	-75202	-12	517,055	452,848	-64207	-12	546,376	478,504	-67872	-12	575,698	504,160	-71537	-12
95	634,341	555,473	-78868	-12	546,376	478,504	-67872	-12	575,698	504,160	-71537	-12	605,019	504,160	-100859	-17
99.9	692,984	606,786	-86198	-12	605,019	504,160	-100859	-17	634,341	555,473	-78868	-12	663,663	555,473	-108189	-16

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	634,341	529,817	-104524	-16	546,376	452,848	-93528	-17	575,698	478,504	-97194	-17	575,698	504,160	-71537	-12
90	634,341	555,473	-78868	-12	546,376	478,504	-67872	-12	575,698	504,160	-71537	-12	605,019	529,817	-75202	-12
95	663,663	581,130	-82533	-12	575,698	504,160	-71537	-12	605,019	529,817	-75202	-12	634,341	555,473	-78868	-12
99.9	722,306	632,442	-89863	-12	634,341	555,473	-78868	-12	663,663	581,130	-82533	-12	692,984	606,786	-86198	-12

8.1.3 Low Traffic Condition

Table 40(a) to 40(e) present the 1-mile JPCP concrete costs for conventional lane with tied shoulder and widened lane with non-tied shoulder under low-traffic conditions across the four locations, covering reliability values and terminal serviceability values.

As observed for JPCP under low traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 12% to 18%. On average, the reduced cost is $60,745, representing approximately a 13% decrease.

Table 40. Comparison of JPCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Low Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	-	-	-	-	-	-	-	-	458,411	401,535	-56876	-12	-	-	-	-

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	458,411	401,535	-56876	-12	-	-	-	-	487,733	427,191	-60542	-12	-	-	-	-

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	458411	401535	-56876	-12	-	-	-	-
99.9	458,411.3	401,534.9	-56876	-12	458,411.3	401,534.9	-56876	-12	487,732.9	427,191.3	-60542	-12	458,411.3	401,534.9	-56876	-12

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	458411	401535	-56876	-12	-	-	-	-
99.9	487,732.9	427,191.3	-60542	-12	458,411.3	401,534.9	-56876	-12	517,054.5	452,847.7	-64207	-12	487,732.9	401,534.9	-86198	-18

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	458,411.3	401,534.9	-56876	-12	-	-	-	-
95	458,411.3	401,534.9	-56876	-12	-	-	-	-	487,732.9	427,191.3	-60542	-12	-	-	-	-
99.9	517,054.5	427,191.3	-89863	-17	487,732.9	427,191.3	-60542	-12	546,376.1	478,504.1	-67872	-12	517,054.5	427,191.3	-89863	-17

8.2 JRCP Concrete Cost Differences Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder

This section presents the cost comparison between conventional 12' lane with tied shoulders and widened lane with non-tied shoulders for JRCP, in terms of high traffic, medium, and low traffic conditions, respectively.

8.2.1 High Traffic Condition

Table 41(a) to 41(e) present the 1-mile JRCP costs for conventional lane with tied shoulder and widened lane with non-tied shoulder under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. The costs in the tables are calculated based on the designed slab thickness, rounded up to the nearest 0.5-inch increment, which reflects standard design practice.

As observed for JRCP under high traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 14% to 19%. On average, the reduced cost is $174,609, representing approximately a 16% decrease.

Table 41. Comparison of JRCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for High Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	971,587	828,306	-143281	-15	971,587	828,306	-143281	-15	971,587	784,844	-186742	-19	1,000,908	828,306	-172603	-17
90	1,000,908	853,962	-146946	-15	1,000,908	853,962	-146946	-15	971,587	828,306	-143281	-15	1,048,035	853,962	-194073	-19
95	1,048,035	879,618	-168416	-16	1,048,035	879,618	-168416	-16	1,000,908	853,962	-146946	-15	1,077,356	879,618	-197738	-18
99.9	1,153,806	948,738	-205068	-18	1,153,806	992,199	-161607	-14	1,124,484	923,081	-201403	-18	1,153,806	992,199	-161607	-14

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	1,000,908	853,962	-146946	-15	1,000,908	853,962	-146946	-15	971,587	828,306	-143281	-15	1,000,908	853,962	-146946	-15
90	1,048,035	853,962	-194073	-19	1,048,035	879,618	-168416	-16	1,000,908	828,306	-172603	-17	1,048,035	879,618	-168416	-16
95	1,077,356	923,081	-154275	-14	1,077,356	923,081	-154275	-14	1,048,035	879,618	-168416	-16	1,077,356	923,081	-154275	-14
99.9	1,153,806	992,199	-161607	-14	1,153,806	992,199	-161607	-14	1,124,484	948,738	-175747	-16	1,200,933	992,199	-208734	-17

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	1,048,035	853,962	-194073	-19	1,048,035	879,618	-168416	-16	1,000,908	828,306	-172603	-17	1,048,035	879,618	-168416	-16
90	1,048,035	879,618	-168416	-16	1,048,035	879,618	-168416	-16	1,000,908	853,962	-146946	-15	1,077,356	923,081	-154275	-14
95	1,124,484	923,081	-201403	-18	1,124,484	948,738	-175747	-16	1,077,356	879,618	-197738	-18	1,124,484	948,738	-175747	-16
99.9	1,200,933	1,017,855	-183077	-15	1,200,933	1,017,855	-183077	-15	1,153,806	948,738	-205068	-18	1,200,933	1,017,855	-183077	-15

