# Preliminary Evaluation of Proposed LLPRS Rigid Pavement Structures and Design Inputs

Report Prepared for

**CALIFORNIA DEPARTMENT OF TRANSPORTATION**

By

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**EXECUTIVE SUMMARY**

Chapter 1 of this report includes a summary of the Caltrans objectives for long life concrete pavement rehabilitation strategies, the objectives of the UCB Contract Team work, and an overview of the four reports containing preliminary findings and recommendations from the UCB Contract Team.

The objectives of the Caltrans Long Life Pavement Rehabilitation Strategies (LLPRS) for rigid pavements (LLPRS-Rigid) are to provide 30 or more years of service life, to require minimal maintenance, and to have a construction production capability of about 6 lane-kilometers in a weekend. The current proposed strategy for LLPRS-Rigid is to use high early strength concretes (4- to 8-hour opening times), retain current base structures below the existing concrete slabs, remove and replace current 200- to 225-mm thick slabs with new slabs of the same thickness, and potentially include design features such as dowels, tied concrete shoulders, and widened truck lanes.

The objectives of the UCB Contract Team are to evaluate potential LLPRS-Rigid strategies with respect to structural adequacy of the designs, materials selection, and construction issues. To meet these objectives, the UCB Contract Team is performing mechanistic analyses of the proposed structures, investigation of design parameters, laboratory testing of paving materials, and verification of failure mechanisms and expected performance through Heavy Vehicle Simulator testing in the field.

This report is one of four presenting preliminary findings regarding the expected performance of LLPRS strategies developed to date by Caltrans. The other reports address potential long term concrete durability problems for concrete paving materials; investigations of the effects of loading configurations, concrete strength versus traffic opening times, and construction production; and the performance under HVS loading of an instrumented test pavement constructed using accelerated Portland cement concrete.

Chapter 2 presents an assessment of design criteria. Rigid pavement distress mechanisms are reviewed from a mechanistic perspective, including a summary of the effects of design, materials, environment, and construction variables on pavement performance. A historical review of distresses typical of Caltrans rigid pavements is made, to identify distress mechanisms that must be considered to obtain pavements with 30 years of service life. Design and construction practices over the past 50 years are reviewed, to obtain a better understanding of past performance, and because current LLPRS-Rigid strategies call for retention of all of the existing structure except for the concrete slab, and existing lanes with their particular joint spacings and slab thicknesses.

The important characteristics of the projects prioritized for inclusion in the LLPRS program are summarized, particularly with regard to environmental variables. The results of a recent condition survey performed to identify distress mechanisms present in the existing structures of LLPRS candidate projects is presented.

The findings of Chapter 2 are as follows:

- The mechanisms for pavement distresses are mostly understood. The distresses found on Caltrans rigid pavements, faulting and transverse, corner, and longitudinal cracking, are caused by mechanisms that for the most part have been investigated by other researchers and observed on rigid pavements in other states as well as in California. The mechanism that causes longitudinal cracking is the only one of those discussed in this report that is not well understood. The mechanisms for corner cracking and transverse joint faulting are understood, however, reliable quantitative models have not yet been developed.

- The most prevalent distress found on the candidate LLPRS projects is transverse joint faulting. Faulting occurs throughout the state. Some routes have faulting over nearly their entire length. Faulting is often severe enough to cause a high level of discomfort to road users.
- Past designs for faulting reduction measures have not been effective. Caltrans rigid pavement designs have changed since construction of the interstate highway system began in California in the mid-1950s. Many of those changes have been introduced to reduce faulting, which has been recognized as one of the most important distresses on California rigid pavements since the early 1960s. The distress mechanism for faulting requires poor levels of load transfer across joints, and the presence of movable materials in the material underlying the joints. The decision to not use dowels for better load transfer across transverse joints is based on construction problems observed in 1949 by Hveem. The use of dowels does not appear to have been the subject of Caltrans research since then. The use of cement treated bases as a non-erodable material beneath the concrete slabs does not appear to have mitigated the occurrence of severe faulting. The use of skewed joints also does not appear to have had much effect on faulting performance.
- Use of joint sealant reduce joint spalling, and may reduce longitudinal cracking. The construction of joint sealant reservoirs and use of long lasting compressible joint sealants can help keep incompressible materials out of the joints, which reduces the potential for joint spalling and possibly longitudinal cracking. Further investigation

of the mechanism for longitudinal cracking is needed to better determine the effects of incompressible materials in the joints.

- Cracking is present on Caltrans rigid pavements. Although cracking is not the most prevalent distress on Caltrans rigid pavements, transverse cracking and longitudinal cracking are present, and corner cracking is present to a lesser extent.
- The measures necessary to reduce joint faulting will probably result in a lower occurrence of corner cracking because both distresses are primarily caused by loss of support under the slab. Such measures may also reduce occurrence of longitudinal cracking. The measures identified to reduce faulting are improved joint load transfer, use of non-erodable materials below the concrete slabs, and elimination of free water beneath the slabs.
- Long joint spacings in proposed LLPRS projects will be critical for transverse (fatigue) cracking. In the current LLPRS-Rigid strategies under review for Caltrans by the University of California Berkeley Contract Team, the joint spacings of the truck lanes to be reconstructed must be the same as those of the inner lanes. Joint spacings on existing inner lanes range between 3.6 and 5.8 m. The longer joint spacings may cause transverse fatigue cracking or environmentally induced cracking to occur faster. (37)
- Flexural strength plays an essential role in cracking, particularly transverse fatigue cracking. Flexural strengths required by Caltrans are less than those of many other states.
- The strategies proposed for rigid pavement reconstruction by the team involved in the TRB evaluation of Interstate 710 call for 300- to 350-mm thick concrete slabs to be

placed on cement stabilized bases. These thick slabs will require substantial work on many bridges to maintain legal height clearances.

- Climatic regions play a significant role in rigid pavement distress mechanisms, but are not currently considered in Caltrans design procedures. The LLPRS candidate projects are located in several climatic regions. Temperature and rainfall play significant roles in rigid pavement distress mechanisms.

Chapter 3 presents an evaluation of the proposed LLPRS strategies using three current rigid pavement design methods: the Portland Cement Association (PCA) method; the American Concrete Paving Association (ACPA) version of the AASHTO method; and, the method developed for the Illinois Department of Transportation by the University of Illinois. The objective of this experiment was to evaluate the effects of various design features and design variables on slab thicknesses required to obtain service lives of 30 years or more.

A summary of preliminary investigations of expected design input variables is presented first. The design input variables include traffic and axle loads expected over the next 30 years, different levels of base and subgrade support, concrete strength, design features such as dowels and tied shoulders, design reliability, climate, drainage, and pavement failure modes.

The findings of Chapter 3 were:

- The various design methods currently in use produce different results. The ACPA/AASHTO and PCA methods consider both transverse fatigue cracking and distresses associated with loss of support to the slab. The Illinois DOT method considers transverse fatigue cracking only. The PCA and Illinois DOT methods use a mechanistic approach for transverse fatigue cracking analysis, while the ACPA/AASHTO method uses an empirical approach. The current ACPA/AASHTO method is extrapolated very far beyond the traffic levels encountered at the AASHO Road Test.

- In general, the required slab thicknesses for the ACPA/AASHTO method are much thicker than those of the Illinois DOT method. The required thicknesses from the Illinois DOT method are typically thicker than those from the PCA method, although at times they are in agreement.
- It is likely that axle loads will increase over the next 30 years due to the need to increase freight throughput without increasing lane capacity.
- Current concrete flexural strengths required by Caltrans are less than those required by many other State DOTs.
- The inclusion of dowels to increase load transfer at the transverse joints is necessary to obtain improved resistance to faulting, based on the results from the PCA and ACPA/AASHTO methods.
- The benefit of including dowels to reduce faulting is substantially increased when large diameter dowels are used. The largest possible size dowel should be used (i.e., 37-mm diameter) provided the concrete slab is thick enough to prevent cracking of the concrete cover around the dowels.
- Use of widened truck lanes or tied concrete shoulders to provide good load transfer across longitudinal joints is necessary to obtain good fatigue cracking performance. These features will improve performance with respect to distresses associated with loss of support to the slab as well.
- Use of non-erodable bases will improve performance for distresses associated with loss of subgrade support, such as faulting and corner cracking. The use of very stiff

bases that cannot accommodate temperature curling may be detrimental to transverse fatigue cracking performance.

- A minimum concrete strength of 650 psi (4.48 MPa) at 90 days is needed to limit the thickness of the concrete slabs.  Concrete strength of less than 650 psi (4.48 MPa) will require thicker slabs to prevent cracking.
- The coefficient of thermal expansion of the concrete plays an important role in determining tensile stresses in the slab due to temperature curling.  The determination of the coefficient of thermal expansion is necessary in order to determine the effect of new fast setting cements on slab cure stresses.
- Axle load spectra play a role in determining required slab thickness because the heaviest loads in the spectrum generally determine pavement performance with respect to both transverse fatigue cracking (single axle loads) and faulting (tandem axle loads).
- Although the three design methods generally did not require the same slab thicknesses for similar design inputs, they are nearly always in agreement as to the benefits and drawbacks of structural design features such as dowels and tied concrete shoulders, concrete flexural strength, thicker concrete slabs, and axle load spectra. The results from the PCA and Illinois DOT methods indicate that it may be possible to obtain 30-year design lives using 8- or 9-inch (203- or 229-mm) concrete slabs. Those methods indicate that for 30-year design lives, the pavements must include all of the following features:
    - concrete flexural strengths of 650 psi (4.48 MPa) or higher,

- concrete coefficient of thermal expansion less than $3 \times 10^{-6}$ to $5 \times 10^{-6}$ in./in./°F ($5.4 \times 10^{-6}$ to $9 \times 10^{-6}$ mm/mm/°C),
- dowels with as large a diameter as possible while providing sufficient concrete cover,
- tied concrete shoulders with high load transfer, or widened (4.3-m) truck lanes,
- non-erodable bases that are not too stiff when the concrete slab is curling due to temperature gradients.

Even with all of these features included in the pavements, 30-year design lives with 8- or 9-inch (203- or 229-mm) slabs may not be obtainable under conditions in which:

- slab lengths are greater than 15 ft. (4.57 m),
- day to night temperature changes introduce large tensile stresses, such as in the Desert and Valley climatic regions, and
- in particular, greater than 15-ft. (4.57 m) slab lengths are used in the Desert and Valley climatic regions.

As presented in Chapter 4, the recommendations to Caltrans based on the findings of this report are:

- **Faulting.** Faulting is the most prevalent distress that occurs in Caltrans rigid pavements. Transverse cracking due to axle loading and temperature curling, corner cracking, and longitudinal cracking are also present in the network. Each distress must be addressed specifically in the pavement designs.
- **Axle Loads.** Axle loads and the number of trucks on the design lanes will undoubtedly increase over the next 30 years. Designs that may have worked in the

past may not work in the future, and designs that did not provide adequate performance in the past will deteriorate even more quickly under the increased loading. This traffic and loading growth must be accounted for in the pavement designs. The efficiency of evaluating truck traffic in terms of ESALs, as opposed to evaluating distress mechanisms in terms of axle load spectra, merits further investigation.

- **Climate and Slab Length.** The performance of the LLPRS proposed pavement structures will depend in large part on the specific climate and the slab lengths of the adjoining lanes. Rigid pavements in the Desert and Valley climates, with their large day to night temperature changes, will deteriorate with respect to cracking faster than the milder coastal climates. Transverse joint spacings greater than 15 ft. (4.57 m) will also experience more rapid cracking than joint spacing less than 15 ft. (4.57 m), all other variables being equal. Pavement structural designs must be considered on a project by project basis, rather than applying a uniform structure across a variety of climates and joint spacings, as well as base, subgrade, and drainage conditions.
- **Stiff Bases.** The use of very stiff bases may lead to earlier cracking because of temperature curling. This is particularly the case in the Valley and Desert climates with long slab lengths large concrete coefficients of thermal expansion. At the same time, bases should be as non-erodable as possible in order to minimize loss of support to the slab, which contributes to faulting and corner cracking. The effectiveness of keeping the existing CTB bears further investigation, especially to evaluate its strength and condition. New asphalt concrete bases with relatively high asphalt contents may provide the desired properties of being non-erodable, yet with low

stiffness under loading times of several hours. Alternative bases should be considered with respect to structural performance and constructability.

- **Flexural Strength and Coefficient of Thermal Expansion.** The most important concrete properties from a pavement structural performance perspective are flexural strength and coefficient of thermal expansion. Long term durability is also important, and is addressed in a separate report. (*38*) Large flexural strengths (650 to 800 psi [4.44 to 5.52 MPa]), and small coefficients of thermal expansion ($3\times10^{-6}$ to $5\times10^{-6}$ in./in./°F) are needed to minimize slab thicknesses. Development of materials meeting these requirements is essential if the desired design life of 30 or more years is to be obtained.
- **Dowels, Tied Concrete Shoulders, and Widened Truck Lanes.** It is apparent from the design methods that the use of dowels is necessary to address faulting. The use of tied concrete shoulders or widened truck lanes is needed to address fatigue cracking and loss of support to the slab, which contributes to faulting and corner cracking. These features should be implemented in the LLPRS-Rigid strategies based on these preliminary investigations performed using existing design methods.
- **Slab Thickness.** Although not exactly in agreement, the PCA and Illinois DOT methods indicate that 8- and 9-inch (203- and 229-mm) concrete slabs may provide adequate design lives, provided that all of the other factors included in these recommendations are addressed. At this time, it can be assumed that 8- to 9-in. (203-229-mm) thicknesses will be adequate for some projects. At the same time, methods for constructing somewhat thicker slab thicknesses, probably ranging from 10 to 12 inches (254 to 305 mm), should be considered for projects with combinations of the

heaviest truck traffic, Valley and Desert climates, and slab lengths greater than 15 ft. (4.57 m).

These recommendations are based on preliminary investigations conducted using existing design methods. Except for the study of the effects of bearing stress and dowel sizes on faulting performance, the design methods used in this report are primarily calibrated for conditions in the Midwestern states. Despite the Midwestern calibration, the results of this study provide good indications of the structure and materials requirements necessary to produce LLPRS pavements that will provide 30 or more years of good performance. Continued investigation of each of the variables included in this study is necessary for verification and calibration under expected conditions in California over the next 30 years.

# 1.0 BACKGROUND OF LLPRS

The California Department of Transportation (Caltrans) Long-Life Pavement Rehabilitation Strategies (LLPRS) Task Force was commissioned on April, 1997. The product that Caltrans has identified for the LLPRS Task Force to develop is Draft Long Life Pavement Rehabilitation guidelines and specifications for implementation on projects in the 1998/99 fiscal year. The focus of the LLPRS Task Force has been rigid pavement strategies. A separate task force has more recently been established for flexible pavement strategies, called the Asphalt Concrete Long-Life (AC Long-Life) Task Force.

The University of California at Berkeley (UCB) and its subcontractors, Dynatest, Inc., the Roads and Transport Technology Division of the Council for Scientific and Industrial Research (CSIR), and Symplectic Engineering Corporation, Inc., are investigating the viability of various proposed LLPRS optional strategies for Caltrans.

## 1.1 Objectives

### 1.1.1 LLPRS Objectives

In recent years, Caltrans engineers and policy makers have felt that existing methods of rigid pavement maintenance and rehabilitation may not be optimum from a benefit/cost or lifecycle cost standpoint. Caltrans is also becoming more concerned about increasingly severe traffic management problems. The agency costs of applying lane closures in urban areas is very large compared to the actual costs of materials and placement, and increased need for maintenance forces to be in the roadway is increasing costs and safety risks. In addition, the costs to Caltrans' clients, the pavement users, are increasing due to the increasing frequency of lane closures, which cause delays, and the additional vehicle operating costs from deteriorating ride quality.

A need to develop lane replacement strategies that will not require long-term closures associated with the use of Portland Cement Concrete (PCC) and that will provide longer lives than the current assumed design life of 20 years was identified. Caltrans has developed strategies for rehabilitation of concrete pavements intended to meet the following objectives (1):

1. Provide 30+ years of service life,
2. Require minimal maintenance, although zero maintenance is not a stated objective,
3. Have sufficient production to rehabilitate or reconstruct about 6 lane-kilometers within a construction window of 67 hours (10 a.m. Friday to 5 a.m. Monday).

### 1.1.2 Contract Team Research Objectives

The objective of the contract work is to develop as much information as possible to estimate whether the Long Life Pavement Rehabilitation Strategies for Rigid Pavements (LLPRS-Rigid) will meet the stated LLPRS-Rigid objectives. The Contract Team research objectives have been determined by the Caltrans LLPRS task force.

The research test plan (*2*) is designed to provide Caltrans with information regarding the following aspects of the LLPRS-Rigid design options being considered by Caltrans. It is hoped that this information will enable Caltrans to increase the performance and reliability of the pavements being placed in the field. The objectives of the test plan research are the following:

- To evaluate the adequacy of structural design options (tied concrete shoulders, doweled joints, and widened truck lanes) being considered by Caltrans at this time, primarily with respect to joint distress, fatigue cracking and corner cracking,

- To assess the durability of concrete slabs made with cements meeting the requirements for early ability to place traffic upon them and develop methods to screen new materials for durability, and
- To measure the effects of construction and mix design variables on the durability and structural performance of the pavements.

To achieve these objectives three types of investigation are being performed:

- Computer modeling and design analysis, including use of existing mechanistic-empirical design methods, and estimation of critical stresses and strains within the pavement structure under environmental and traffic loading for comparison with failure criteria;
- Laboratory testing of the strength, fatigue properties, and durability of concrete materials that will be considered for use in the LLPRS pavements; and
- Verification of failure mechanisms and design criteria and validation of stress and strain calculations under traffic and environmental loading by means of accelerated pavement testing using the Heavy Vehicle Simulator (HVS) on test sections constructed in the field.

The first milestone in the research project is the preparation of a set of reports and presentations identifying key issues that will affect the potential for success of the proposed rehabilitation strategies. The presentations of preliminary results were made to the Caltrans Long Life Rehabilitation Strategies (LLPRS) Task Force on 18 June, 1998 in Woodland, California. This report and three other reports (*9, 37, 38*) are part of the first milestone.

## 1.2 Overview of Preliminary Reports

Four reports have been prepared for the June, 1998 milestone. They are as follows

- This report, which presents an assessment of the critical design criteria and an evaluation of the proposed strategies using three rigid pavement design methodologies.
- A report that includes preliminary results of investigations of load equivalence factors for design, potential new axle configurations and load limits, the development of longitudinal cracking, and the relationships between strength gain in concrete, traffic opening times, and construction productivity. (*9*)
- A report that presents an assessment of the causes of long-term chemical durability problems in cements and concretes that have high early strength properties desired for LLPRS projects. (*38*)
- A report that describes the construction of an instrumented test pavement using calcium chloride accelerated PCC, and the results and analysis of HVS testing of this test section pavement. (*37*)

Together, these reports identify the most important issues that need to be addressed in the evaluation of the LLPRS-Rigid proposed strategies, and provide preliminary results and recommendations regarding these issues.