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	1,077,356	879,618	-197738	-18	1077356	923,081	-154275	-14	1,048,035	853,962	-194073	-19	1,077,356	923,081	-154275	-14
90	1,077,356	923,081	-154275	-14	1077356	923,081	-154275	-14	1,048,035	879,618	-168416	-16	1,124,484	923,081	-201403	-18
95	1,153,806	948,738	-205068	-18	1153806	992,199	-161607	-14	1,124,484	923,081	-201403	-18	1,153,806	992,199	-161607	-14
99.9	-	-	-	-	-	-	-	-	1,200,933	992,199	-208734	-17	-	-	-	-

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	1,124,484	948,738	-175747	-16	1,124,484	948,738	-175747	-16	1,077,356	879,618	-197738	-18	1,124,484	948,738	-175747	-16
90	1,153,806	948,738	-205068	-18	1,153,806	992,199	-161607	-14	1,124,484	923,081	-201403	-18	1,153,806	992,199	-161607	-14
95	1,200,933	1,017,855	-183077	-15	1,200,933	1,017,855	-183077	-15	1,153,806	992,199	-161607	-14	1,200,933	1,017,855	-183077	-15
99.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

8.2.2 Medium Traffic Condition

Table 42(a) to 42(e) present the 1-mile JRCP concrete costs for conventional lane with tied should and widened lane with non-tied shoulder under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values.

As observed for JRCP under medium traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 12% to 18%. On average, the reduced cost is $134,812, representing approximately a 15% decrease.

Table 42. Comparison of JRCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Medium Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	800,883	690,069	-110814	-14	724,434	595,294	-129140	-18	771,561	646,607	-124954	-16	771,561	646,607	-124954	-16
90	848,010	715,725	-132285	-16	724,434	620,951	-103483	-14	800,883	646,607	-154275	-19	800,883	690,069	-110814	-14
95	877,332	759,188	-118144	-13	771,561	646,607	-124954	-16	800,883	690,069	-110814	-14	848,010	715,725	-132285	-16
99.9	971,587	828,306	-143281	-15	848,010	715,725	-132285	-16	877,332	759,188	-118144	-13	924,459	784,844	-139614	-15

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	848,010	715,725	-132285	-16	724,434	620,951	-103483	-14	771,561	646,607	-124954	-16	800,883	690,069	-110814	-14
90	848,010	715,725	-132285	-16	771,561	620,951	-150610	-20	800,883	690,069	-110814	-14	848,010	690,069	-157942	-19
95	877,332	759,188	-118144	-13	800,883	646,607	-154275	-19	848,010	715,725	-132285	-16	848,010	715,725	-132285	-16
99.9	971,587	828,306	-143281	-15	848,010	715,725	-132285	-16	924,459	759,188	-165271	-18	924,459	784,844	-139614	-15

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	848,010	715,725	-132285	-16	771,561	620,951	-150610	-20	800,883	690,069	-110814	-14	800,883	690,069	-110814	-14
90	877,332	759,188	-118144	-13	771,561	646,607	-124954	-16	848,010	690,069	-157942	-19	848,010	715,725	-132285	-16
95	924,459	784,844	-139614	-15	800,883	690,069	-110814	-14	848,010	715,725	-132285	-16	877,332	759,188	-118144	-13
99.9	1,000,908	853,962	-146946	-15	877,332	759,188	-118144	-13	924,459	784,844	-139614	-15	971,587	828,306	-143281	-15

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	877,332	759,188	-118144	-13	771,561	646,607	-	-	848,010	690,069	-157942	-19	848,010	715,725	-132285	-16
90	924,459	759,188	-165271	-18	800,883	690,069	-110814	-14	848,010	715,725	-132285	-16	877,332	759,188	-118144	-13
95	971,587	828,306	-143281	-15	848,010	690,069	-157942	-19	877,332	759,188	-118144	-13	924,459	784,844	-139614	-15
99.9	1,048,035	879,618	-168416	-16	924,459	759,188	-165271	-18	971,587	828,306	-143281	-15	1,000,908	828,306	-172603	-17

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	924,459	784,844	-139614	-15	800,883	690,069	-110814	-14	877,332	715,725	-161607	-18	877,332	759,188	-118144	-13
90	971,587	828,306	-143281	-15	848,010	715,725	-132285	-16	877,332	759,188	-118144	-13	924,459	784,844	-139614	-15
95	1,000,908	853,962	-146946	-15	877,332	759,188	-118144	-13	924,459	784,844	-139614	-15	971,587	828,306	-143281	-15
99.9	1,077,356	923,081	-154275	-14	971,587	784,844	-186742	-19	1,000,908	853,962	-146946	-15	1,048,035	879,618	-168416	-16

8.2.3 Low Traffic Condition

Table 43(a) to 43(e) present the 1-mile JRCP concrete costs for conventional lane with tied shoulder and widened lane with non-tied shoulder under low-traffic conditions across the four locations, covering reliability values and terminal serviceability values.

As observed for JRCP under low traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 11% to 19%. On average, the reduced cost is $105,881, representing approximately a 16% decrease.

Table 43. Comparison of JRCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Low Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	618,663	526,175	-92488	-15	-	-	-	-
90	-	-	-	-	-	-	-	-	647,985	551,832	-96153	-15	-	-	-	-
95	618,663	526,175	-92488	-15	647,985	526,175	-121809	-19	695,113	551,832	-143281	-21	618,663	526,175	-92488	-15
99.9	695,113	551,832	-143281	-21	647,985	551,832	-96153	-15	724,434	620,951	-103483	-14	695,113	595,294	-99818	-14

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	647,985	526,175	-121809	-19	-	-	-	-
90	-	-	-	-	-	-	-	-	647,985	551,832	-96153	-15	618,663	526,175	-92488	-15
95	647,985	526,175	-121809	-19	618,663	526,175	-92488	-15	695,113	595,294	-99818	-14	647,985	526,175	-121809	-19
99.9	695,113	595,294	-99818	-14	695,113	595,294	-99818	-14	771,561	620,951	-150610	-20	695,113	595,294	-99818	-14

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	647,985	551,832	-96153	-15	618,663	482,714	-135949	-22
90	618,663	526,175	-92488	-15	458,411	401,535	-56876	-12	695,113	551,832	-143281	-21	618,663	526,175	-92488	-15
95	647,985	551,832	-96153	-15	647,985	526,175	-121809	-19	695,113	595,294	-99818	-14	647,985	551,832	-96153	-15
99.9	724,434	595,294	-129140	-18	695,113	595,294	-99818	-14	771,561	646,607	-124954	-16	724,434	595,294	-129140	-18

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	618,663	526,175	-92488	-15	-	-	-	-	695,113	551,832	-143281	-21	618,663	526,175	-92488	-15
90.9	647,985	551,832	-96153	-15	647,985	551,832	-96153	-15	695,113	620,951	-74162	-11	647,985	551,832	-96153	-15
95	695,113	595,294	-99818	-14	695,113	595,294	-99818	-14	724,434	646,607	-77827	-11	724,434	595,294	-129140	-18
99	771,561	646,607	-124954	-16	771,561	646,607	-124954	-16	771,561	715,725	-55836	-7	771,561	646,607	-124954	-16

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	647,985	551,832	-96153	-15	618,663	526,175	-92488	-15	647,985	595,294	-52690	-8	647,985	551,832	-96153	-15
90	647,985	551,832	-96153	-15	647,985	551,832	-96153	-15	695,113	620,951	-74162	-11	695,113	551,832	-143281	-21
95	695,113	595,294	-99818	-14	695,113	595,294	-99818	-14	724,434	646,607	-77827	-11	724,434	595,294	-129140	-18
99.9	771,561	646,607	-124954	-16	771,561	646,607	-124954	-16	771,561	715,725	-55836	-7	771,561	646,607	-124954	-16

8.3 CRCP Concrete Cost Differences Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder

This section presents the cost comparison between conventional 12' lane with tied shoulders and widened lane with non-tied shoulders for CRCP, in terms of high traffic, medium, and low traffic conditions, respectively.

8.3.1 High Traffic Condition

Table 44(a) to 44(e) present the 1-mile CRCP costs for conventional lane with tied shoulder and widened lane with non-tied shoulder under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values ranging from 1.5 to 3.5. The costs in the tables are calculated based on the designed slab thickness, rounded up to the nearest 0.5-inch increment, which reflects standard design practice.

As observed for CRCP under high traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 15% to 19%. On average, the reduced cost is $158,573, representing approximately a 16% decrease.

Table 44. Comparison of CRCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for High Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	841,683	717,232	-124451	-15	841,683	717,232	-124451	-15	804,448	683,662	-120786	-15	841,683	717,232	-124451	-15
90	878,918	750,802	-128116	-15	878,918	750,802	-128116	-15	841,683	683,662	-158021	-19	878,918	750,802	-128116	-15
95	924,067	784,372	-139695	-15	924,067	784,372	-139695	-15	878,918	717,232	-161686	-18	924,067	784,372	-139695	-15
99.9	998,537	851,512	-147025	-15	998,537	851,512	-147025	-15	961,302	784,372	-176930	-18	998,537	851,512	-147025	-15

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	878,918	750,802	-128116	-15	878,918	750,802	-128116	-15	841,683	683,662	-158021	-19	878,918	750,802	-128116	-15
90	924,067	750,802	-173265	-19	924,067	750,802	-173265	-19	841,683	717,232	-124451	-15	924,067	750,802	-173265	-19
95	961,302	784,372	-176930	-18	961,302	784,372	-176930	-18	878,918	750,802	-128116	-15	961,302	784,372	-176930	-18
99.9	1,043,687	885,082	-158605	-15	1,043,687	885,082	-158605	-15	961,302	817,942	-143361	-15	1,043,687	851,512	-192175	-18