## 1.3 Overview of this Report

Chapter 2.0 of this report contains an assessment of the important criteria for design of rigid pavements in California based on past experience. The assessment includes a review of the evolution of Caltrans designs and failure modes for those designs, and a review of the existing pavement structures, climate, and future traffic conditions in which the LLPRS strategies will be expected to perform.

Chapter 3.0 presents the results of using three structural design methods commonly used in practice to estimate the performance of the proposed LLPRS-Rigid strategies.

Chapter 4.0 includes a summary of the results included in this report, conclusions drawn from the results, and preliminary recommendations based on the conclusions.

## 2.0 ASSESSMENT OF DESIGN CRITERIA

Caltrans has been building, operating, and maintaining rigid pavements for more than 60 years. Traditionally, Caltrans has referred to rigid pavements as PCCP or Portland Cement Concrete Pavement. The potential for using materials other than Portland Cement Concrete for similar pavement structures requires that they be referred to as rigid pavements for this report.

Caltrans operates a state highway network of more than 24,000 centerline kilometers, with over 78,000 lane-kilometers of pavement. Rigid pavements make up 32 percent, or about 25,000 lane-kilometers, of the Caltrans pavement network. Most of the Caltrans rigid pavements are on heavy truck routes and/or are in urban areas where heavy traffic volumes exist. Rigid pavements were used extensively for construction of the California State Interstate Highway system (*3*).

Approximately 75 percent of California state highway pavements were constructed in the 15 years between 1959 and 1974, and were designed for 20 year lives based on traffic volumes and loads estimated at that time. (*3*) It has been estimated that approximately 90 percent of the rigid pavements were constructed in those 15 years (*4*), which means that those pavements will have been in service for 25 to 40 years by 1999.

### 2.1 Rigid Pavement Distress Mechanisms

In order to develop effective pavement designs, it is essential to understand the mechanisms that cause pavement distresses. The mechanisms responsible for the most common rigid pavement distresses occurring in California are briefly summarized herein as a point of reference for the discussion of design methods and the proposed LLPRS rehabilitation design strategies that follow.

### 2.1.1 Faulting

Transverse joint faulting is the difference in elevation between abutting slab faces. The difference in elevation is the result of the build-up of material under the approach slab, and often the loss of material under the leave slab, as shown in Figure 1.

Faulting is primarily the result of a combination of heavy axle loads, pumpable materials in the layers beneath the concrete slab, and presence of moisture beneath the pavement. Heavy axle loads passing over the transverse joint or crack causes the rapid upward deflection of the approach slab and downward deflection of the leave slab, which in turn causes material to accumulate under the approach slab. The rapid deflections result in the movement of material from under the leave slab to under the approach slab, and may also bring materials from the subgrade or other layers to the underside of the approach slab.

Faulting is primarily reduced or prevented through good load transfer between concrete slabs, which minimizes the differential deflection caused by axle loads passing over the joint. The use of non-erodable materials that do not migrate and the elimination of free water in the layers under the slab also aid in the reduction of faulting.

### 2.1.2 Pumping

Pumping is the ejection of loose materials and water from under the pavement through cracks and joints under large deflections, as illustrated in Figure 2. Pumping becomes a serious problem when the volume of displaced materials results in loss of support to the slab at the corners, which causes larger deflections and stresses at the corners and may result in corner cracks. Pumping can also cause incompressible material to accumulate in the joints between concrete slabs, which can lead to cracking and spalling at the joints, referred to as “blow-ups,” and may be a cause of longitudinal cracking.

a)

b)

c)

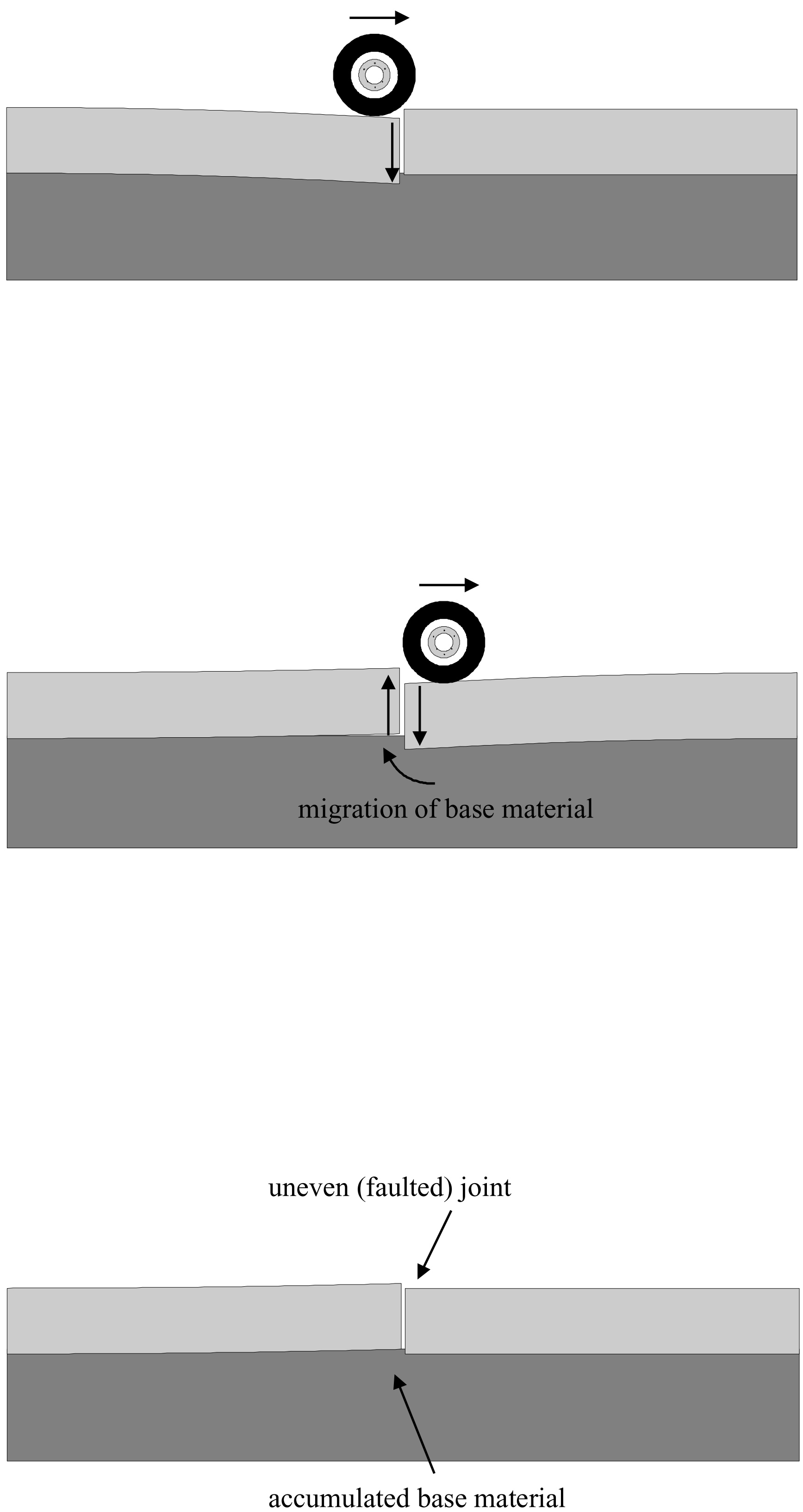



**Figure 1. Schematic representation of faulting distress mechanism in rigid pavements.**

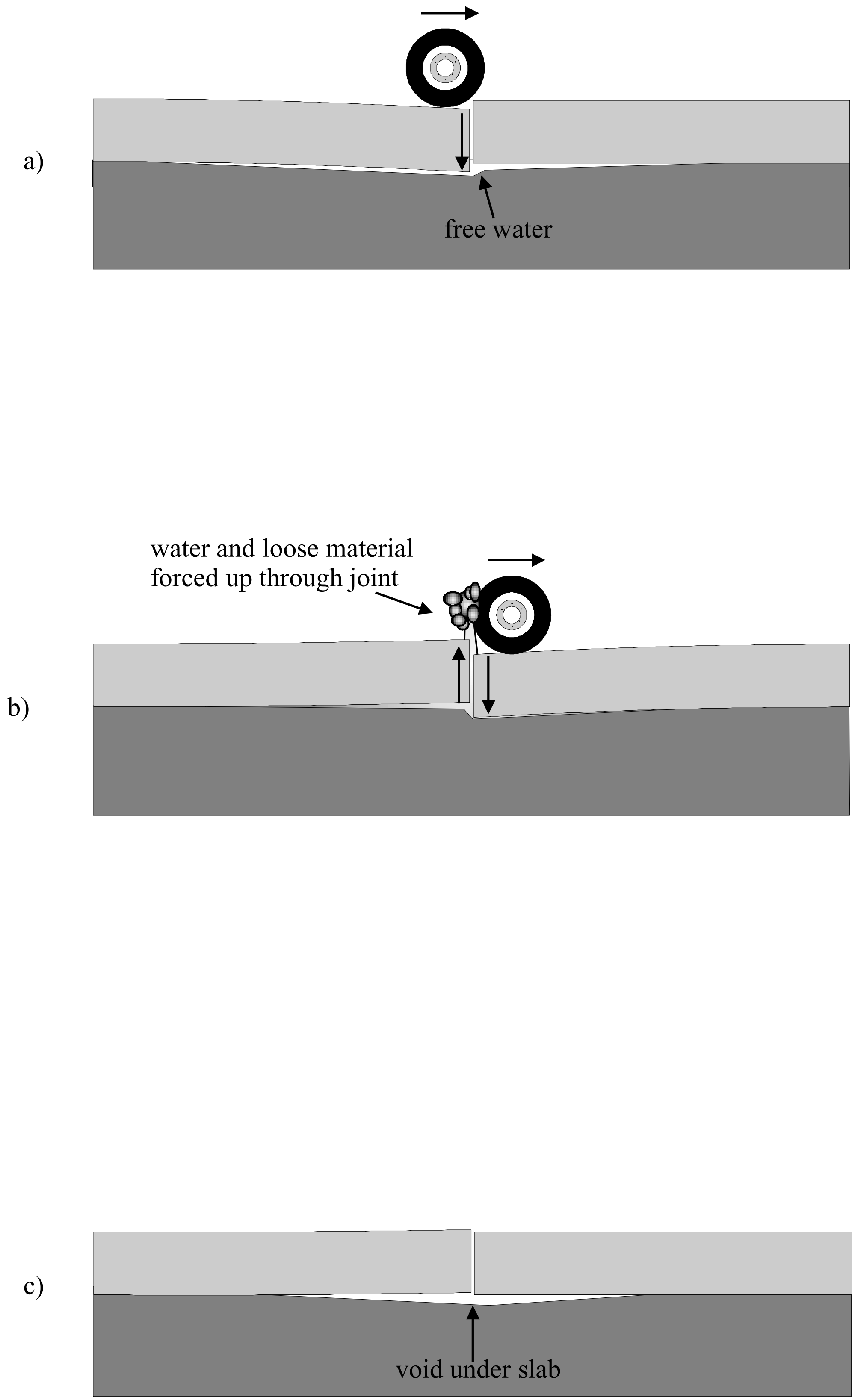



**Figure 2. Schematic representation of pumping distress mechanism in rigid pavements.**

Pumping is primarily reduced or prevented by the elimination of free water in the layers under the concrete slab. Pumping is also reduced by employing the same tactics as those used to reduce faulting (i.e., ensuring good load transfer between joints and using non-erodable materials).

### 2.1.3 Corner Cracking

A corner crack is a crack that intersects a transverse joint and the pavement edge at a distance of about 2 m or less on each side from the corner of the slab, as illustrated in Figure 3.

Corner cracks are caused by loss of support under the slab corner and loading from one or a combination of heavy axles, thermal curling, moisture warping, and high deflections. Loss of slab support can be the result of voids under the slab corners caused by pumping or faulting, or poor load transfer across longitudinal and transverse joints and/or shoulders.

Corner cracks are reduced or prevented primarily by measures that prevent loss of support under the slab corners, including good load transfer from dowels and/or tied concrete shoulders, widened truck lanes, use of non-erodable material below the slabs, good drainage, and reduction of corner deflection.

### 2.1.4 Transverse (Fatigue) Cracking

Transverse cracks generally cross the slab in a direction perpendicular to the slab edge and the direction of traffic, and are located near the transverse centerline of the slab, as illustrated in Figure 4.

Transverse cracks occurring soon after construction are typically caused by stress levels greater than the flexural strength of the concrete. These conditions are the result of some combination of restraint forces from shrinkage or temperature changes, thermal curling, moisture

**Figure 3. Typical corner cracks in rigid pavements.**

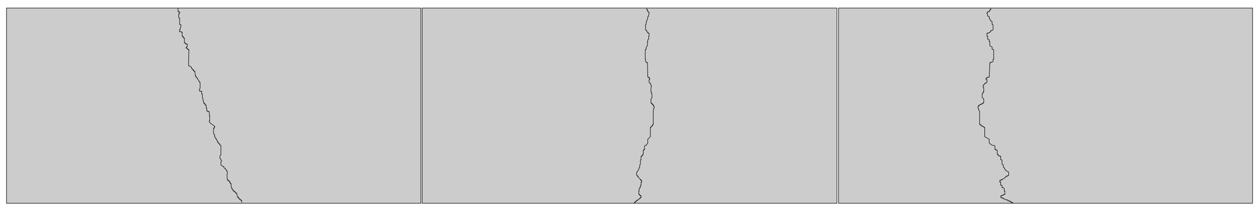


**Figure 4. Schematic of typical transverse fatigue cracks in rigid pavements.**

warping, and/or traffic loads placed on the concrete before it has sufficient strength. Transverse cracking caused by these mechanisms can largely be prevented through timely sawing of contraction joints, proper design of slab lengths, construction practices with consideration for the control of moisture warping and thermal curl during curing, and control of traffic to provide sufficient strength development in the concrete before loading.

Transverse cracks that occur in the years following construction are primarily the result of fatigue of the concrete slab caused by repeated heavy axle loads and temperature curling at tensile stress levels less than the flexural strength of the concrete. If the concrete has particularly low flexural strength, temperature stresses alone or a few load repetitions may be sufficient to cause transverse cracking. The fatigue damage caused by a truck load or curling stress is a function of the stress ratio:

$$\sigma / MR$$

where $\sigma$ is the tensile bending stress in the slab caused by the truck load and/or stress caused by curling due to a thermal gradient in the slab, and *MR* is the flexural strength of the concrete.

A larger ratio of stress to strength results in cracking after fewer repetitions of the stress. The strength to stress ratio indicates the two factors controlling fatigue cracking: tensile bending stress in the slab and flexural strength of the concrete. The stress in the slab is determined by the truck axle load, the thermal gradient in the slab, slab thickness, slab length, subgrade support, and the edge support provided to the slab by load transfer devices (e.g., dowels, tied shoulders, and/or widened lanes) near the axle load. The flexural strength of the concrete is controlled by the concrete materials, mix design, construction variability, and curing time and conditions.

Many state highway agencies (SHAs) specify the flexural strength of concrete used for pavements, primarily to control fatigue cracking. Table 1 shows the summary of a recent survey

**Table 1 Minimum Concrete Flexural Strengths Required by State Highway Agencies**

| **Minimum Required 28-day Flexural Strength (MPa)** | **Number of State Highway Agencies** |
|---|---|
| 4.13 | 3 |
| 4.27 | 1 |
| 4.34 | 2 |
| 4.48 | 11 |
| 4.57 | 1 |
| 4.62 | 1 |
| 4.75 | 1 |
| 4.82 | 4 |

of SHA requirements for the minimum 28-day modulus of rupture. (*5*)

The Federal Aviation Administration (FAA) requires 4.82 MPa (700 psi) at 28 days. Caltrans currently requires a minimum 14-day flexural strength of 3.79 MPa (550 psi).

Typically, 90-day strengths for Portland cement concrete are about 1.2 times greater than 14-day strengths. Similarly, 90-day strengths are about 1.1 times greater than 28-day strengths. Therefore, 28-day strengths are approximately 1.1 times greater than 14-day strengths. Using this strength relationship, the Caltrans specification of 3.79 MPa at 14 days is approximately equivalent to a 28-day strength of 4.17 MPa, or about 1.1 times the 14-day strength value. As can be seen in Table 1, most SHAs and the FAA require much greater flexural strengths.

The resistance of the slab near the axle load depends on the underlying materials, but more importantly on the location of the axle load relative to unsupported vertical edges of the slab. Because the left side of the truck is the side where drivers can make visual contact with the road, truck drivers tend to follow the left lane line. Heavy axle loads cause much more fatigue damage when they pass at a slab edge than when they pass on the interior of the slab. Figure 5 shows a typical distribution of fatigue damage as a function of the distance from the edge at which the axle load passes. (*6*) For this reason, design techniques that limit axle loads near the

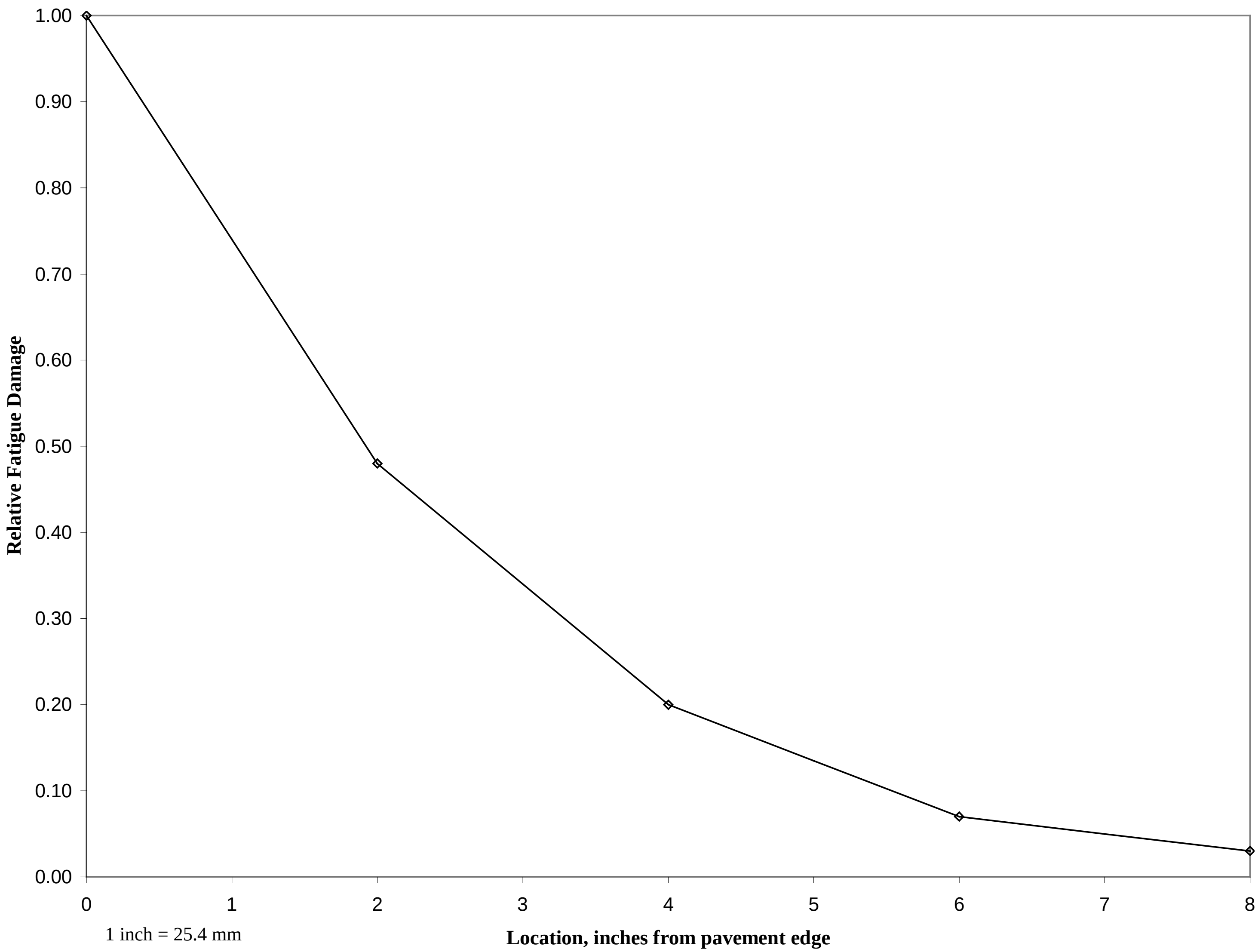



**Figure 5. Typical distribution of fatigue damage as function of the distance from the edge at which the axle load passes. (*6*)**

edge of the slab such as widened truck lanes, or provide improved load transfer across slab edges such as tied concrete shoulders and tied longitudinal joints, reduce fatigue damage, as illustrated in Figures 6 and 7. (*7*)

### 2.1.5 Longitudinal Cracking

Longitudinal cracks generally run parallel to the edge of the slab in the direction of traffic, as illustrated in Figure 8. Longitudinal cracks can be caused by poor or late sawing of longitudinal joints, warping or curling of the slab, or loss of support to the slab caused by movement of underlying materials. (*8*)

Longitudinal cracking may also be caused by non-uniform accumulation of incompressible fines in transverse joints, which can cause high tensile stresses when the slabs expand with increasing temperature. The potential for this mechanism is presented in more detail in the companion to this report. (*9*)

Longitudinal cracking can be controlled by timely and proper sawing of longitudinal joints, good slab support, and potentially by elimination of incompressible fines from transverse joints.