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	924,067	750,802	-173265	-19	924,067	750,802	-173265	-19	841,683	717,232	-124451	-15	924,067	750,802	-173265	-19
90	924,067	784,372	-139695	-15	924,067	784,372	-139695	-15	878,918	750,802	-128116	-15	924,067	784,372	-139695	-15
95	998,537	817,942	-180596	-18	998,537	817,942	-180596	-18	924,067	784,372	-139695	-15	961,302	817,942	-143361	-15
99.9	1,080,922	885,082	-195840	-18	1,080,922	885,082	-195840	-18	998,537	851,512	-147025	-15	1,080,922	885,082	-195840	-18

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	961,302	784,372	- 176930	-18	961,302	784,372	- 176930	-18	878,918	750,802	- 128116	-15	961,302	784,372	- 176930	-18
90	961,302	817,942	- 143361	-15	961,302	817,942	- 143361	-15	924,067	750,802	- 173265	-19	961,302	817,942	- 143361	-15
95	1,043,687	851,512	- 192175	-18	1,043,687	851,512	- 192175	-18	961,302	817,942	- 143361	-15	998,537	851,512	- 147025	-15
99.9	1,118,157	918,652	- 199505	-18	1,118,157	918,652	- 199505	-18	1,043,687	885,082	- 158605	-15	1,118,157	918,652	- 199505	-18

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	998,537	851,512	- 147025	-15	998,537	851,512	- 147025	-15	924,067	784,372	- 139695	-15	998,537	851,512	- 147025	-15
90	1,043,687	851,512	- 192175	-18	1,043,687	851,512	- 192175	-18	961,302	817,942	- 143361	-15	1,043,687	851,512	- 192175	-18
95	1,080,922	918,652	- 162270	-15	1,080,922	918,652	- 162270	-15	998,537	851,512	- 147025	-15	1,080,922	918,652	- 162270	-15
99.9	1,155,392	985,792	- 169600	-15	1,200,541	985,792	- 214749	-18	1,118,157	918,652	- 199505	-18	1,155,392	985,792	- 169600	-15

8.3.2 Medium Traffic Condition

Table 45(a) to 45(e) present the 1-mile CRCP concrete costs for conventional lane with tied should and widened lane with non-tied shoulder under high-traffic conditions across the four locations, covering reliability values and terminal serviceability values. As observed for CRCP under medium traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 14% to 20%. On average, the reduced cost is $118,799, representing approximately a 16% decrease.

Table 45. Comparison of CRCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Medium Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	722,064	582,952	-139112	-19	602,444	515,812	-86633	-14	639,679	549,382	-90298	-14	684,828	549,382	-135447	-20
90	722,064	616,522	-105542	-15	639,679	515,812	-123868	-19	684,828	549,382	-135447	-20	684,828	582,952	-101876	-15
95	759,299	650,092	-109207	-14	639,679	549,382	-90298	-14	684,828	582,952	-101876	-15	759,299	616,522	-142777	-19
99.9	841,683	717,232	-124451	-15	722,064	616,522	-105542	-15	759,299	650,092	-109207	-14	841,683	683,662	-158021	-19

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	722,064	616,522	-105542	-15	602,444	515,812	-86633	-14	639,679	549,382	-90298	-14	684,828	582,952	-101876	-15
90	759,299	616,522	-142777	-19	639,679	549,382	-90298	-14	684,828	582,952	-101876	-15	722,064	582,952	-139112	-19
95	804,448	650,092	-154356	-19	684,828	582,952	-101876	-15	722,064	582,952	-139112	-19	722,064	616,522	-105542	-15
99.9	841,683	717,232	-124451	-15	722,064	616,522	-105542	-15	759,299	650,092	-109207	-14	804,448	683,662	-120786	-15

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	759,299	616,522	-142777	-19	639,679	549,382	-90298	-14	684,828	582,952	-101876	-15	684,828	582,952	-101876	-15
90	759,299	650,092	-109207	-14	639,679	549,382	-90298	-14	684,828	582,952	-101876	-15	722,064	616,522	-105542	-15
95	804,448	683,662	-120786	-15	684,828	582,952	-101876	-15	722,064	616,522	-105542	-15	759,299	650,092	-109207	-14
99.9	878,918	750,802	-128116	-15	759,299	650,092	-109207	-14	804,448	683,662	-120786	-15	841,683	683,662	-158021	-19

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	759,299	650,092	-109207	-14	684,828	549,382	-135447	-20	722,064	582,952	-139112	-19	722,064	616,522	-105542	-15
90	804,448	683,662	-120786	-15	684,828	582,952	-101876	-15	722,064	616,522	-105542	-15	759,299	650,092	-109207	-14
95	841,683	717,232	-124451	-15	722,064	616,522	-105542	-15	759,299	650,092	-109207	-14	804,448	650,092	-154356	-19
99.9	924,067	784,372	-139695	-15	804,448	650,092	-154356	-19	841,683	717,232	-124451	-15	878,918	717,232	-161686	-18

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	841,683	683,662	-158021	-19	722,064	582,952	-139112	-19	759,299	616,522	-142777	-19	759,299	650,092	-109207	-14
90	841,683	717,232	-124451	-15	722,064	616,522	-105542	-15	759,299	650,092	-109207	-14	804,448	683,662	-120786	-15
95	878,918	750,802	-128116	-15	759,299	650,092	-109207	-14	804,448	683,662	-120786	-15	841,683	717,232	-124451	-15
99.9	961,302	817,942	-143361	-15	841,683	717,232	-124451	-15	878,918	750,802	-128116	-15	924,067	784,372	-139695	-15

8.3.3 Low Traffic Condition

Table 46(a) to 46(e) present the 1-mile CRCP concrete costs for conventional lane with tied shoulder and widened lane with non-tied shoulder under low-traffic conditions across the four locations, covering reliability values and terminal serviceability values.