### 2.1.6 Spalling

Spalling typically occurs at transverse joints, and is the fracture or chipping of the slab edges within one meter of the joint. Spalling can occur at transverse and corner cracks as well, however control of those distress mechanisms negates the need to control spalling at cracks. Spalling can be caused by:

- the presence of incompressible materials in the joints, which causes large stresses when the slab expands with increasing temperature,

- poor durability of the concrete because of chemical reactions between the aggregate and cement or between the concrete and the environment (water, adjacent materials), or frost damage,
- inadequate densification of the concrete near joints with load transfer devices such as dowels and tie bars, and
- misaligned or corroded transverse joint load transfer devices such as dowels. (*6, 8*)

Spalling can be controlled by elimination of each of these potential distress mechanisms.

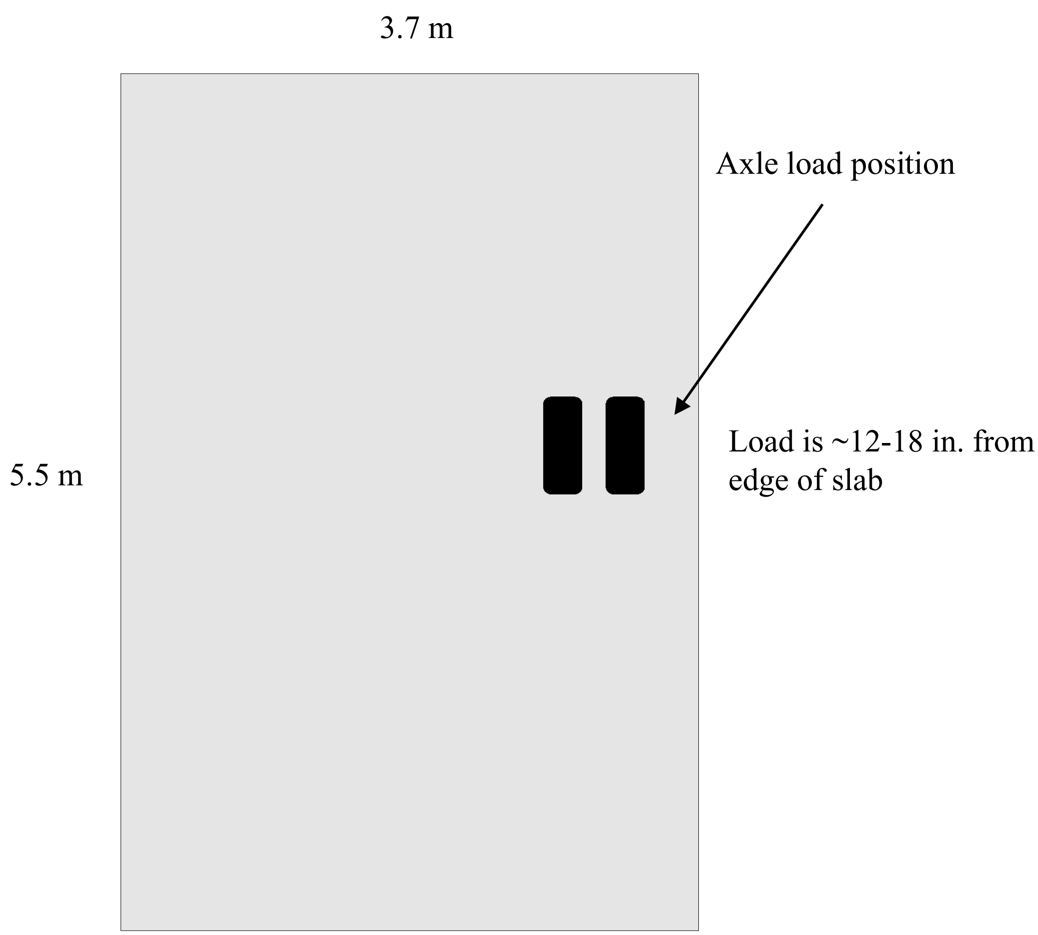



**Figure 6. Standard lane width and corresponding axle load location.**

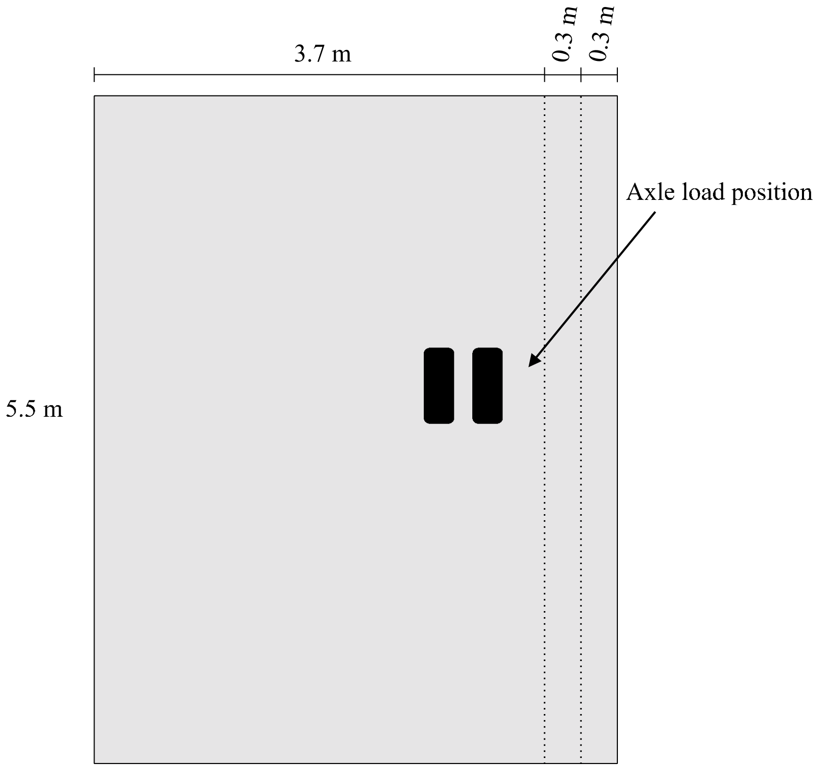



**Figure 7a. Wide lane widths and corresponding axle load locations.**

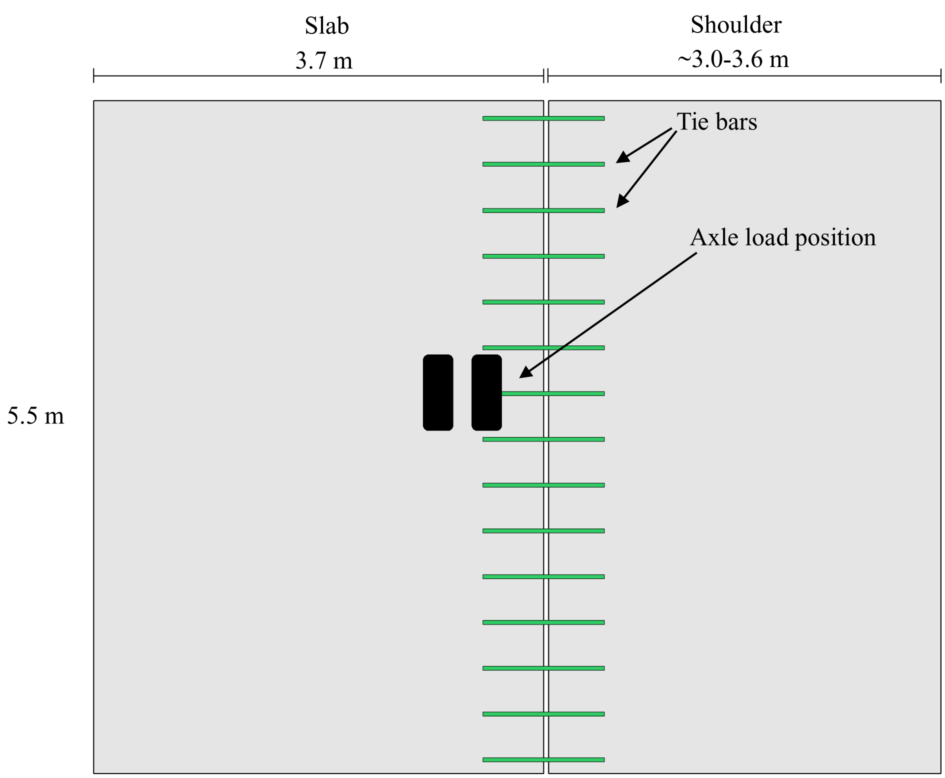



**Figure 7b. Tied shoulder and corresponding axle load location.**

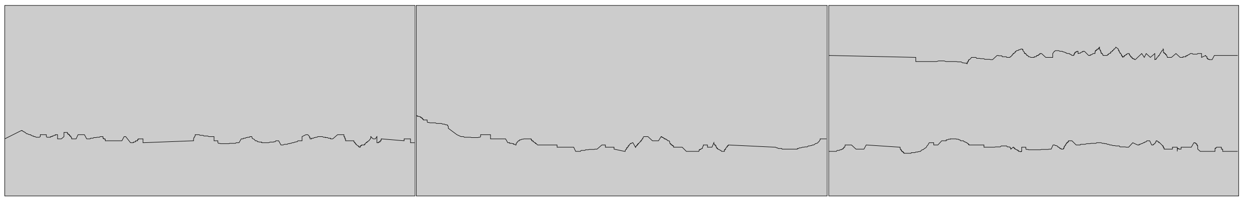


**Figure 8. Schematic of typical longitudinal cracks in rigid pavements.**

## 2.2 Caltrans Rigid Pavement Design Evolution since 1959

The Caltrans rigid pavement design method is essentially an empirical method based on experience gained from long-term performance observations of in-service pavements and engineering judgement. Changes to the design procedure have occurred when problems have been observed in the performance of mainline pavements or a limited number of test sections. The Caltrans rigid pavement design guide does not fall into a mechanistic-empirical framework accounting for traffic, materials, and environment.

### 2.2.1 Design Features Continuously Used Since 1959

Although Caltrans rigid pavement designs have changed several times since 1959, some design features have been used continuously since at least 1959. Some non-standard design features, such as continuous reinforcement, have been used in test sections. However, their use has been confined to one or two locations.

Caltrans exclusively uses plain jointed concrete, meaning that the slabs do not contain steel rebar or wire mesh. In reinforced concrete, the rebar or wire mesh is intended to hold cracks in the slab together and maintain load transfer across the cracks through aggregate interlock.

All standard Caltrans rigid pavements are jointed, meaning that they have no load transfer devices at the joints. The joint load transfer devices typically used by many other state highway agencies (SHAs) are steel dowels.

Caltrans rigid pavements usually have asphalt concrete shoulders. Alternatives to asphalt concrete shoulders are tied concrete shoulders that provide load transfer across longitudinal joints between the edge of the loaded slab and the adjoining slab or concrete shoulder.

Caltrans saws concrete joints, but does not form transverse joint sealant reservoirs in the cuts. Joint sealing is typically not performed, although at times joints are sealed using poured crack sealant type material. For a time, preformed joint seals were tried, but they gave poor performance because joints did not crack, the forms often became bent or tilted during construction, and transverse joints in adjacent lanes often did not line up.

### 2.2.2 1952 to 1964

Slab thicknesses, slab lengths, joint types and joint details have changed over time. Between 1952 and August, 1964 slab thicknesses were 200 or 225 mm, depending upon the design truck traffic. Slab lengths were uniform at 4.6 m, with perpendicular or skewed joints optional. An Aggregate Subbase (ASB) was placed over the subgrade, and a Cement Treated Base (CTB) placed on ASB before placement of the concrete slab. The CTB layer was 100 mm thick and had a compressive strength requirement of 2067 kPa (300 psi) at 7 days when the PCC slab was 200 mm thick; and 100 mm thick with a strength requirement of 4830 kPa (700 psi) when the PCC slab was 225 mm thick. The CTB was usually road mixed, which resulted in a layer with a relatively high variability in strength. The 1952-1964 Caltrans rigid structures are shown in Figure 9.

### 2.2.3 1964 to 1967

From 1964 until 1967, slab thicknesses remained 200 and 225 mm, although the allowable truck traffic for slabs was made less conservative, as shown in Figure 10. Slab lengths followed an alternating pattern of 3.7, 4.0, 5.5, 5.8 m, and all joints were required to be skewed at an angle of 9.5 degrees. Requirements for the CTB layer changed to a thickness of 100 mm and a compressive strength of 2756 kPa (400 psi) under 200-mm thick PCC slabs; and, a 150-

mm thickness and a compressive strength of 5168 kPa (750 psi) under 225-mm thick PCC slabs. The R-value requirements were also increased for the ASB. The CTB was still road mixed.

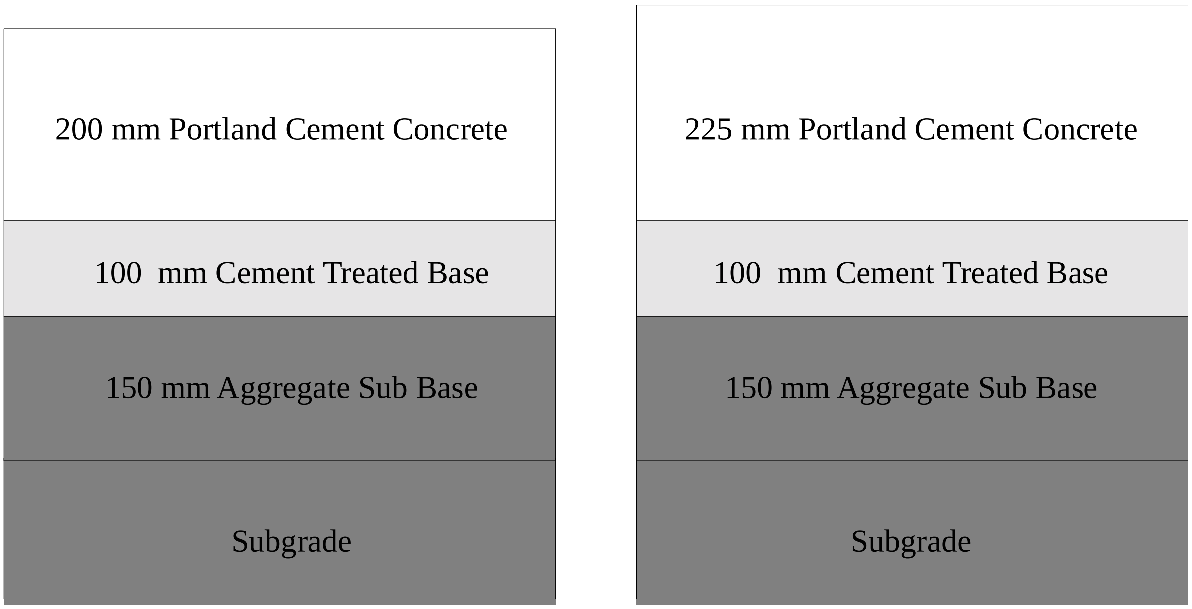
### 2.2.4 1967 to 1983

During the period from 1967 to 1983, a modified version of the Portland Cement Association (PCA) method was used to design rigid pavements. The resulting designs typically consisted of 200- or 225-mm thick slabs with 150 mm of CTB and a varying thickness of ASB depending on the truck traffic. Asphalt concrete bases (ACB) and aggregate bases (AB) were also permitted in the early years of this period, and asphalt concrete and lean concrete bases (LCB) were permitted in the latter years. After 1967, CTB was required to be plant mixed, which produced a more uniform layer than did the previously used road mix. The minimum R-value for the aggregate subbase was 40. Slab lengths were required to follow a pattern of 3.7, 4.0, 5.5, 5.8 m. Skewed joints were also required. The pavement structure from this period is shown in Figure 11.