As observed for CRCP under low traffic condition, the cost of the widened lane with a non-tied shoulder is consistently lower than that of the conventional lane with a tied shoulder, with a reduction ranging from 14% to 20%. On average, the reduced cost is $92,040, representing approximately a 15% decrease.

Table 46. Comparison of CRCP Cost Between Conventional Lane with Tied Shoulder and Widened Lane with Non-Tied Shoulder for Low Traffic Condition

(a) Pt = 1.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	-	-	-	-	-	-	-	-	602,444	515,812	-86633	-14	-	-	-	-

(b) Pt = 2.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.9	602,444	515,812	-86633	-14	-	-	-	-	639,679	549,382	-90298	-14	602444	-	-	-

(c) Pt = 2.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	602444	515812	-86633	-14	-	-	-	-
99.9	602,444	515,812	-86633	-14	602,444	515,812	-86633	-14	639,679	549,382	-90298	-14	602,444	515,812	-86633	-14

(d) Pt = 3.0

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	602444	515812	-86633	-14	-	-	-	-
99.9	639,679	549,382	-90298	-14	602,444	515,812	-86633	-14	684,828	582,952	-101876	-15	639,679	515,812	-123868	-19

(e) Pt = 3.5

Location	Mobile				Montgomery				Birmingham				Huntsville			
R, %	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.	C ($)	W ($)	Diff. ($)	% Diff.
85	-	-	-	-	-	-	-	-	602,444	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	602,444	515,812	-86633	-14	-	-	-	-
95	602,444	515,812	-86633	-14	602,444	-	-	-	639,679	549,382	-90298	-14	602,444	-	-	-
99.9	684,828	549,382	-135447	-20	639,679	549,382	-90298	-14	722,064	616,522	-105542	-15	684,828	549,382	-135447	-20

8.4 Chapter Summary

This chapter presents a comparative cost analysis between conventional lanes with tied shoulders and widened lanes with non-tied shoulders for JPCP, JRCP, and CRCP under varying traffic levels. The results consistently show that widened lanes with non-tied shoulders offer lower construction costs across all pavement types, traffic levels, and conditions.

For JPCP, the widened lane design achieved cost reductions ranging from 12% to 18%, with average savings of $100,584 (14%) at high traffic levels, $77,172 (14%) at medium traffic levels, and $57,895 (12%) at low traffic levels.

For JRCP, the cost reduction ranged between 11% and 19%, with average savings of $174,609 (16%), $134,812 (15%), and $95,643 (14%) for high, medium, and low traffic levels, respectively.

For CRCP, similar trends were observed, with cost reductions between 14% and 20%. The average savings were $158,573 (16%) at high traffic levels, $118,799 (16%) at medium traffic levels, and $92,040 (15%) at low traffic levels.

Overall, the findings indicate that widened lanes with non-tied shoulders are more cost-effective than conventional lanes with tied shoulders, regardless of pavement type or traffic level. This suggests that adopting widened lane designs may provide significant cost savings based on AASHTO 1998 design method.

9. CONCLUSION AND RECOMMENDATION

Concrete pavement design is a dynamic and multifaceted process that requires careful consideration of traffic, climate, material properties, reliability, terminal serviceability, and project-specific conditions. This study focused on a comprehensive case analysis in Alabama, reviewing current AASHTO 1993 design practices, conducting a comparative analysis with the AASHTO 1998 method, and evaluating the effects of lane configurations and cost implications on pavement design.

The study described three main types of concrete pavements: (1) JPCP (Jointed Plain Concrete Pavement): concrete slabs with joint spacing of 12–20 ft.; (2) JRCP (Jointed Reinforced Concrete Pavement): concrete slabs with joint spacing of 25–30 ft and steel reinforcement; and (3) CRCP (Continuously Reinforced Concrete Pavement): concrete slabs without joints and continuous steel reinforcement. Designing these pavements requires integrating multiple inputs, including traffic, climate, reliability, terminal serviceability, and material characteristics. The study also considered two lane configurations: lanes with tied shoulders and wider lanes with non-tied shoulders, and their impact on pavement performance and thickness.

9.1 Conclusions

Survey results indicated that the AASHTO 1993 method remains the most commonly used approach among practitioners, with reported reliability between 91%–99.99% and terminal serviceability between 2.0–2.5. Practitioners also noted that wider lanes without tied shoulders could be suitable under certain project conditions, while both state-specified and commercial software are widely used for pavement design. Common challenges included selecting appropriate design parameters and balancing the use of AASHTO 1993 and 1998 methods.