### 2.2.5 1983 to Current

Since 1983, constructed slab thicknesses have been between 150 and 260 mm, depending upon the design truck traffic, as shown in Figure 12. Slab lengths are 3.6, 4.6, 4.0, and 4.3 m, with joints skewed counterclockwise at an angle of 9.5 degrees. Of the four types of base and subbase system shown in Figure 12, the use of Asphalt Treated Permeable Base (ATPB) with Aggregate Base (AB) and Aggregate Subbase (ASB), or Cement Treated Permeable Base (CTPB) with AB and ASB, are required to be given first consideration because they are considered to provide better drainage. They are to be used with an edge drain collector and outlet system. The Lean Concrete Base (LCB) with ASB, or Asphalt Concrete Base (ACB) with

# 1952 - 1964

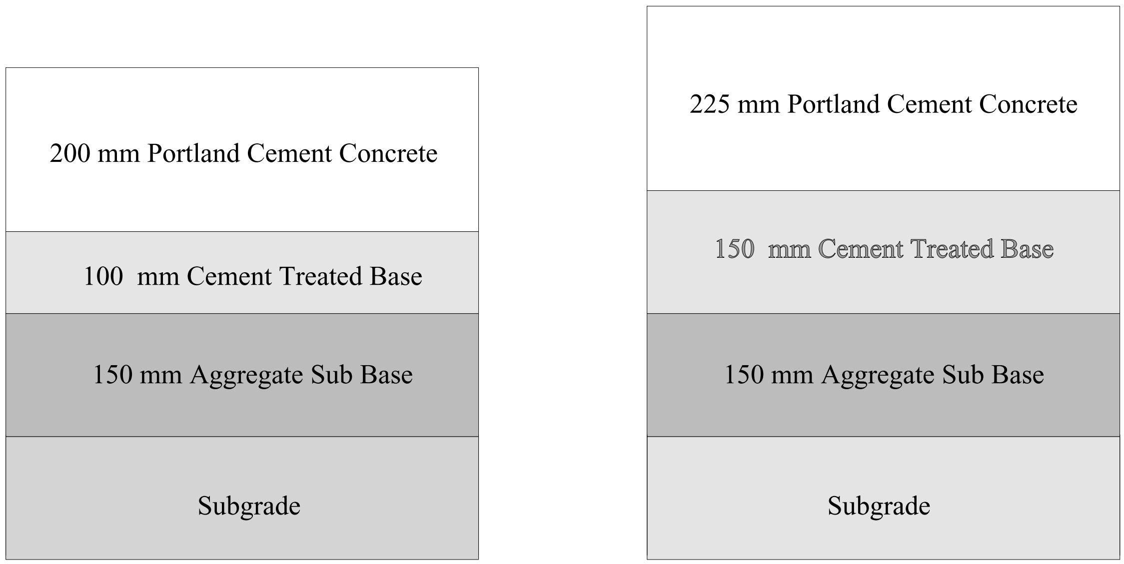



CTB = 350 psi (2.41 MPa) at 7 days
$R_{min}$ = 30 for aggregate subbase
Joint spacing = 15 ft. (4.57 m)
Joint skewing optional
TI < 10 (ESALs < 2.5 million)

CTB = 700 psi (4.83 MPa) at 7 days
$R_{min}$ = 30 for aggregate subbase
Joint spacing = 15 ft. (4.57 m)
Joint skewing optional
TI > 10 (ESALs > 2.5 million)

**Figure 9. Caltrans rigid pavement design structures from 1959 to August 1964.**

# 1964 - 1967

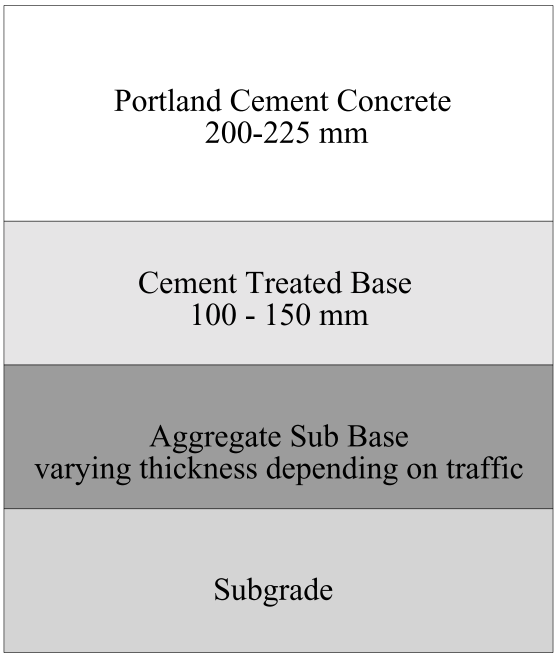



CTB = 400 psi (2.76 MPa) at 7 days
Rmin = 40 for aggregate subbase
Random joint spacing
Joints skewed by 2 ft. in 12 ft. (.61 m in 3.66 m)
TI < 12 (ESALs < 11.5 million)

CTB = 750 psi (5.17 MPa) at 7 days
Rmin = 40 for aggregate subbase
Random joint spacing
Joints skewed by 2 ft. in 12 ft. (.61m in 3.66 m)
TI > 12 (ESALs < 11.5 million)

**Figure 10. Caltrans rigid pavement design structures from 1964 to 1967.**

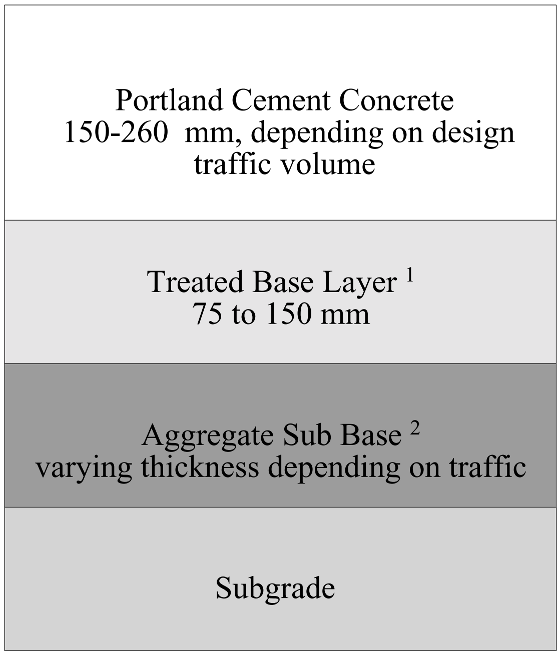
1967 - 1983




CTB = 400 psi (2.76 MPa)
Rmin =  40 for Aggregate Sub Base
Joints spaced at 3.6, 4.6,4.0, 4.3 m pattern
Joints skewed

**Figure 11.  Caltrans rigid pavement design structures from 1967 to 1983.**

1983 to present




CTB = 400 psi (2.76 MPa)
Rmin = 40 for Aggregate Sub Base
Joints spaced at 3.6, 4.6,4.0, 4.3 m pattern
Joints skewed at 9.5 degrees counterclockwise

1) Base layer could also be Asphalt Concrete Base, Asphalt Concrete Base, Lean Concrete Base, ATPB, or CTPB.

2) ASB layer typically eliminated when Subgrade R-value > 40.

**Figure 12. Caltrans rigid pavement design structures since 1983.**

ASB underlying layer systems also require the use of an edge drain collector and outlet system. The ASB layer is typically eliminated when the subgrade R-value is greater than 40.

Many rigid pavements were retrofitted with edge drain systems in the late 1980s and early 1990s. The retrofitting did not include installation of a treated permeable base under the concrete slab. The program of edge drain retrofits has not been continued because of observed problems with clogging of the drainage systems with fine soils, and problems maintaining the edge drain systems due to technical and maintenance staffing reasons. These observed problems have at times resulted in "bathtub" conditions in which water remains trapped under the concrete slabs. Problems of stripping of the Asphalt Treated Permeable Base (ATPB) layer as it is currently designed have also been observed. (*10, 11*)

## 2.3 Previous Reviews of Caltrans Designs

The performance of Caltrans rigid pavement design has been comprehensively reviewed several times over the past fifty years, and changes to the standard designs have often been based on the recommendations of those reviews. Two primary sources were reviewed to evaluate the evolution of Caltrans rigid pavement designs and the performance observations upon which changes to the standard designs were based:

- A 1979 report by McLeod and Monismith (*12*) that primarily provided a detailed review of the effects on performance of the 1964 changes to the standard designs, and
- A 1991 report by Wells and Nokes (*10*) that evaluated the evolution of Caltrans standard designs since 1949, and also compared Caltrans design practice to that of other states in the early 1990s.

2.3.1 McLeod and Monismith

The report by McLeod and Monismith evaluated the effects of the 1967 changes to the standard designs on rigid pavement performance about 15 years after those changes were first implemented. The 1967 changes primarily consisted of slab lengths following a pattern of 3.7, 4.0, 5.5, 5.8 m instead of a uniform joint spacing of 4.6 m, skewed joints, a thicker, plant-mixed CTB layer with greater compressive strength, and increased R-values requirements for the ASB.

The authors found that the change to plant-mixed, higher compressive strength CTB improved the performance of rigid pavements with respect to faulting. Their data indicated an increase in the number of equivalent single axle loads (ESALs) to a given severity of faulting, as shown in Table 2.

**Table 2 Effects of CTB Specifications on Faulting Performance (from FHWA Report [9]).**

| | Millions of ESALs | |
|---|---|---|
| **Faulting Severity** | **CTB before 1967** | **CTB after 1967** |
| Moderate Faulting Begins | 1.0 | 1.0 |
| Severe Faulting Begins | 1.5 | 2.0 |
| Severe Faulting is Typical | 2.5 | 4.0 |

It is interesting to note that although the CTB specification change improved faulting performance, severe faulting typically still occurred after only 4.0 million ESALs. Many of the pavements that are candidates for LLPRS based on their distress condition and traffic levels are subjected to more than 4.0 million ESALs within two years, and will be expected to carry 100 million to potentially more than 200 million ESALs over their intended 30-year design life.

McLeod and Monismith found that on highway US 101, the change to plant mix cement treated base in the mid-1960s resulted in better cracking performance. It was found that the extent of transverse fatigue cracking versus longitudinal cracking changed as well. Cracked pavement with road mix bases from before 1967 had 97 percent transverse fatigue cracking and 3 percent longitudinal cracking. Cracked pavement with plant mix bases from after 1967 had 40 percent transverse fatigue cracking and 60 percent longitudinal cracking. Finite element analyses indicated that the greater strength of the plant mix material after 1967 provided greater support to the concrete and reduced critical tensile stresses caused by loads, compared to the road mix material used prior to 1967. The road mix material was estimated to have an elastic modulus between 980 and 4,100 MPa, compared to 5,450 to 7,965 MPa for the plant mix material, based on compressive and diametral strength laboratory tests.

For their transverse fatigue cracking analysis, McLeod and Monismith calculated load stresses and thermal stresses independently and then calculated fatigue lives for the combined stress state using modified Goodman diagrams. They found that the fatigue equation proposed by Vesic (*13*) matched the observed performance of the rigid pavements analyzed, with the analysis including a detailed evaluation of the axle load spectra, thermal stresses, and material variabilities. The Vesic fatigue relation derived from the AASHO Road Test is the following:

$$Nf = 225{,}000\ (MR/\sigma)^4$$

where $Nf$ is the number of repetitions to transverse fatigue cracking,

$MR$ is the flexural strength of the concrete (in this case estimated from diametral and compressive strengths), and

$\sigma$ is the maximum tensile bending stress calculated for the axle load applied.

The longitudinal cracking occurred primarily in the inner wheelpath of the outer lane. Explanation of some other factors that may have contributed to the difference in cracking mode, such as concrete strength and joint sealing practices, were not provided.

McLeod's and Monismith's recommendations were primarily directed towards the development of maintenance strategies for rigid pavements. Several are of interest to evaluation of rigid pavement design:

- Faulting is the prime cause for ride deterioration in rigid pavements, and faulting was found to be a function of truck loading.
- Severe faulting could be expected after about 2.5 million ESALs on pavements with road mix bases, and after about 4.0 million ESALs on pavements with plant mix bases.
- The fatigue equation proposed by Vesic predicted fatigue life well for the pavements analyzed.
- The time between a cracking extent of 15 to 20 percent of slabs cracked and the presence of widespread third stage cracking (breakup of the slabs with many intersecting cracks) was typically three to four years.
- Pavement researchers had difficulty in evaluating pavement performance because of unreported maintenance activities.

### 2.3.2 Wells and Nokes

The report by Wells and Nokes was intended to review the field performance results of prior rigid pavement design research, primarily to support interim design recommendations. It was also intended to cite areas for future rigid pavement research with regard to both new construction and rehabilitation.

The report first reviewed research that lead to earlier decisions regarding rigid pavement design features. In particular, they cited a 1949 report by Hveem (*14*) describing the results of test slabs with 6.0-, 9.0-, 12.0-, and 18.0-m lengths and 25-mm diameter dowels. Hveem concluded that long slab lengths led to transverse fatigue cracking. He also concluded that dowels helped reduce faulting, however, dowel performance was poor because most dowels became corroded, bent, broken, or frozen in the joint. Dowel hole widening from 25 to 32 mm was common due to repeated degradation. Primarily based on that experience, Caltrans has not used dowels as a standard design feature.

The use of skewed joints as a design feature was intended to deal with faulting based on reports by the Portland Cement Association (PCA) in 1955 (*15*), and Caltrans in 1961 (*16*). These reports were based on test section results in California, and indicated that skewed joints significantly reduced faulting compared to perpendicular joints.

The use of non-uniform joint spacings was primarily based on a 1961 report by General Motors (*17*), which indicated that bump attenuation was greatest for a 3.7-, 4.0-, 5.5-, 5.8-m spacing.

The recommendations of Wells and Nokes were based on results from some California test sections and review of practices by other states, although results from California sections in different locations were at times conflicting. In summary, Wells and Nokes recommended:

- Continued use of skewed joints
- Continued use of the 3.6-, 4.6-, 4.0- and 4.3-m joint spacing
- Tie bars across longitudinal joints
- Sealing of joints and development of joints with sealant reservoirs
- Continued use of treated permeable based on primed aggregate base
- Use of tied and sealed concrete shoulders
- Investigation of the use of continuously reinforced concrete pavement (CRCP).

## 2.4 Caltrans Rigid Pavements Current Conditions

In 1995, about 22,500 lane-kilometers of the Caltrans highway network—nearly thirty percent—required corrective maintenance or rehabilitation. Nearly 7,000 lane kilometers required immediate attention to avoid further damage or loss of the facility. Rigid pavements (Portland cement concrete pavements [PCCP]) make up 48 percent of the rehabilitation project needs. Rigid pavements had 41 percent of the lane-kilometers requiring immediate attention. It has also been estimated that approximately 80 percent of the rigid pavements needing rehabilitation are in urban areas in Southern California. The remaining pavements are in urban areas in the San Francisco Bay Area and rural areas.

The most common rehabilitation strategy used for failed PCCP is an asphalt concrete overlay preceded by cracking and seating of the existing PCC slabs. Faulted pavements are typically smoothed with a diamond grinding process.

In 1993-94, Caltrans contracted out about $73,500,000 on AC overlays of rigid pavements, $37,900,000 on other rehabilitation methods including grinding, and $2,900,000 on slab replacement. Maintenance and rehabilitation work performed by Caltrans forces are not included in these costs. (*3*)

## 2.5 LLPRS Strategies Proposed by Caltrans

The initial strategy developed by the Caltrans LLPRS Task Force includes the following key features:

- Removal of existing concrete slabs in the truck lanes, which are typically 200 to 225 mm thick, by means of sawing and lifting

- Retention of the existing 100 to 150 mm of CTB, unless analyses or testing show that it will not provide sufficient support, or that there are other problems associated with its retention
- Replacement of the removed slabs with slabs of same thickness, using Fast Setting Hydraulic Cement Concrete (FSHCC) with strength gain specified to provide 400 psi beam strength within 4 to 8 hours after placement
- Use of perpendicular joints, and same joint spacings as adjacent lanes
- Consideration of dowels, tied shoulders, and/or widened truck lanes

The underlying assumptions of this strategy were:

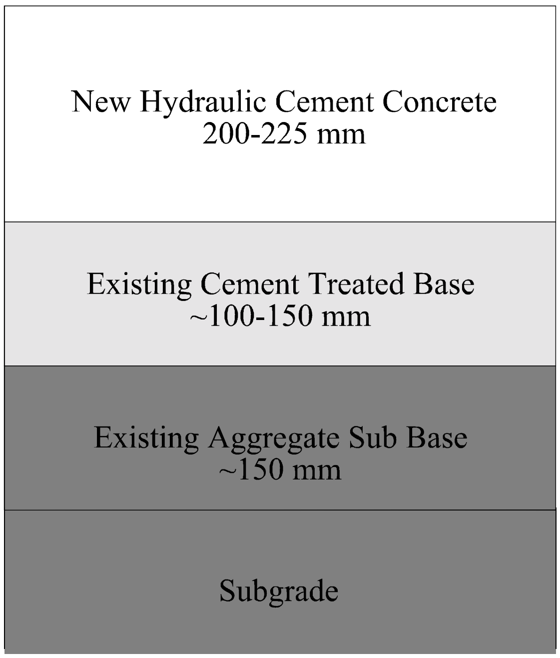
- the use of FSHCC will provide performance at least equal to that of PCC
- the use of FSHCC will permit Caltrans to replace approximately 6 to 8 lane-kilometers in a weekend
- the use of dowels, tied shoulders, and/or widened truck lanes would extend the life of the reconstructed pavements from the current 20-year design life assumption to at least 30 years.

The proposed structure is illustrated in Figure 13.

## 2.6 Summary of Recommendations from TRB Workshop on Pavement Renewal for Urban Freeways

In February, 1998, Caltrans and the Transportation Research Board (TRB) convened a workshop to evaluate pavement renewal design concepts for the Interstate 710 corridor in Los Angeles and Long Beach.  Four teams from across the country were formed with experts in construction, traffic, and pavements.

# Proposed LLPRS




Keep existing CTB
Match existing joint spacing
Perpendicular joints
TI = approximately 18 (ESALs ~ 300 million)

**Figure 13. Proposed LLPRS structure.**

Two teams developed rigid pavement strategies and two teams developed flexible pavement strategies. The teams were provided with preliminary information and visited the corridor. They were then asked for recommendations regarding the pavement structure, traffic control, and other improvements to the corridor infrastructure.

The common objectives of the teams were to provide a safe and efficient facility while minimizing the community impact, maintenance costs, and construction time.

The recommendations of the four teams are briefly summarized here, with emphasis on the rigid pavement solutions and the pavement structures proposed, as opposed to the flexible pavement solutions and the construction and traffic control details. This summary is based on the draft summary of the team presentations. (*18*)

### 2.6.1 710 Design Constraints

The same constraints were provided to all teams. Each team was asked to develop a pavement structural solution and a traffic control plan. For the traffic control plan, only one lane in each direction could be closed, and no additional lanes could be added. A total of 32 bridges cross the 42 kilometer length of the project, and solutions had to account for required clearance between the pavement and bridge structures.

Caltrans District 7 provided cost estimates for the strategies proposed by each team. Implementation of the Caltrans LLPRS proposed strategy, summarized previously herein, was estimated to cost about $80 million. This cost may not have included the additional cost of placing dowels in the new slabs, or adding tied shoulders or widened truck lanes.

Each team noted that their recommendations had to be made without a quantitative assessment of the subgrade support conditions, and that their recommendations could be drastically changed depending on the measured subgrade support.

No lifecycle cost estimates were made, and all cost estimates made by District 7 only included construction costs. The teams did not select their structures based on lifecycle cost estimates for a 30-year design life. Instead, the proposed structural designs reflected opinions and experience regarding what would provide a relatively long pavement service life.

### 2.6.2 TRB Team Recommendations

The existing pavement structures were not subjected to a thorough review of as-built drawings, and were not subjected to coring and testing to determine layer thicknesses, slab lengths, or materials properties. Most of the I-710 project to be reconstructed was originally built in the late 1950s and completed in the mid-1960s, and probably has an existing structure similar to the one shown in Figure 10, with a slab thickness of about 225 mm.

The Green and Yellow Teams were assigned to develop rigid pavement strategies. Both of these teams indicated that they would expect 40 years of service life from their proposals.

The Green team recommended removal of the entire existing pavement structure down to the subgrade. Any existing PCC and AC material would be recycled into a Lean Concrete Base (LCB) layer, 350 mm thick. Traffic would be expected to travel on the LCB for short periods of time during construction. A 300-mm thick PCC slab would be placed on the LCB. The PCC would have a low water/cement ratio and include pozzolanic materials for high strength. The PCC slabs would be doweled at the joints. The Green team's proposed structure is shown in Figure 14. This proposal would require rebuilding all bridges in the project to maintain required height clearances.

The Yellow team recommended selection of one of two strategies, the final selection depending on a more extensive investigation of the existing pavement structure and subsurface conditions. The first option, shown in Figure 15, involves recycling of the existing PCC and

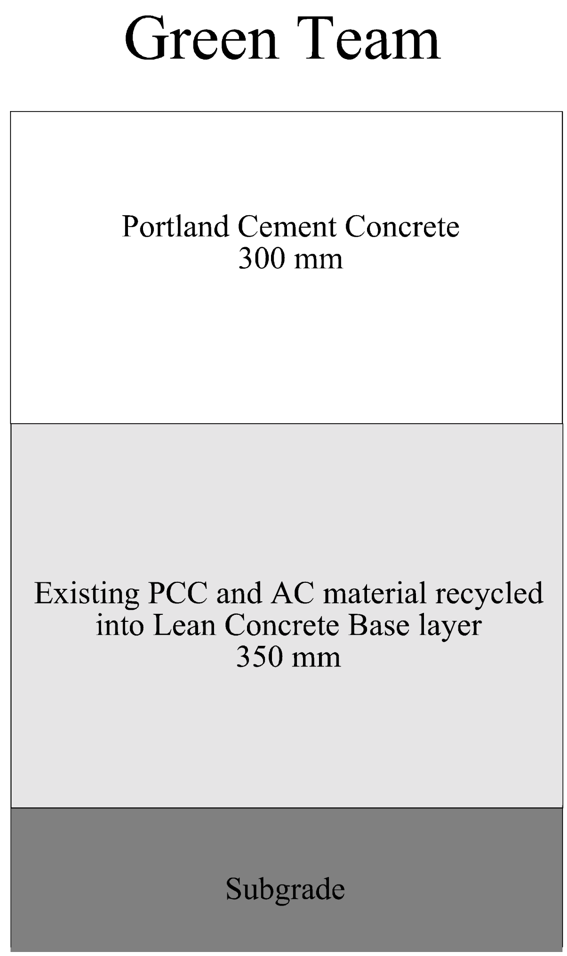



**Figure 14. Rigid pavement structure proposed by Green team.**

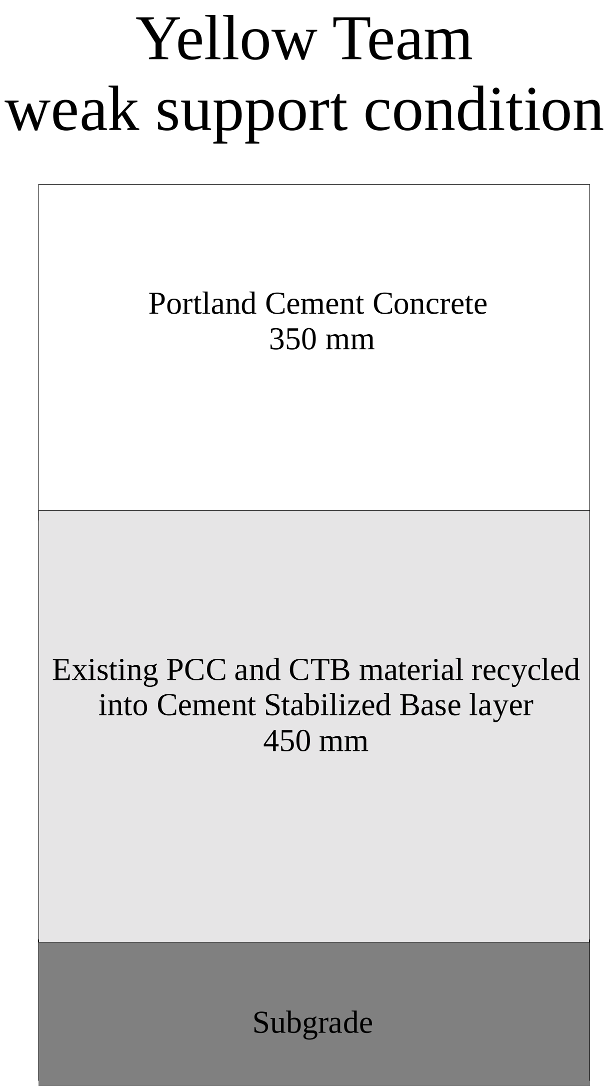



**Figure 15.  Rigid pavement structure proposed by Yellow team for areas without sufficient support for an unbonded PCC overlay.**

CTB layers into a new 450-mm thick cement stabilized base layer under the heavy truck lanes. A new PCC slab, 350 mm thick would be placed on the base in the truck lanes.

The second option was recommended for areas where the existing subgrade provides sufficient support. This strategy, shown in Figure 16, consists of placement of a 300-mm thick unbonded PCC overlay on the existing structure. The bond breaking layer would consist of 50 mm of AC. Dowels were not mentioned by the Yellow team. Excavation would be required under some bridges with this strategy.

The Blue and Brown teams were assigned to develop flexible pavement solutions. Both of these teams indicated that their strategies would provide about 40 years of design life, but would require a surface treatment after about 25 years.

The Blue team recommended that the existing PCC slabs be repaired and replaced where required, and would provide a base for a stone matrix asphalt (SMA) overlay. The SMA overlay would consist of 150 mm with a maximum aggregate size of 19 mm, followed by 50 mm of SMA with a maximum aggregate size of 9.5 mm. An open graded friction course could be placed on the surface for safety, if necessary. The Blue team's proposed structure is shown in Figure 17.

The Brown team recommended that existing PCC and CTB be rubblized, and then rolled to stabilize it so that it can serve as a base layer. A 200-mm thick polymer modified AC layer would then be placed on the base. The rubblization is intended to delay or eliminate reflection cracking. The Brown team's proposed structure is shown in Figure 18.

All of the teams utilized some type of recycling, and recommended complete reconstruction of the facility rather than just the truck lanes. They also recommended that the project be reconstructed at one time, as opposed to stage construction over the 40-year design

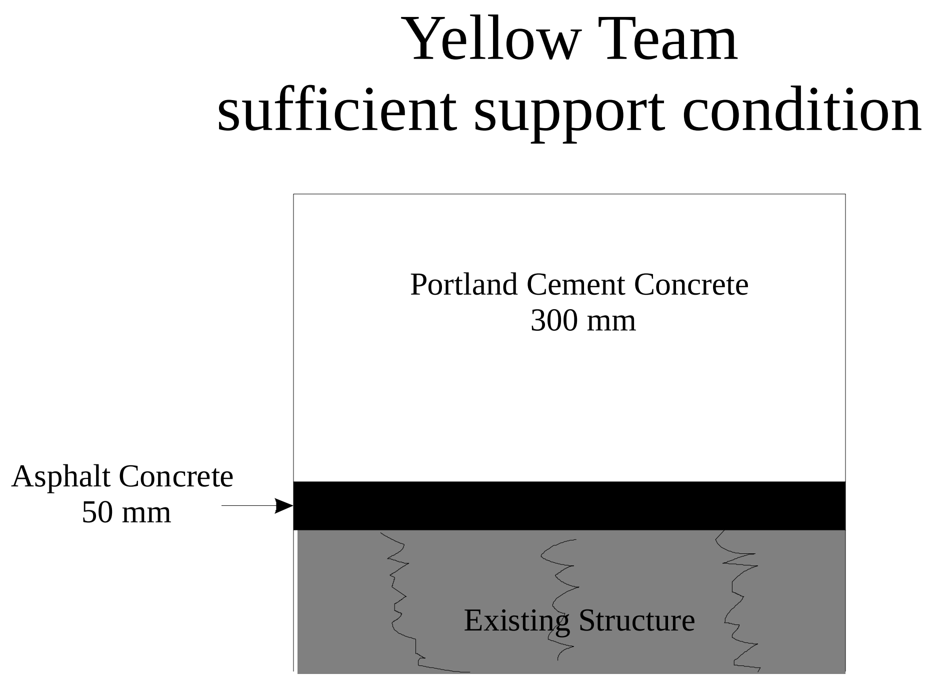



**Figure 16. Rigid pavement structure proposed by Yellow team for areas with sufficient subgrade support.**

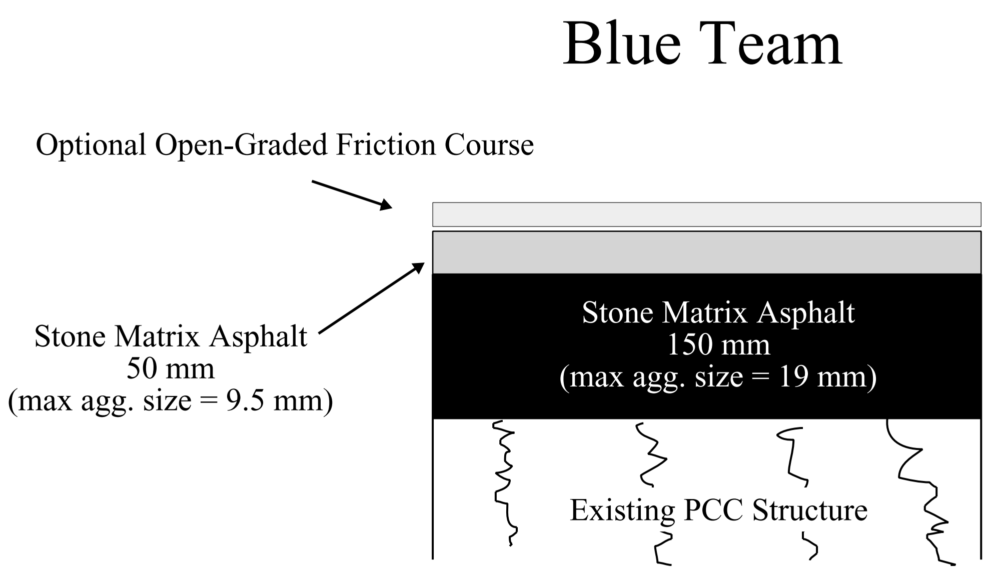



**Figure 17. Flexible pavement structure proposed by Blue team.**

Brown Team

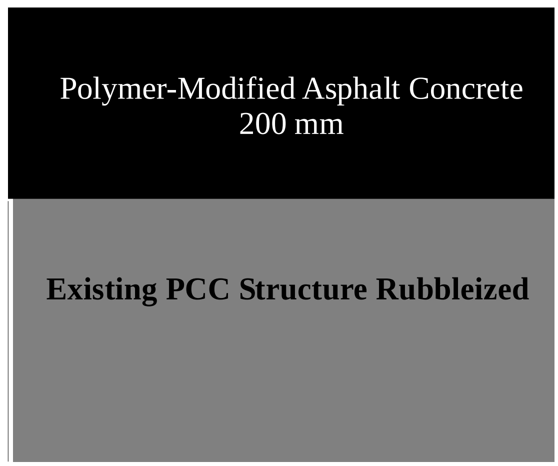



**Figure 18.  Flexible pavement structure proposed by Brown team.**

life.  The primary reason for precluding stage construction was to minimize user delay costs.

All four teams recommended drainage improvements.  The teams visited the site during the height of the unusually heavy rainstorms in February, 1998.

### 2.7 Characteristics of candidate projects

The designs developed by the four teams for the I-710 corridor project were developed for a specific location.  Preliminary economic analyses performed by Caltrans for the California Transportation Commission (CTC) indicate that for pavements with high priority for rehabilitation based on ride score and observed cracking, reconstruction of the existing rigid pavement is economically advantageous when the traffic on the facility is greater than 150,000 ADT (Average Daily Traffic), or when more than 10 percent of the vehicles are trucks.  These conditions exist, or are expected to exist within the next few years, on a large number of projects within the California.  Projects identified as candidates for LLPRS implementation by the Pavement Management Information Branch of the Caltrans Maintenance Program based on 1995 data (*19*), are shown in Figures 19-22

In addition to traffic volumes, other variables critical to the design of rigid pavements differ across the potential candidate projects.  These variables include the pavement structure, climate, expected truck loading, and the presence of alternate routes.  These variables were quantified for the projects identified as candidates for LLPRS, as shown in Table 3.

It can be seen in Figures 19-21 that the LLPRS candidate projects are located in Districts 3, 4, 7, 8, 11, and 12—the "urban" districts.  There are 199 candidate projects, totaling 2,290 lane-kilometers.

The location of the projects is important because it determines the climate in which the pavement will have to perform, as well as the presence of alternate routes for traffic during construction.  California can be divided, somewhat arbitrarily, into six climate regions with respect to the effect of climate on rigid pavement performance: North Coast, San Francisco Bay Area, Central Valley, Mountain, Desert, South Coast, as shown in Figure 22.  The primary environmental variables affecting rigid pavement performance are temperatures and rainfall. Average values for important temperature and rainfall variables are summarized for each of the six regions in Table 4.

Greater rainfall and larger diurnal temperature changes are typically detrimental to rigid pavement performance.  Greater rainfall results in greater chance of loss of support, which causes pumping, faulting, corner cracking, and potentially contributes to longitudinal cracking. Larger diurnal temperature changes result in more slab curling, which contributes to cracking.