The comparative analysis of the AASHTO 1993 and 1998 methods demonstrated that: (1) Pavement thickness increases with higher reliability and terminal serviceability, as these factors account for greater uncertainty and stricter performance criteria. (2) The AASHTO 1998 method consistently produces thicker pavements than AASHTO 1993: approximately 1 inch thicker for JPCP, 2.5 inches thicker for JRCP, and 1 inch thicker for CRCP, representing increases of 10%–37% across conditions. The thicker pavement designs under the AASHTO 1998 method are partly attributed to the use of the load transfer coefficient (J), which accounts for joint performance. Optimizing J through improved joint design, such as using dowel bars, tied shoulders, or stabilized bases, can help reduce the required slab thickness and associated costs.

The study also compared conventional lanes with tied shoulders to widened lanes without tied shoulders. Results showed that widened lanes typically require slightly thinner pavements, less than 0.5 inches (1–2%), due to more uniform stress distribution and effective load sharing. Despite this minor reduction in thickness, the practical impact on structural performance is negligible, suggesting that widened lanes can achieve cost savings without compromising durability. Conventional 12 ft lanes with tied shoulders have thicker pavement slabs than widened lanes without tied shoulders because tied shoulders provide lateral restraint, reduce deflection, control thermal expansion, and improve durability under traffic and environmental loads.

Cost analysis revealed that: (1) Pavements designed using the AASHTO 1998 method consistently exhibit higher construction costs compared to those designed using the AASHTO 1993 method. The cost increases generally range from 7% to 46% across pavement types and traffic levels, with reinforced pavement types (JRCP and CRCP) showing comparatively higher percentage increases than JPCP. (2) Widened lanes with non-tied shoulders provide significant cost reductions across all pavement types and traffic levels, with savings of 12%–20%, demonstrating that adopting such configurations can improve economic efficiency without negatively affecting performance.

In summary, this study highlights several key conclusions:

1. Concrete pavement design is context-specific: there is no single method suitable for all projects; design depends on traffic, reliability, terminal serviceability, and project conditions.
2. AASHTO 1998 offers more conservative designs: thicker pavements provide increased durability and reliability but at a higher cost.
3. Lane configuration affects thickness and cost: widened lanes without tied shoulders slightly reduce required thickness and offer notable cost savings without compromising structural performance.
4. Practitioner experiences and challenges are consistent: survey results show common considerations across states, including software use, parameter selection, and balancing older and newer design methods.

9.2 Recommendations

Recommendation for ALDOT includes:

1. For future concrete pavement projects, the choice of design methodology should align with project priorities, traffic levels, and performance expectations. The AASHTO 1998 design method provides a more robust and comprehensive framework by explicitly accounting for joint performance, temperature gradients, edge support, and mid-slab tensile stresses. Although it typically results in slightly thicker and more costly designs, it offers improved reliability and long-term durability, particularly for high-traffic corridors and new pavement construction. In contrast, the AASHTO 1993 design method may be adequate for projects with lower traffic volumes or where budget constraints and acceptable risk levels justify a more economical design. However, adopting state-specific methods can be even more effective, as they modify or calibrate standard AASHTO procedures to reflect local conditions, materials, and experience, ensuring more accurate, practical, and cost-efficient pavement performance predictions within each state.

2. Note that a load transfer coefficient (J) value of 2.9 was consistently used for all pavement types in this study. Where possible, the J factor should be calibrated using local performance data, test sections, or short-term construction monitoring rather than relying solely on national averages. The selection of ALDOT-specific J values may help reduce conservative over-design or mitigate the risk of under-performance.

3. For lane widening projects, the decision between tied and non-tied shoulders should be based on a balanced evaluation of cost, performance, and maintenance implications. Tied shoulders enhance structural continuity, reduce slab deflection and fatigue cracking, and improve thermal movement control, contributing to extended pavement life and reduced long-term maintenance. However, they increase both slab thickness and initial construction costs. Conversely, non-tied shoulders may be suitable for low-volume or low-traffic roadways, where cost savings outweigh the minor reduction in structural performance.

4. Pavement thickness design should explicitly consider local climatic conditions, particularly temperature differentials and anticipated traffic loading. Regions experiencing large seasonal temperature variations or heavy truck traffic may benefit from adopting thicker slabs and tied shoulders to enhance performance and mitigate thermal stress-related distresses.

For future study, it is recommended to utilize the MEPDG for supplemental analyses to compare outcomes and improve prediction accuracy. MEPDG incorporates traffic load spectra, environmental effects, and material behavior, offering a more data-driven approach to pavement design. Furthermore, long-term field evaluations of widened lanes with non-tied shoulders should be conducted to validate the design thicknesses, assess performance under Alabama's climatic conditions, and perform life-cycle cost analyses to guide future implementation.

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APPENDIX A. SURVEY QUESTIONS

A-1. Part I: Pavement Design Methods and Parameters

1. Which state do you work for?

Alabama

Please click above in the drop-down box (Alabama as the default selection) to answer the question.