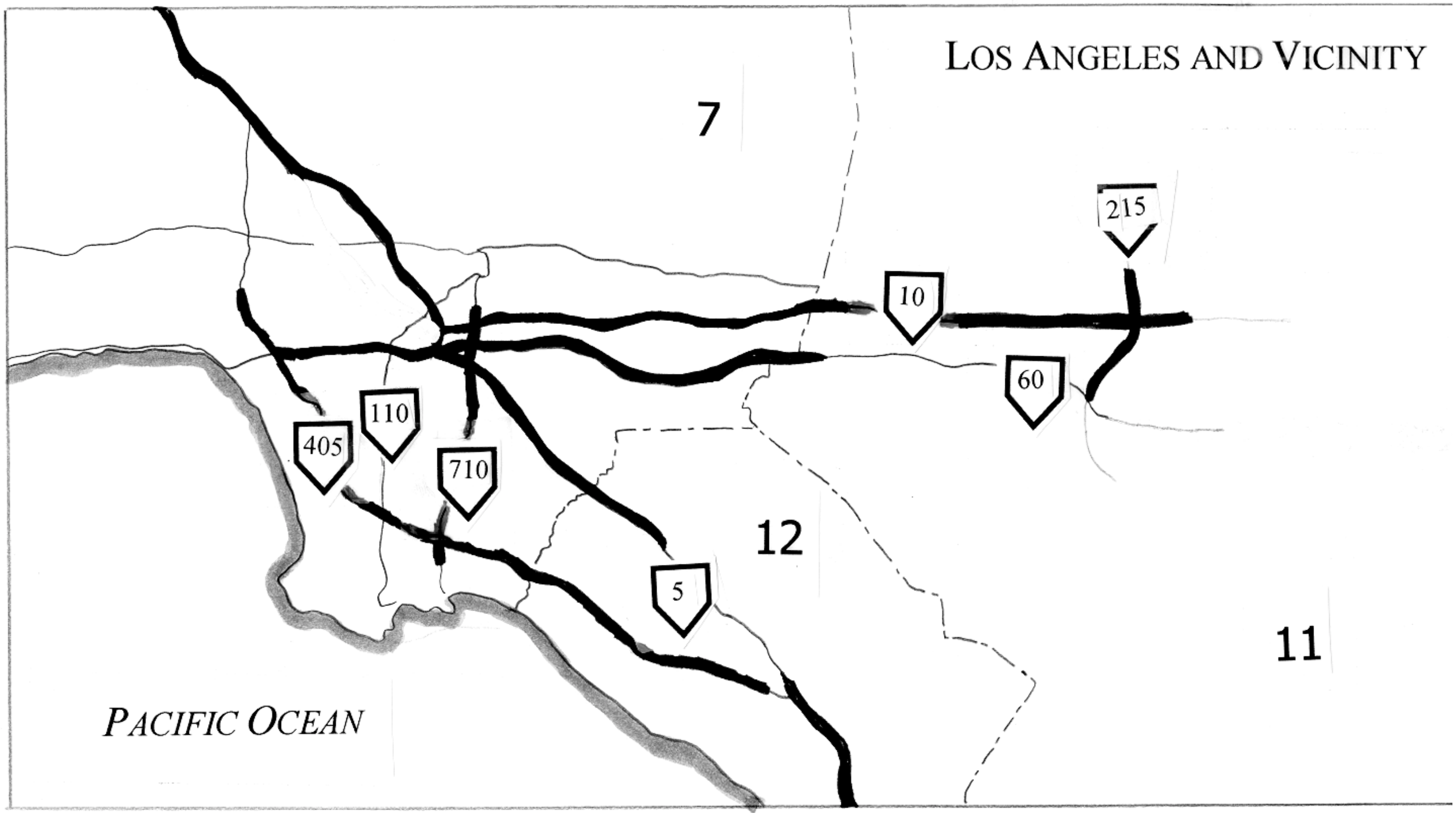



**Figure 19. Locations of projects meeting criteria for LLPRS implementation, based on 1995 data.**

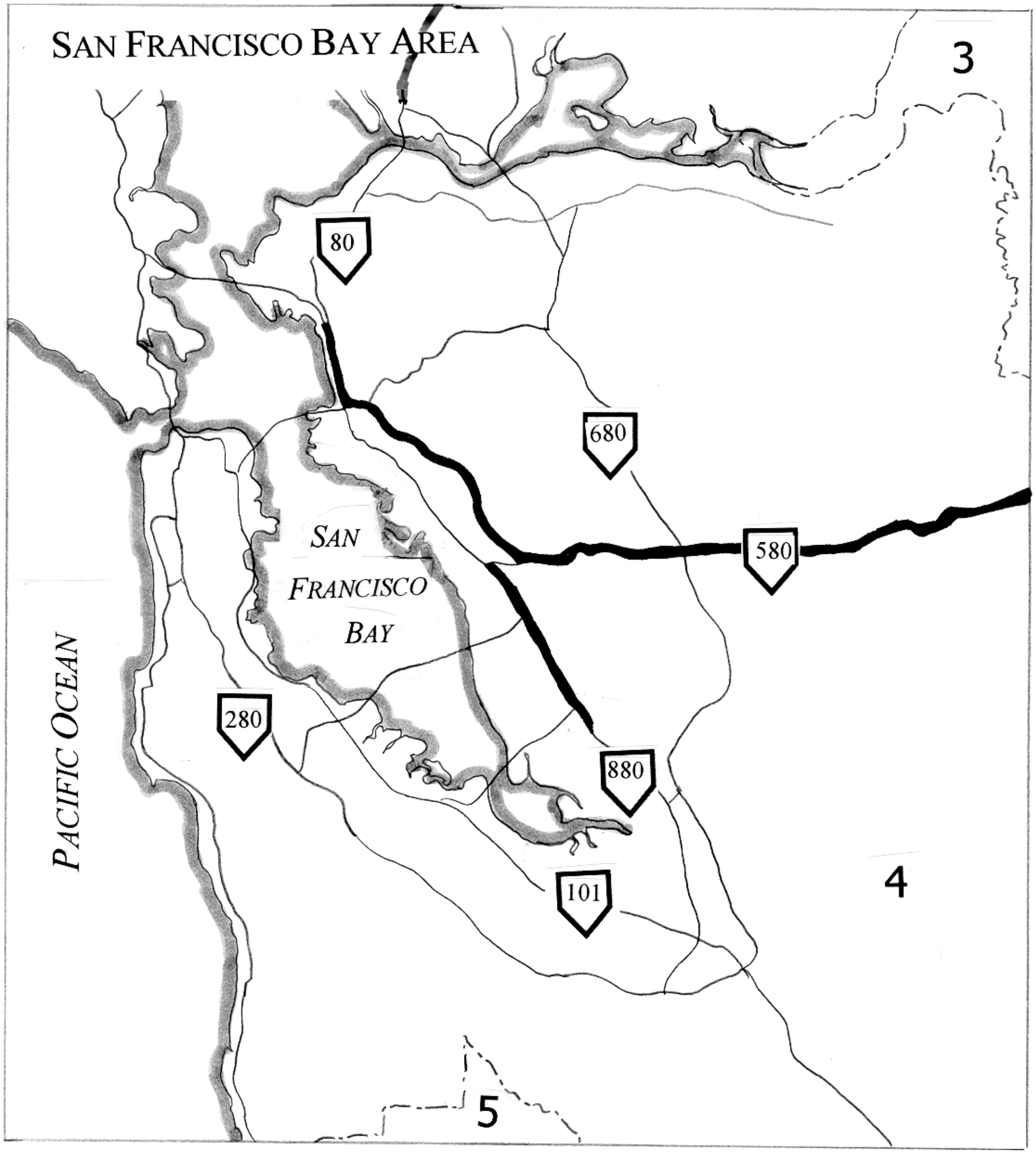



**Figure 20. Locations of projects meeting criteria for LLPRS implementation, based on 1995 data.**

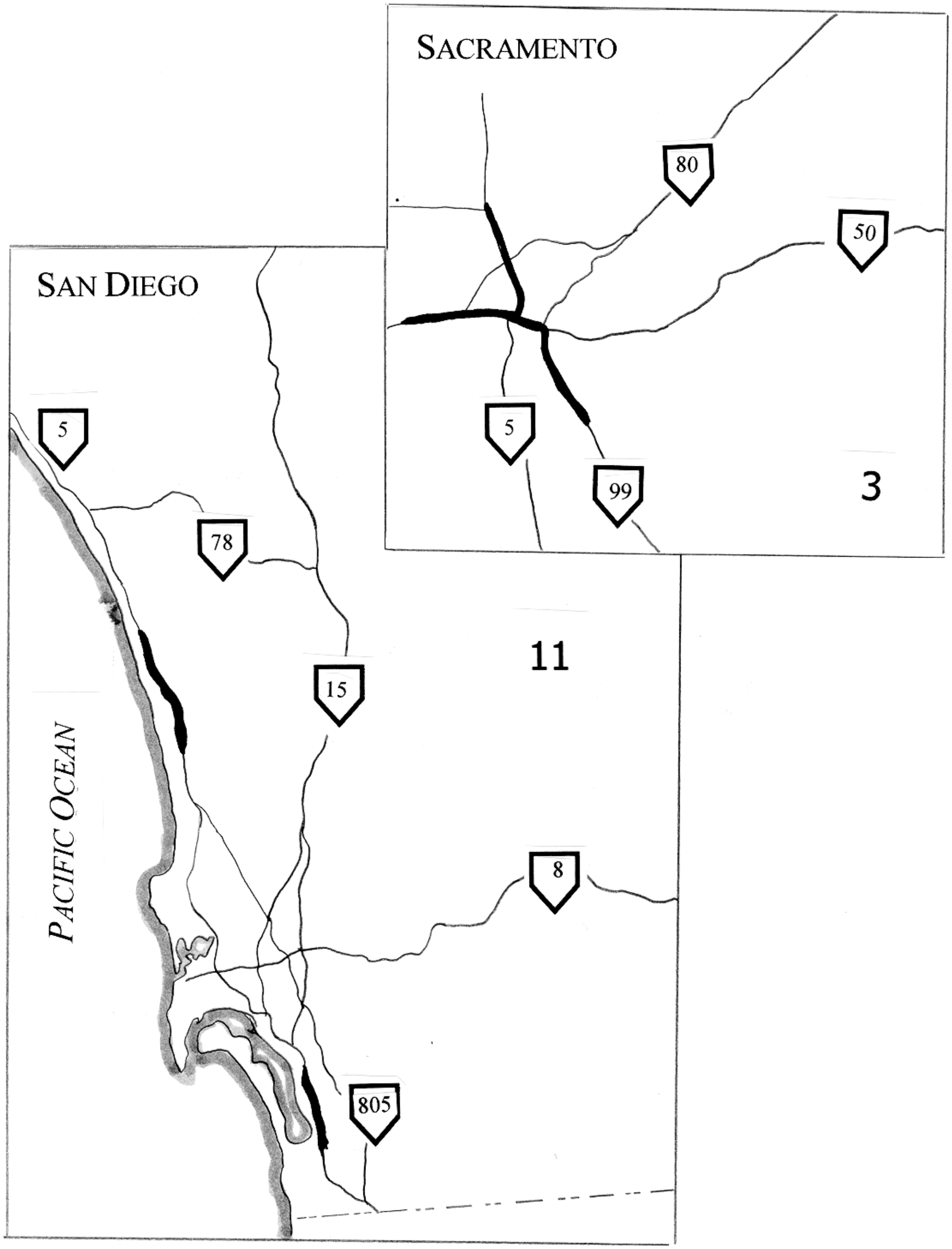



**Figure 21. Locations of projects meeting criteria for LLPRS implementation, based on 1995 data.**

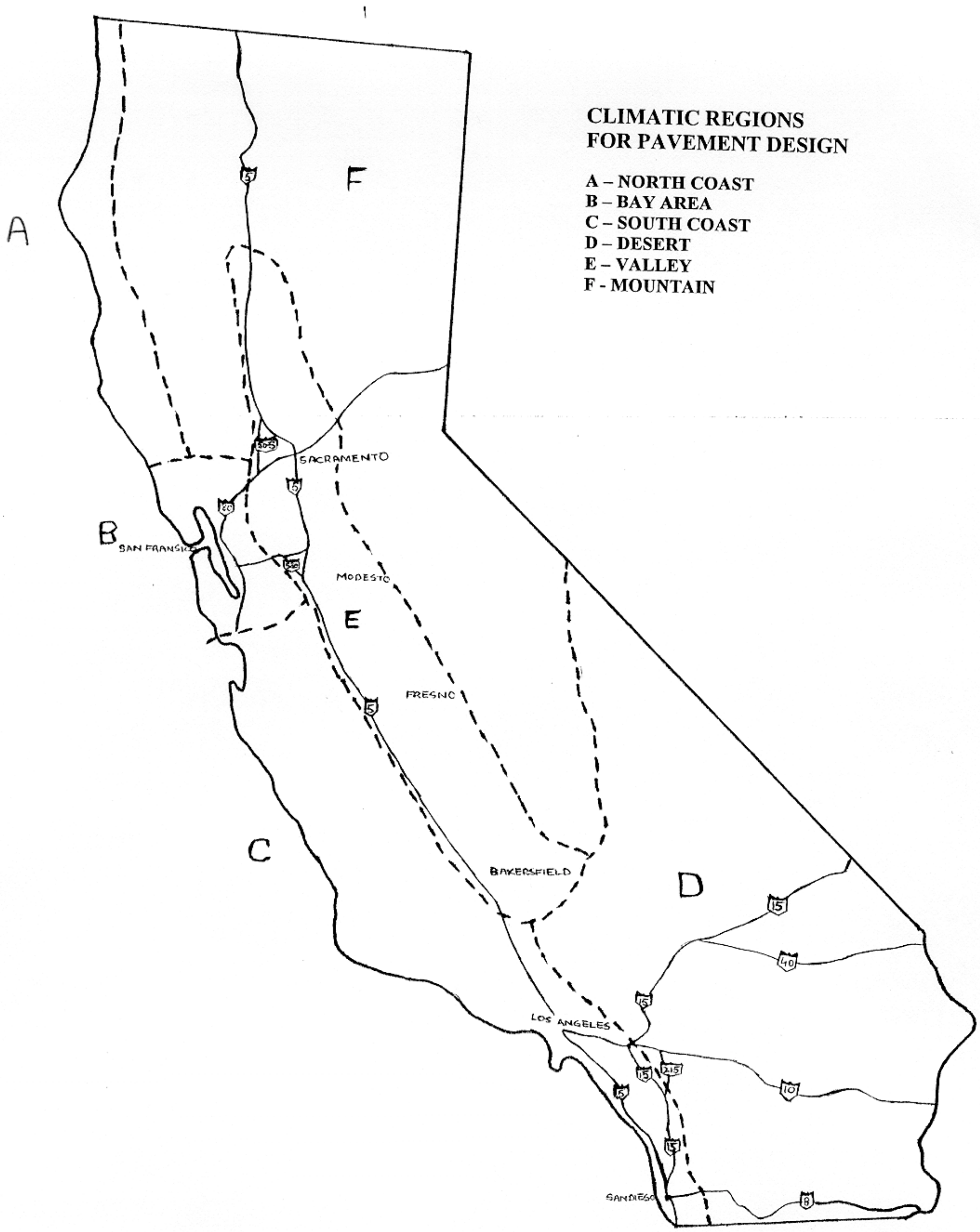



**Figure 22. Five climate regions affecting pavement performance in California.**

From Table 3, it can be seen that the LLPRS candidate projects were mostly constructed in the 1950s and 1960s, although some portions were constructed as recently as the 1980s in locations where new interchanges or realignments were constructed. This indicates that the LLPRS candidate projects include a variety of CTB strengths, slab lengths, and slab thickness.

The LLPRS candidate projects are also spread across four of the six climate regions identified in Table 4. These include the temperate San Francisco Bay Area and South Coast regions, and the more extreme Desert and Valley regions. The wide range of slab lengths and thicknesses required to match existing adjacent lanes, and the range of climate regions indicates that each candidate project must be individually designed. A uniform design across all projects will most likely result in a wide range of performance. In addition, there are differences in axle loads, truck traffic volumes, subgrade stiffnesses, and available construction windows due to the presence of alternate routes. Each of these factors will play a role in the selection of structural design and selection of concrete materials with sufficient strength gain for the construction time window.

Only limited axle load distributions were obtained in time for this report. The load distributions obtained are for Interstate 5 in San Joaquin county and Interstate 15 in San Diego county. Better evaluations of the design traffic for each project can be made when weigh-in-motion (WIM) data (where they exist) can be obtained from Caltrans for locations on each of the candidate projects. Axle load and configuration data is essential for the design of rigid pavements.

The presence of alternate routes to which traffic can be diverted during reconstruction will play a role in determining the time available for reconstruction during each construction window. If adequate alternate routes are available, the use of materials with normal strength

**Table 3 Summary of Preliminary Design Variables for LLPRS Candidate Projects.**

| | | | Postmile | | Average Daily Traffic | | Daily Trucks in Design Lane (2 Truck Lanes each Direction) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Route | District | County | First | Last | Max | Min | Max | Min | Climate Region | Probable Construction | Alternate Routes |
| 80 | 3 | Sacramento | 10 | 17 | 195,000 | 130,000 | 3,213 | 1,584 | Valley | 1960s | - |
| 99 | 3 | Sacramento | 19 | 24.2 | 155,000 | 130,000 | 3,990 | 3,160 | Valley | 1960s-1970s | 5 |
| 80 | 4 | Alameda | 3.9 | 6.6 | 233,000 | 227,000 | 4,033 | 3,873 | Bay Area | 1950s | - |
| 580 | 4 | Alameda | 11 | 45.7 | 164,000 | 131,000 | 4,189 | 2,875 | Bay Area | 1960s | - |
| 880 | 4 | Alameda | 6.7 | 11.4 | 156,000 | 138,000 | 2,742 | 2,406 | Bay Area | 1960s-1970s | 680 |
| 380 | 4 | San Mateo | 6.3 | 6.3 | 133,000 | 133,000 | 3,830 | 3,830 | Bay Area | 1970s | 92 |
| 80 | 4 | Solano | 9.7 | 25 | 125,000 | 125,000 | 3,232 | 3,232 | Bay Area | 1960s | - |
| 5 | 7 | Los Angeles | 0.4 | 47.8 | 237,000 | 133,000 | 7,303 | 3,754 | South Coast | 1950s-1960s | 91/105,22/605 |
| 10 | 7 | Los Angeles | 6.1 | 47.6 | 309,000 | 186,000 | 5,400 | 2,007 | South Coast | 1960s | 60,210/134 |
| 60 | 7 | Los Angeles | 1 | 29.4 | 287,000 | 170,000 | 9,975 | 2,705 | South Coast | 1960s | 10,91 |
| 405 | 7 | Los Angeles | 0.3 | 44.7 | 308,000 | 156,000 | 3,565 | 1,494 | South Coast | mid-1960s | - |
| 710 | 7 | Los Angeles | 6.8 | 25.6 | 198,000 | 126,000 | 9,560 | 2,665 | South Coast | late 1950s, 1980s | 110,605 |
| 60 | 8 | Riverside | 0 | 1 | 147,000 | 147,000 | 4,161 | 4,161 | Desert | 1960s | 10,91 |
| 215 | 8 | Riverside | 38.6 | 43.3 | 150,000 | 143,000 | 5,341 | 2,665 | Desert | 1960s | 15 |
| 10 | 8 | San Bernardino | 0 | 30.4 | 238,000 | 130,000 | 5,595 | 3,510 | Desert | 1960s | 60 |
| 215 | 8 | San Bernardino | 6.9 | 8 | 130,000 | 130,000 | 2,010 | 2,010 | Desert | 1960s | 15 |
| 5 | 11 | San Diego | 11.7 | 14.4 | 166,000 | 166,000 | 1,568 | 1,568 | South Coast | 1960s | 52/15/78 |
| 5 | 11 | San Diego | 32.9 | 43.6 | 199,000 | 154,000 | 4,050 | 4,050 | South Coast | 1960s | 52/15/78 |
| 5 | 12 | Orange | 7.8 | 18.7 | 242,000 | 148,000 | 3,984 | 2,736 | South Coast | 1960s | 405,55/91 |
| 5 | 12 | Orange | 36.8 | 42.6 | 176,000 | 166,000 | 4,344 | 2,976 | South Coast | 1960s | 405,55/91 |
| 405 | 12 | Orange | 2.5 | 23.7 | 327,000 | 235,000 | 4,742 | 4,111 | South Coast | late 1960s | 22/5 |

**Table 4 Summary of Typical Values for Important Climate Variables for Six California Regions.**

| Climate Region | Location for Calculations | Maximum Slab Temperature Gradient (°C/m) | Minimum Slab Temperature Gradient (°C/m) | Average Slab Temperature Gradient (°C/m) | Average Annual Rainfall (mm) |
|---|---|---|---|---|---|
| North Coast | Arcata | not yet evaluated | not yet evaluated | not yet evaluated | Not yet evaluated |
| Bay Area | San Francisco | 0.001 | -0.117 | -0.072 | 501 |
| South Coast | Los Angeles | -0.007 | -0.109 | -0.070 | 304 |
| South Coast | San Diego | not yet evaluated | not yet evaluated | not yet evaluated | 199 |
| Valley | Fresno | 0.021 | -0.125 | -0.069 | 268 |
| Mountain | Reno | not yet evaluated | not yet evaluated | not yet evaluated | not yet evaluated |
| Desert | Daggett | 0.022 | -0.122 | -0.068 | ~ 0 |

gains can be considered. Compromises will need to be made between the performance expected from different materials, and the time necessary for curing or cooling between placement and opening to traffic.

## 2.8 Condition Survey of Candidate LLPRS Pavements

Condition survey information is available from the Caltrans Pavement Management System (PMS) database for all of the projects meeting the current requirements for inclusion in the LLPRS-Rigid reconstruction program, namely those with a high priority for rehabilitation based on ride score and cracking, an average daily traffic of 150,000 or greater, and/or more than 10 percent trucks. However, the condition survey information in the Caltrans PMS is primarily designed to program maintenance activities, and does not provide some critical information for determining failure modes and design criteria for rigid pavements.

The Caltrans PMS includes information regarding cracking classified into first, second, and third stage cracking. The classifications indicate stage at which cracks are interconnected and the slab has broken up. This provides information for maintenance and rehabilitation programming based on whether the slabs are “repairable” or must be replaced. For design purposes and development of mechanistic models for cracking prediction, the information regarding the type of cracking is needed. The type of cracking, transverse (fatigue) cracking, corner cracking or longitudinal cracking, can then be related to the distress mechanism for each type, as described previously in Section 2.1. Other important information needed to evaluate the design for cracking for a given project is the following:

- transverse joint spacings,
- presence of tied concrete shoulders,
- skewed or perpendicular transverse joints.
- strength of base and subgrade
- pavement thickness and stiffness

The presence of faulting is monitored in the Caltrans PMS by the ride score and observations in the condition survey as to whether or not faulting is present. This information provides a good indication of the development of faulting. The inclusion of fault height measurements in locations where faulting is present will aid the development of better mechanistic models for faulting prediction.

In May, 1998, a three day survey was made of most of the candidate projects for implementation of LLPRS in Southern California. The survey was undertaken to augment the information included in the Caltrans PMS, and to provide an update to the information in the list of candidate projects, which is based on 1995 and 1996 data. (*19*) The survey was also intended to provide an indication of the distribution of different joint spacings and types of joints.

The survey included 540 kilometers, counting different directions separately, as shown in Figure 23. Less rigorously documented observations of pavement distress mechanisms for LLPRS candidate projects in Northern California are also included in the survey. Miles are the measurement unit for this survey instead of kilometers because the results are based on the post-miles shown on paddles and emergency call boxes along each route. The notes from the condition survey in Southern California are included in Appendix A of this report.