2. What concrete pavement design method do you currently use in your state?

☐ AASHTO 1972 Interim Guide

☐ AASHTO 1993 Guide

☐ AASHTO 1998 Supplement

☐ AASHTO Pavement-ME

☐ State-specific design method

☐ Other

2. a. If your response to the previous question is "other", please specify it.

Response (Florida): FDOT has design tables that has tables based on both AASHTO 1993 and MEPDG.

Response (Illinois): IL uses a state specific method.

Response (Iowa): Use Pavement ME and PCA procedure.

3. If you are using AASHTO 1993 design guide, how satisfied are you with the concrete pavement design method?

☐ Very satisfied

☐ Satisfied

☐ Neutral

☐ Dissatisfied

☐ Very dissatisfied

4. To what extent do you believe that the AASHTO 1993 Guide for Design of Pavement Structures results in conservative (over-designed) concrete pavement designs? (Only applicable for AASHTO 1993 design method users)

☐ To a great extent

☐ To a moderate extent

☐ Neutral

☐ To a small extent

☐ Not at all

5. What is the typical reliability level range used in your state for concrete pavement design? (Please select whichever applies.)

☐ 50% - 60 %

☐ 61% - 70%

☐ 71% - 80%

☐ 81% - 90%

☐ 91 % - 99.99%

☐ Does not apply

5.a. Can you please specify the typical reliability level used in your state based on your selection of range in above question? (e.g., 95%)

Response (Alabama): Values are based on traffic levels in that location. 95% is normally used and 90% is the second most used while 85% is rarely used.

Response (Texas): For CRCP selection is based on state specific ME design. For JPCP with <5 million ESALs, 90% is used and for >=5 million ESALs, 95% is used.

Response (Georgia): We normally use 95% reliability.

Response (Tennessee): A reliability level of 95% is generally used for Interstates and Principal Arterials and for local streets and roads, a reliability level of 90% is used.

Response (Louisiana): Urban Interstate:99%; Rural Interstate:97%; Urban Principal:97%; Rural Principal:95%, Urban Collector:90%, Rural Collector:85%.

Response (Florida): FDOT has a set policy but should be based on roadway classification and traffic volumes per the AASHTO 93 Design guide recommendations.

Response (North Carolina): We normally use 95% reliability.

6. What range of terminal serviceability index (Pt) do you typically use for concrete pavement design in your state? (Please select whichever applies.)

☐ 1.5 - 2.0

☐ 2.1 - 3.5

☐ 2.6 - 3.0

☐ 3.1 - 3.5

6.a. Can you please specify the typical terminal serviceability used for concrete pavement design based on your selection of range in above question? (e.g., 3.5)

Response (Alabama): Values are based on traffic levels in that location. 3.5 is normally used and 3.0 is the second most used while 2.5 is rarely used.

Response (Texas): For CRCP selection is based on state specific ME design. For JPCP 2.5 is normally used.

Response (Georgia): We normally use 2.5.

Response (Tennessee): We use 2.0.

Response (Louisiana): Interstate: 2.8; Principal: 2.5; Collector:2.0.

Response (Florida): FDOT has a set policy but should be based on roadway classification and traffic volumes per the AASHTO 93 Design guide recommendations.

Response (North Carolina): We use 2.5, 2.75, and 3.0 based on roadway classification and traffic volumes.

Response (Illinois): This input will also vary based on functional classification, but I don't agree with agencies that use a value greater than 3.

7. How confident are you in the accuracy and reliability of the input parameters (e.g., traffic data, material properties, environmental factors) used in your concrete pavement design?

☐ Extremely confident

☐ Very confident

☐ Moderately confident

☐ Slightly confident

☐ Not confident at all

8. Have you or your state conducted any studies or do you have data to justify the selection of reliability and terminal serviceability values?

☐ Yes

☐ No

8.a. If your response to the above question is "yes," can you please provide the process of selection of reliability and terminal serviceability values details? (Example: Performance, Cost, Safety, Service life, and so on)

Response (Alabama): Was based on Auburn University Study, which was not based on concrete pavements.

Response (Texas): Based on performance of our pavements that are lasting longer than their initial design life.

Response (North Carolina): We tried to be consistent with asphalt design, which is also 1993 design.

Response (Illinois): I'm not aware of any such studies. Again, IL uses their own state method.

9. What type of contract does your state typically use when implementing a pavement construction project?

☐ In-house contract

☐ External contractor

☐ Public-private partnership

☐ Joint venture

10. What process do you follow for reviewing consultants' concrete pavement designs?

☐ Detailed review of all design inputs and calculations

☐ Spot-check review of selected design inputs and calculations

☐ Rely on consultants' expertise and experience

☐ Other

10.a. If your response to the previous question is "other", please specify the process you follow for reviewing.

Response (Illinois): Since I'm not a DOT, I don't have a process for this. Occasionally, I will review a DOT's design to see if there's anything that I would have done different, but that's on a case-by-case basis and usually at the request of a local ACPA chapter (or occasionally a DOT itself).

A-2. Part II: Concrete Shoulder Design

11. Is the use of non-tied concrete shoulders permissible for lane widening projects in your state?

☐ Yes

☐ No

☐ Depends on specific project conditions.