All surveys were performed in the truck lanes at approximately 80 kph. At a few locations on each route, a walking survey was made in which distresses were more closely observed, transverse joint spacings were measured, photographs were taken, and the joint type (skewed or perpendicular) was noted. For the survey, faulting was classified based on the discomfort level for the driver (one driver for all sections) in a 1993 Plymouth Acclaim.

Slight faulting indicated that the presence of faulting was barely noticeable. Moderate faulting indicated some discomfort to the driver. Terrible faulting indicated a high level of discomfort for the driver. Cracking was classified by type: transverse, corner, or longitudinal.

The presence of faulting and cracking was noted at approximately 0.3 kilometer intervals. The extent of the distresses was not measured or estimated within each interval. If the presence of a distress remained the same for long intervals, a note was only made when the type of distress changed.

### 2.8.1 Interstate 5

In District 7 (Los Angeles County), Interstate 5 was surveyed from postmiles 42.7 to 3.7 in the southbound direction, and postmiles 0 to 4.4 and 34.2 to 37.2 in the northbound direction.

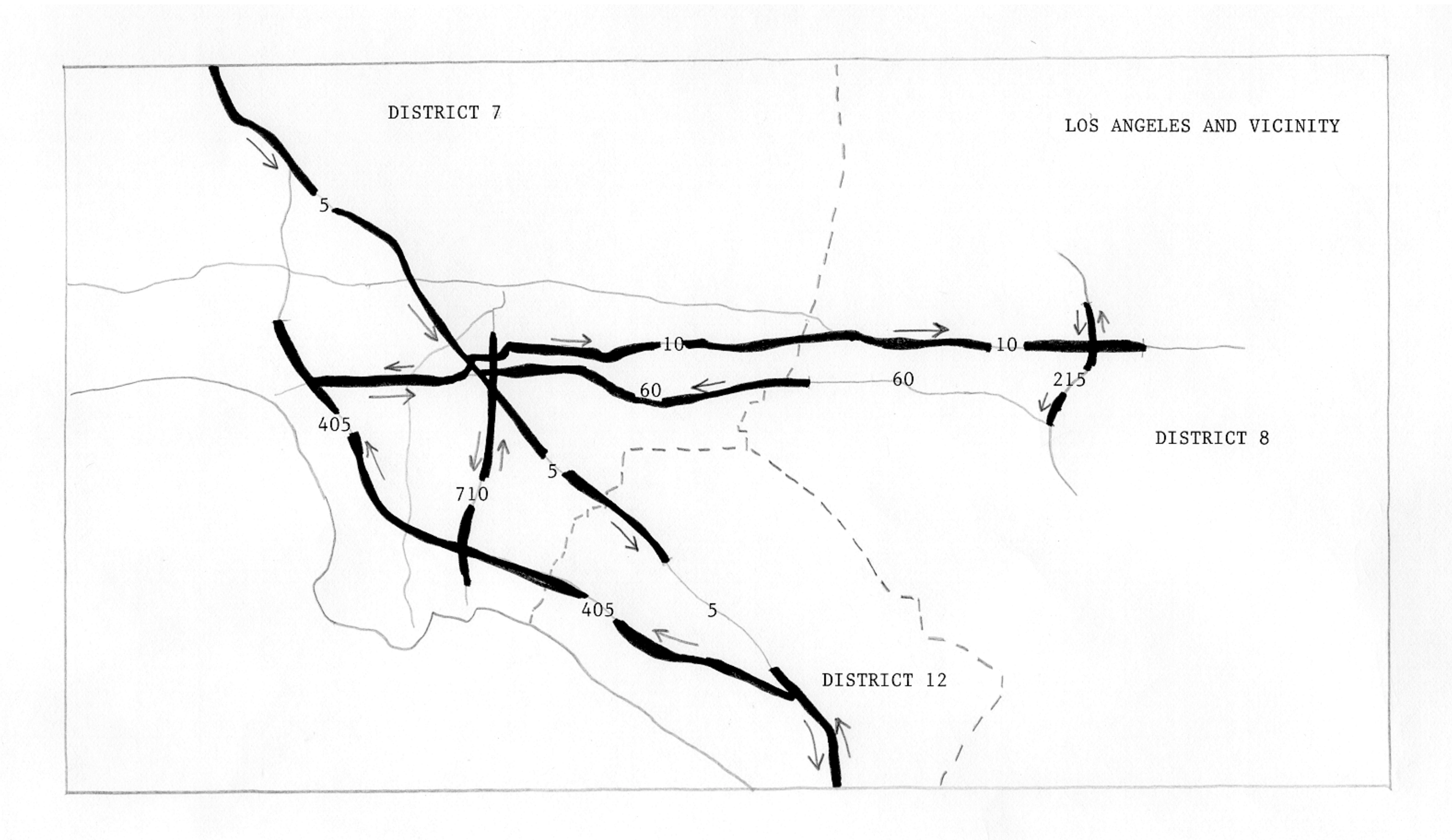



**Figure 23. LLPRS candidate projects surveyed for distress mechanisms in May, 1998.**

The primary distresses in the truck lanes were faulting and transverse fatigue cracking, as shown in Table 5. Most of the sections surveyed have faulting, and much of the faulting is severe.

**Table 5 Condition Survey Summary for Interstate 5 in District 7.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 15 | 13 | 8 | 41 |
| Percentage | 37% | 31% | 19% | 87% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 16 | 3 | 3 | 41 |
| Percentage | 39% | 8% | 8% | |

Interstate 5 was primarily constructed in the late 1950s and in the 1960s. The oldest sections, in East Los Angeles, were constructed in 1959, with a pavement structure consisting of 225 mm of PCC placed on 100 mm of road mix CTB, 75 mm of AB, and 200 mm of ASB. Cores taken in the CTB in 1997 indicated poor cementing in some areas, with the CTB breakable by hand. Construction proceeded in the 1960s, both north and south. The use of plastic preformed joint spacers was used towards the south end of District 7 in place of sawing the joints. In many cases the plastic spacers tilted from a vertical orientation, and became bowed in the horizontal direction under the force of the concrete in front of the paver. This resulted in joints that are poorly formed and difficult to maintain. In the 1970s, 1980s and 1990s various sections were rehabilitated by cracking and seating the concrete slabs and overlaying with asphalt concrete. No second AC overlays have been placed on those sections. (*20*)

Observations at postmile 23.7 southbound included 4.6-m transverse joint spacing with perpendicular joints. Large vertical deflections were observed at slab corners under heavy trucks. Transverse and corner cracking, and moderate faulting were observed in this area, as shown in Figures 24 and 25.

Perpendicular joints with approximately 4.6-m transverse joint spacing were also observed at postmile 10.9 southbound in an area with transverse cracking and slight faulting.

In District 12 (Orange County), Interstate 5 was surveyed from postmiles 44.6 to 17.6 in the southbound direction, and postmiles 0 to 43.4 in the northbound direction. The primary distresses in the truck lanes were faulting and longitudinal cracking, as shown in Table 6.

**Table 6 Condition survey summary for Interstate 5 in District 12.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 8 | 11 | 8 | 46 |
| Percentage | 17% | 24% | 18% | 59% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 2 | 2 | 9 | 46 |
| Percentage | 5% | 4% | 19% | |

**Figure 24. Pavement distresses at postmile 23.7 southbound, Interstate 5, Los Angeles County: transverse fatigue cracking and perpendicular joints.**

**Figure 25. Pavement distresses at postmile 34.9 southbound, Interstate 5, Los Angeles County: transverse fatigue cracking and perpendicular joints.**

Several sections of Interstate 5 in District 12 have asphalt concrete overlays, indicating that the sections with the worst condition have been rehabilitated. Skewed joints were observed at postmile 33.8 southbound in an area with slight faulting and no cracking.

Interstate 5 was surveyed in San Diego County (District 11) from postmile 35 to 69 in the northbound direction. No cracking was observed. The entire section had badly faulted pavements, with about half moderate faulting and half terrible faulting, as shown in Table 7.

**Table 7 Condition Survey Summary for Interstate 5 in District 11.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 0 | 17 | 17 | 34 |
| Percentage | 0% | 49% | 51% | 100% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 0 | 0 | 0 | 34 |
| Percentage | 0% | 0% | 0% | |

2.8.2 Interstate 10

In District 7, Interstate 10 was surveyed between postmiles 4.6 and 48.4 in the eastbound direction and postmiles 18.3 and 6.7 in the westbound direction. Faulting was present in nearly all of the pavements surveyed. Transverse, corner, and longitudinal cracking were present in nearly equal amounts, and were fairly common, as shown in Table 8.

**Table 8 Condition Survey Summary for Interstate 10 in District 7.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 9 | 29 | 13 | 45 |
| Percentage | 20% | 42% | 28% | 89% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 6 | 7 | 8 | 45 |
| Percentage | 14% | 16% | 19% | |

Interstate 10 through Santa Monica was constructed in 1964 and 1965. I-10 was constructed east of Los Angeles to the border with District 8 in the early 1960s. The concrete slabs were 225 mm thick. In 1997, inspection of the CTB after sawing and liftoff of the PCC slabs near postmile 25 showed the CTB to have a smooth surface with few loose fines and little cracking. (*20*)

At postmile 12.9 westbound, skewed joints with joint spacings of 3.7, 4.0, 5.5, and 5.8 m were observed in an area with slight faulting and no cracking. Longitudinal and transverse joints were observed to be open and had joint openings of several centimeters in which incompressible fines had been deposited, as shown in Figure 26.

At postmile 6.8 eastbound, skewed joints and joint spacings of 3.7, 4.0, 5.5, and 5.8 m were again observed in an area of moderate faulting and no cracking.

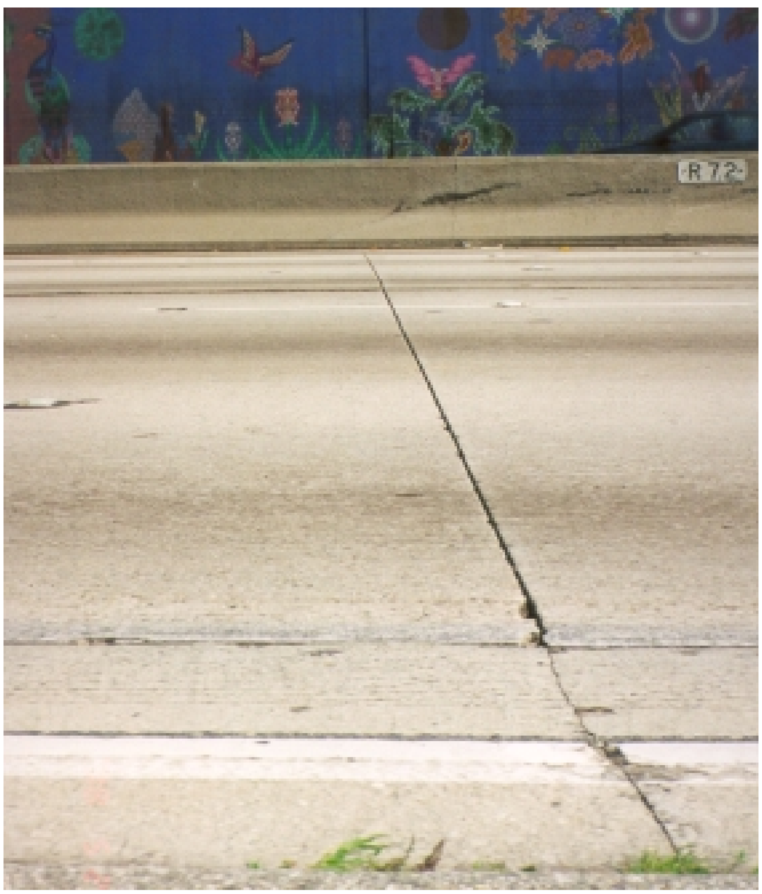



**Figure 26. Pavement distress at postmile 12.9 westbound, Interstate 10, between Los Angeles and District 7/District 8 boundary: large joint openings, faulting, no cracking.**

At postmile 30.0 eastbound, the joint spacing is 4.6 m and the joints were perpendicular. Longitudinal and corner cracking was present in this area, and faulting was moderate. The condition of the pavement is shown in Figures 27-29.

The eastbound direction between postmiles 43 and 45.5 had third stage cracking with transverse, longitudinal, and corner cracking that can likely be attributed to a drainage problem. (*20*)

In District 8, Interstate 10 was surveyed in San Bernardino County between postmiles 25.7 and 31.5 westbound, and postmiles 0 and 31.2 eastbound. All of the sections surveyed had faulting, and nearly half had terrible faulting. Cracking was also widespread, particularly transverse fatigue cracking and longitudinal cracking, as shown in Table 9.

**Figure 27. Pavement distress at postmile 30.0 eastbound, Interstate 10, between Los Angeles and District 7/District 8 boundary: large joint openings, no cracking.**

**Figure 28. Pavement distresses at postmile 30.0 eastbound, Interstate 10, between Los Angeles and District 7/District 8 boundary: longitudinal cracking.**

**Figure 29. Pavement distresses at postmile 30.0 eastbound, Interstate 10, between Los Angeles and District 7/District 8 boundary: corner cracking.**

**Table 9 Condition Survey Summary for Interstate 10 in District 8.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 6 | 15 | 17 | 37 |
| Percentage | 16% | 39% | 45% | 100% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 11 | 4 | 10 | 37 |
| Percentage | 29% | 11% | 26% | |

Faulting was particularly severe in the eastbound direction from postmile 0. A Caltrans engineer has observed that when slabs were removed near postmile 5, the upper 50 mm of the 100 mm thick CTB was not cemented, and consisted of loose, relatively fine grained material. Cores from these sections indicated that the cemented material looked like sandstone, and produced fines from the friction of running a hand over the core. (*20*) This observation of easily transportable material beneath the slab indicates that this material probably contributed to the severe faulting, due to the mechanism described in Section 2.1.1 of this report. Some other nearby sections did not have the loose material under the slab, and were very hard and well cemented.

At postmile 9.6 in the eastbound direction, joint spacings were approximately 3.7, 4.0, 5.5, 5.8 m, and the joints were skewed. The pavement at this location was exhibiting terrible faulting and transverse cracking. The transverse cracking only occurred in the slabs that were between 5.5 and 5.8 m long, and did not occur in the slabs 3.7 to 4.0 m long. This observation matches the expected distress mechanism for transverse fatigue cracking, described in Section 2.1.4. The condition of the pavement can be seen in Figures 30 and 31.

At postmile 17.5 in the eastbound direction, joint spacing was about 4.6 m, and the joints were perpendicular. At this location, there was moderate faulting and transverse fatigue cracking in every slab.

### 2.8.3 Interstate 215

Interstate 215 was surveyed in District 8 in San Bernardino County between postmiles 4 and 8.6 northbound, and postmiles 4.3 and 9.3 southbound. In Riverside County, the sections between postmiles 38.5 and 42.6 were surveyed northbound, and between postmiles 43.5 and 38.5 southbound. Faulting was present in nearly all of the sections surveyed with 25 percent of the sections having severe faulting. Transverse fatigue cracking was also widespread. Corner and longitudinal cracking were also present, as shown in Table 10.

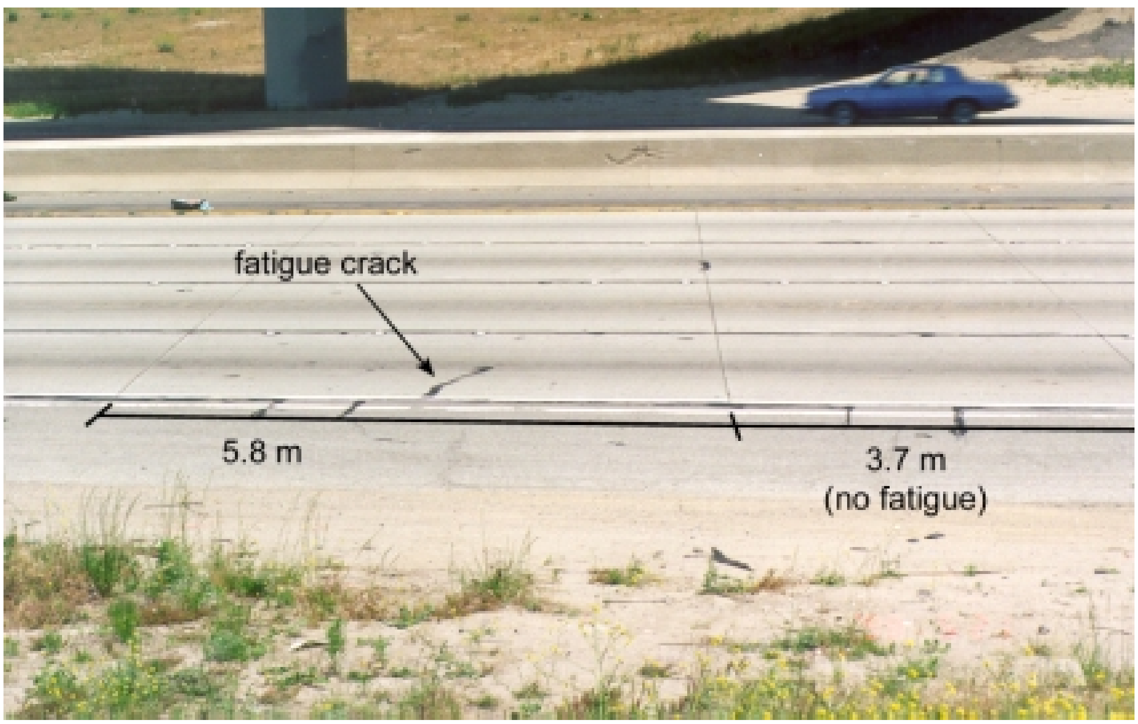



**Figure 30. Pavement distress at postmile 9.6 eastbound, Interstate 10, San Bernardino county: transverse fatigue cracking in long slab, none in short slab.**

**Figure 31. Pavement distress at postmile 9.6 eastbound, Interstate 10, San Bernardino county: large joint opening.**

**Figure 32. Pavement distress at postmile 7.7 southbound, Interstate 215, District 8: sealed corner and transverse fatigue cracking.**

At postmile 7.7 southbound in San Bernardino County, joint spacings were between 4.0 and 4.6 m with perpendicular joints. Approximately half of the slabs at this location had transverse cracks and moderate faulting. The cracking patterns can be seen in Figure 32.

**Table 10 Condition Survey Summary for Interstate 215 in District 8.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 2 | 6 | 3 | 14 |
| Percentage | 16% | 47% | 25% | 88% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 9 | 1 | 4 | 14 |
| Percentage | 62% | 10% | 28% | |

2.8.4 Interstate 405

Intestate 405 was surveyed in District 7 between postmiles 0 and 16.6 in the northbound direction. Interstate 405 was constructed in the mid to late 1960s. The structure consists of 225 mm of PCC on 100 mm of CTB, 100 mm of AB, and 200 mm of ASB (20). Cracking was nearly nonexistent on this route. However, almost the entire route had faulting, and more than half of the route had terrible faulting, as shown in Table 11.