11.a. Please can you explain the project conditions permissible for the use of the non-tied shoulders. (Example: Low traffic volume, stable climate and subgrade conditions, limited space for traffic operations, and so on)

Response (Alabama): We would not be opposed to their use depending on the conditions.

Response (Alabama): They should tie all shoulders on all projects, but ALDOT does not know the benefit of tied shoulders and many concrete pavements have asphalt and RCC shoulders.

Response (Texas): Non-tied shoulder is not allowed in our state.

Response (Georgia): New widening lanes are not tied to existing/old concrete.

Response (Florida): City streets, low volume roads, etc. Shoulders should be part of ALL designs and depending on that project specifics, their use can be determined. Concrete pavement design is about choosing the right features and AASHTO 93 and Policies often limit what can be done.

Response (North Carolina): Depend on the number of lanes.

12. Have you conducted any studies or have data on the cost-effectiveness of a wider slab (13'-14') and non-tied concrete shoulder versus a 12' slab width and tied concrete shoulder?

☐ Yes

☐ No

☐ Not sure

12.a. If the response to the previous question is “yes”, please provide details or refer to the relevant report.

Response (Florida): Need to use 13 ft widened lanes. Lots of research that show that moving loads in 18 inches makes it an interior load. Problem is 14 ft wide slabs have tendency to crack to get long cracks (~5%). Going to 13 ft wide lanes keeps slabs from getting to wide (and thus no long cracks) and virtually eliminates long cracking. Can also do 13ft and tied concrete shoulder. Again, all this should be project specific design options.

Response (Illinois): We have not written any formal report, but our back of the envelope calculations usually show that the cost of widening by 1 ft is equivalent to 1" of concrete.

So the question becomes, does widening save at least 1" of concrete and are there any major hurdles with paving wider than 12 ft.

Response (Iowa): We used a 14' widened lane for 25 years and are now dealing with a huge problem of extensive longitudinal cracking 3'-4' in from the edge of the widened slab. We switched back to a 12' wide slab with tied concrete shoulders in 2019 because of this problem. I would caution any state looking at or using widened slabs to consider the potential risks. I would definitely NOT use a 14' slab. Some states get away with a 13' slab and it works for them.

13. To what extent do you believe that a wider slab (13’-14’) and non-tied concrete shoulder can be a cost-effective alternative to a 12’ slab with tied concrete shoulder?

☐ To a great extent

☐ To a moderate extent

☐ Neutral

☐ To a small extent

☐ Not at all

A-3. Part III: Pavement Design Software

14. What software or spreadsheet do you use for concrete pavement design calculations?

☐ Agency-developed spreadsheet

☐ Commercially available software

☐ Manual calculations

☐ Other

14. a. If the response to the above question is “Commercially available software”, can you name it?

Response (Alabama): DARWin 3.1 (AASHTO '93)

Response (Texas): JPCP (AASHTO 1993 design method)

Response (Florida): FDOT uses design tables based off of AASHTO 93 and P-ME. My recommendation is use multiple programs b/c get insight from them all, but should rely on P-ME the most.

Response (Illinois): ACPA uses all different types of design software to illustrate the difference. Preference is typically AASHTOWare's Pavement ME. WinPAS is our software for AASHTO 93 (usually my least favorite). We have PavementDesigner.org which is a simple ME based design tool that's free.

14. b. If your response to the above question is “other”, please specify the method you use for calculations of concrete pavement design.

Response (Florida): We use all of them. P-ME, PavementDesinger.org, AASHTO 93, BCOA from Univ of Pitt, and some FEM occasionally.

15. If you have used the AASHTO 1998 Supplement for rigid pavement design, what were your experiences and challenges? (Example: Improved performance predictions, Calibration for local conditions, designing thinner pavements, Extensive data inputs, need of accurate calibrations, Sensitive to input variables, and so on.)

Response (Alabama): Need newer pavement design guidelines and Pavement ME is the best so far.

Response (Texas): Not much difference, while the thinner designs are slightly closer, AASHTO 1998 is still over designing.

Response (Florida): It gives OK values but compared to 93, it only shows minimal improvement. I rarely use it. State needs to adopt P-ME.

Response (North Carolina): Tried but not comfortable with results it gave the Department. Too much variability.

Response (Illinois): I do not recommend AASHTO 98. This procedure was an interim step to get to the MEPDG / AASHTOWare’s Pavement ME (PMED). The only state that has used it is CO and they have moved on to PMED. As far as I know, it was never fully calibrated, so I would be wary of using it.

16. How challenging is it to obtain approval for using alternative design methods or inputs (other than the standard methods used by your agency)?

☐ Extremely challenging

☐ Very challenging

☐ Moderately challenging

☐ Slightly challenging

☐ Not challenging at all

17. How important is the consideration of life-cycle cost analysis in your concrete pavement design process?

☐ Extremely important

☐ Very important

☐ Moderately important

☐ Slightly important

☐ Not important at all

18. Would you like to share any other notable practices, challenges, or considerations related to concrete pavement design?

19. Would you be interested in participating an in-depth interview about concrete pavement design?

☐ Yes, I would be interested if time permits.

☐ No, thank you.

☐ Maybe, if time permits.