In District 12, Interstate 405 was surveyed between postmiles 0 and 24.3 in the northbound direction. As in District 7, nearly the entire route had faulting. The faulting was typically slight in District 12, whereas it was typically terrible in District 7. A considerable extent of the route had longitudinal cracking, as shown in Table 12.

**Table 11 Condition Survey Summary for Interstate 405 in District 7.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 2 | 4 | 7 | 14 |
| Percentage | 15% | 28% | 53% | 96% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 0 | 0 | 0.4 | 0.4 |
| Percentage | 0% | 0% | 3% | |

**Table 12 Condition Survey Summary for Interstate 405 in District 12.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 8 | 7 | 3 | 19 |
| Percentage | 42% | 37% | 16% | 95% |
| | **Type of Cracking** | | | Total |
| | Transverse | Corner | Longitudinal | |
| Miles Surveyed | 0 | 0 | 4 | 19 |
| Percentage | 0% | 0% | 21% | |

At postmile 2.7 northbound, the joint spacing followed a pattern of 3.7, 4.0, 5.5, 5.8 m, and the joints were skewed. The skewing appears to be more than the typical 9.5 degrees. Slight faulting was present at this location. The pavement condition is shown in Figure 33.

### 2.8.5 Interstate 710

Interstate 710 was surveyed between postmiles 6.8 and 27.4 northbound, and postmiles 27.3 and 6.8 southbound. The entire route had faulting, and most of the faulting was moderate to terrible. The route also had a large extent of transverse fatigue cracking, as well as corner and longitudinal cracking, as shown in Table 13.

**Figure 33. Pavement distress at postmile 2.7 northbound, Interstate 405, District 12: longitudinal cracking.**

**Table 13 Condition Survey Summary for Interstate 710.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 7 | 15 | 17 | 40 |
| Percentage | 18% | 38% | 43% | 99% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 13 | 8 | 8 | 40 |
| Percentage | 33% | 210% | 21% | |

Interstate 710 was built in the late 1950s, although sections on either side of the interchange with Interstate 105 were rebuilt more recently. The pavement structure consists of 200 or 225 mm of PCC on 100 mm of CTB, 100 mm of AB, and 200 mm of ASB. Failed slabs on I-710 have been replaced at various times. Many of the slab replacements consisted of calcium chloride accelerated PCC with 0.3 m or more of CTB, AB, and ASB below. Re-compaction of the remaining ASB after excavation may have been cursory, and at times may not have been done at all due to pressures to quickly open to traffic. (*20*) Performance of the slab replacements has often been poor.

At postmile 8.3 southbound, joint spacing varied between approximately 3.7 to 4.6 m, and joints were perpendicular. Terrible faulting and spalled transverse cracks are present at this location. A transverse joint fault of about 10 mm was visible. Some joints appear to be preformed rather than sawed. The pavement condition is shown in Figures 34 and 35.

At postmile 14.8 northbound, the joints were skewed in a short section, which had slight faulting and was probably more recently constructed. At postmile 16.5 northbound, joints were perpendicular in an area with terrible faulting and extensive transverse, corner, and longitudinal cracking.

Interstate 710 exhibited more crack and joint spalling than any other pavement surveyed. In some locations, cracked portions of slabs have subsided, effectively creating a punchout. This condition was not observed on any other highways surveyed.

### 2.8.6 State Route 60

In District 7, State Route 60 was surveyed between postmiles 0 and 29.4 westbound. Nearly the entire route had faulting, and more than 80 percent was moderate or terrible faulting. The route also had a large extent of longitudinal cracking, and some corner and transverse

**Figure 34. Pavement distress at postmile 8.3 southbound, Interstate 710: transverse fatigue cracking and badly spalled, badly faulted joint.**

**Figure 35. Pavement distress at postmile 8.3 southbound, Interstate 710: spalled joint, transverse fatigue cracking.**

cracking, as shown in Table 14. State Route 60 was constructed in the late 1960s and early 1970s. The pavement structure consists of a 225-mm thick PCC slab on 120 mm of CTB. (*20*)

**Table 14 Condition Survey Summary for Interstate 60 in District 7.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 4 | 15 | 9 | 29 |
| Percentage | 14% | 52% | 32% | 98% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 2 | 4 | 10 | 29 |
| Percentage | 8% | 14% | 35% | |

At postmile 17.3 westbound, the joint spacing was approximately 3.7, 4.0, 5.5, 5.8 m and skewed. There was moderate faulting, and longitudinal, transverse, and corner cracking at this location, as shown in Figure 36. In addition, there were plastic shrinkage cracks at this location not visible in the photo.

State Route 60 was surveyed in District 8, in Riverside County between postmiles 0.2 and 0.8, and in San Bernardino County between postmiles 0 and 9.5. All of the area surveyed had faulting, with more than half moderate and terrible faulting. Approximately a third of the section also had transverse cracking, as shown in Table 15.

### 2.8.7 Summary of Southern California Survey

The extent of distresses observed for all sections surveyed in Southern California is summarized in Table 16. The results show that faulting was the most widespread distress, with

**Table 15 Condition Survey Summary for State Route 60 in District 8.**

| | Degree of Faulting | | | Total |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 4 | 11 | 4 | 19 |
| Percentage | 38% | 40% | 22% | 100% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 6 | 0 | 0 | 19 |
| Percentage | 32% | 0% | 0% | |

**Figure 36. Pavement distress condition at postmile 17.3 westbound Interstate 60, District 7: corner cracking, transverse cracking, moderate faulting.**

**Table 16 Summary of Distresses for all Southern California Sections Surveyed.**

| | **Degree of Faulting** | | | **Total** |
|---|---|---|---|---|
| | **Slight** | **Moderate** | **Terrible** | |
| Miles Surveyed | 65 | 132 | 108 | 336 |
| Percentage | 19% | 39% | 32% | 91% |
| | **Type of Cracking** | | | **Total** |
| | **Transverse** | **Corner** | **Longitudinal** | |
| Miles Surveyed | 65 | 30 | 56 | 336 |
| Percentage | 19% | 9% | 17% | |

more than 90 percent of the sections surveyed having noticeable faulting. Almost a third of the sections had faulting severe enough to cause a high level of discomfort for the driver.

Corner cracking was the least common distress. Transverse fatigue cracking and longitudinal cracking occurred in less than 20 percent of the sections surveyed.

These results indicate that faulting is the major form of distress for existing Caltrans rigid pavements. Faulting significantly affects ride scores and is highly correlated with user opinion of rigid pavement quality. (*21*) A reduction in the extent and severity of faulting will likely result in a much greater level of satisfaction for the public regarding Caltrans rigid pavements. In addition, a reduction in faulting may result in an increase in pavement fatigue life due to a reduction in vehicle dynamic loading.

### 2.8.8 Northern California Routes

In District 3 (Sacramento County), Interstate 80 was surveyed in the eastbound and westbound directions between postmiles 10 and 17. Slight to moderate faulting was present in most of the sections. The only cracking observed was longitudinal cracking, which was present in most of the sections.

In District 4 (Alameda County), Interstate 580 was surveyed between postmiles 11 and 46 in the eastbound direction. Faulting was present in most of the sections. Corner, transverse and longitudinal cracking were present at several locations.

## 2.9 Findings: Summary of Important Design Considerations

The distresses present in current Caltrans rigid pavements and the performance of those pavements is a function of the structural design, materials, and construction of those pavements under truck traffic and environmental conditions. In this chapter, a review has been made of the distresses present in Caltrans rigid pavements, and the mechanisms for those distresses have been briefly described. In addition, the designs, materials, and construction used for those pavements over the years have been presented, as well as historical reviews of rigid pavement performance.

The findings of this chapter are summarized in the following sections.

### 2.9.1 The mechanisms for pavement distresses are mostly understood.

The distresses found on Caltrans rigid pavements, faulting and transverse, corner, and longitudinal cracking, are caused by mechanisms that have been investigated by other researchers and observed on rigid pavements in other states as well as in California. The mechanism for longitudinal cracking is the only distress that is not well understood. The mechanisms for corner cracking and transverse joint faulting are understood, however, reliable quantitative models have not yet been developed.

2.9.2 Transverse joint faulting is the most prevalent distress on LLPRS candidate projects.

The most prevalent distress found on the candidate LLPRS projects was transverse joint faulting. Faulting occurs throughout the state. Some routes have faulting nearly their entire length. Faulting is often severe enough to cause a high level of discomfort to road users.

2.9.3 Faulting reduction measures have not been effective.

Caltrans rigid pavement designs have changed since construction of the interstate highway system began in California in the mid-1950s. Many of those changes have been introduced to reduce faulting, which has been recognized as one of the most important distresses on California rigid pavements since the early 1960s. The distress mechanism for faulting requires poor levels of load transfer across joints, and the presence of movable materials in the material underlying the joints. The decision to not use dowels for better load transfer across transverse joints is based on construction problems observed in 1949 by Hveem. (*14*) The use of dowels does not appear to have been the subject of Caltrans research since then. The use of cement treated bases as a non-erodable material beneath the concrete slabs does not appear to have mitigated the occurrence of severe faulting after about 2,000,000 equivalent single axle loads, which was observed in 1979 by McLeod and Monismith. (*12*) In District 8, it has been observed that the CTB can produce significant quantities of fines beneath the slabs. The use of skewed joints does not appear to have reduced faulting.

2.9.4 Use of joint sealants may reduce joint spalling and longitudinal cracking.

The construction of joint sealant reservoirs and use of long lasting compressible joint sealants can help keep incompressible materials out of the joints, which reduces the potential for joint spalling, and may also reduce the potential for longitudinal cracking. Further investigation of the mechanism for longitudinal cracking is needed to better determine the effects of incompressible materials in the joints.

### 2.9.5 Cracking is present on Caltrans rigid pavements.

Although cracking is not the most prevalent distress on Caltrans rigid pavements, transverse cracking and longitudinal cracking are present, and corner cracking is present to a lesser extent.

### 2.9.6 Future efforts to reduce joint faulting will also probably reduce occurrence of corner cracking.

The measures necessary to reduce joint faulting will probably result in a lower occurrence of corner cracking because both distresses are primarily caused by loss of support under the slab. The measures identified to reduce faulting are joint load transfer, non-movable materials below the concrete slabs, and elimination of free water beneath the slabs.

### 2.9.7 Long joint spacings in proposed LLPRS-Rigid strategies will increase the likelihood of transverse (fatigue) cracking.

In the current LLPRS-Rigid strategies under review for Caltrans by the University of California Berkeley Contract Team, the joint spacings of the truck lanes to be reconstructed must be the same as those of the inner lanes. Joint spacings on existing inner lanes range between 3.6 and 5.8 m. The longer joint spacings may cause transverse fatigue cracking.

### 2.9.8 Flexural strength plays a key role in cracking.

Flexural strength plays a key role in cracking, particularly transverse fatigue cracking. Flexural strengths required by Caltrans are less than those of many other states that specify flexural strength. The effect of flexural strength on the slab thicknesses required to prevent transverse fatigue cracking is investigated in the next chapter of this report.

### 2.9.9 Proposed strategies for pavement reconstruction will require substantial work on many bridges to maintain legal height clearances.

The strategies proposed for rigid pavement reconstruction by the team involved in the TRB evaluation of Interstate 710 call for 300- to 350-mm thick concrete slabs to be placed on cement stabilized bases. These thick slabs will require substantial work on many bridges to maintain legal height clearances. A preliminary evaluation of concrete slab thicknesses is included in the next chapter of this report.

### 2.9.10 Climatic regions play a significant role in rigid pavement distress mechanisms, but are not currently considered in Caltrans design procedures.

The LLPRS candidate projects are located in several climatic regions. Temperatures and rainfall play a significant role in rigid pavement distress mechanisms. Climatic regions are not currently considered in Caltrans design procedures.

# 3.0 EVALUATION OF PROPOSED STRATEGIES USING EXISTING DESIGN METHODS

## 3.1 Description and Applicability of Methods Used

In a recent NCHRP survey, it was found that 21 states use the AASHTO 1986 guide for design of jointed plain concrete pavements, 12 states use the 1972 AASHTO guide, two states use the PCA method, and two states use a combination of the 1986 AASHTO guide and the PCA method. (*22*) The Illinois Department of Transportation (IDOT) method is used only by that state. Caltrans is the only state following the California method.

### 3.1.1 PCA Method

The latest version of the Portland Cement Association (PCA), thickness design guide for concrete highway and street pavements (23, 24), has more mechanistic features than the empirically based AASHTO guide. For fatigue cracking analysis, the PCA uses load spectra analysis (traffic characterization) to calculate the bending stress in the concrete due to various axle loads and configurations. Load spectra analyses also allow for calculation of pavement stresses due to axle loads and configurations not originally considered in the AASHO Road Test.

The PCA guide also has many limitations, including:

- no accounting for temperature stresses in the slab,
- no ability to analyze widened lanes or different joint spacings,
- the use of top of the base k-value (combined base/subgrade k-value),
- no direct inclusion of reliability in the overall design, and
- no ability to change the load transfer across longitudinal joints between the lane and shoulder.

The PCA recommends maximum slab length of 15 feet (4.57 m) or less. The computer program developed by the PCA (PCAPAV) for their design method, was used to conduct the experiment. (*25*)

### 3.1.2 ACPA/AASHTO Method

Many existing design procedures are empirically based. The AASHTO Pavement Design Guide (*26*) is based on the field testing of flexible and rigid pavement structures in Ottawa, Illinois in the late 1950s and early 1960s. (*27*) The AASHTO guide is based on the performance of these test sections under truck traffic and environmental conditions.

One major output of the AASHO Road Test was the load equivalency factor (LEF) concept. LEFs were used to quantify the damage different axle loads and configurations caused to the different pavement structures relative to an 80-kN single axle load (dual wheels). The concept of equivalent single axle loads (ESAL) was developed to quantify the damage caused by a given axle load in terms of equal damage caused by a certain number of passes of an 80-kN standard axle. ESALs are calculated by multiplying and summing each individual axle load and configuration by its corresponding LEF for a particular pavement structure.

One shortcoming of rigid pavement LEFs is that they were based on the performance of the concrete pavements at AASHO Road Test, which mostly failed due to pumping and erosion. This type of failure is not the predominant failure mode in many rigid pavement structures. Many rigid pavements fail because of faulting and fatigue cracking. Some further limitations of the AASHTO Design guide are that the effects of wide truck lanes or tied concrete shoulders cannot be analyzed. Joint spacing and curling stresses in the rigid pavement are also not directly considered in the existing design guide.

The 1986 AASHTO Guide was revised in 1993 with respect to concrete overlay design. The American Concrete Pavement Association (ACPA) has taken the 1993 version of the AASHTO method, which contained some updates to the rigid pavement design procedure, and adopted it with some modifications of their own. The following modifications regarding concrete pavement design (not overlays) were made by the ACPA to the AASHTO method:

- More specific guidelines were made by ACPA than were given by the AASHTO guide regarding load transfer coefficients, referred to as "J factors" in the design method.
- The ACPA recommended that "loss of support" factors not be used. These factors are included in the AASHTO guide because pumping was the primary cause of failure at the AASHTO Road Test. These factors are not applicable to most other pavement structures built today. Faulting, rather than pumping is a major distress in California.
- Axle load spectrum data can be input, and the design method converts the axle loads to ESALs using LEFs from the AASHTO design method.

The computer program PAS was used to produce results for this experiment, following the 1993 AASHTO design method, as modified by the ACPA. (*28*)

### 3.1.3 Illinois DOT Method

The need has been growing for mechanistic-empirical design procedures in order to account for situations where existing empirical studies could not be extrapolated to find a reasonable solution. Mechanistic-based design guides address the theoretical stresses, strains, and deflections in the pavement structure due to the environment, pavement materials, and traffic. These stresses, strains, and deflections are then related to the field performance of in-service rigid pavements through transfer functions. A common transfer function for concrete pavements is to relate fatigue damage to cracking.

In a mechanistic-empirical design procedure, new, old, and current pavement features may be analyzed to determine their effect on the pavement performance. Examples of pavement design features are slab thickness, shoulder type, joint spacing, load transfer devices, and base type. These features allow the pavement engineer to make changes to the design to accommodate the specific location and constraints of the proposed pavement structure.

Mechanistic-empirical design procedures also can be used to evaluate pavement structural performance in specific environments. For example, the behavior of a pavement in a high desert environment, such as Palmdale, should not be expected to be the same as a pavement in a coastal environment, such as Los Angeles. With an empirical design guide such as AASHTO, only variables that were included in the original field testing can be reliably considered in the procedure. Extrapolation of designs not included in the field testing could result in unrealistic designs, especially for current traffic volumes. For example, only a few million ESALs were applied to the pavements at the AASHO Road Test. Extrapolation of those empirical results to 100 to 200 million ESALs for some LLPRS pavements may result in unrealistic designs.

A pavement program, using the results of finite element analyses, was developed as a pavement analysis supplement for the Illinois Department of Transportation (IDOT) mechanistic-based rigid pavement design procedure. (*29*) The ILLICON program (*30*) calculates the total edge stresses, load plus curl stresses, for a given set of pavement features. ILLICON uses algorithms derived from a factorial of finite element analyses, using the program ILLI-

SLAB, for various pavement parameters. ILLICON allows the user to answer a variety of “what if?” questions regarding changes in the material properties, environmental conditions, and pavement features.

Mechanistic models are calibrated with field performance data for each distress type to account for factors not included in the mechanistic model. In the fatigue design of concrete pavements, laboratory and field tests are used to derive relationship between concrete stress ratio and the number of cycles to failure. Currently, laboratory fatigue tests by themselves cannot be accurately used to predict field performance of concrete slabs.

ILLICON permits the use of ESALs or the more mechanistic approach of calculating stresses in the pavement from each axle configuration and weight (load spectra analysis). The climatic region is included in the design procedure in terms of the temperature differential through the slab. Heat transfer models (*31*) are able to predict the temperature gradient in the slab given the climatic conditions (e.g., rainfall, solar radiation, wind speed, air temperature, etc.) for any locations. These models enable designers to predict maximum temperature differentials in regions where concrete pavements are going to be built without the necessity of field measurements. The models only require air temperature, rainfall, cloud cover, and wind speed data, which are easily accessible from local weather stations.

The flexural strength or concrete modulus of rupture must be known to complete a mechanistic-based design. The flexural strength of a beam is tested in the laboratory to give an idea what the strength of the slab is in the field. Currently, the flexural strength of the beam is assumed to be equal to the in-situ strength of the slab. The flexural strength of the beam is used in the fatigue analysis to calculate the concrete slab stress ratio (slab bending stress divided by concrete modulus of rupture). The Illinois DOT uses the following concrete fatigue equation for their thickness design determination:

$$\log N = 17.61 - 17.61 \, \sigma / M_R$$

where

| | | |
|---|---|---|
| $N$ | = | number of cycles to failure |
| $\sigma$ | = | total bending stress, and |
| $M_R$ | = | concrete modulus of rupture |

## 3.2 Variables Considered

The Illinois DOT method, ILLICON, is the most comprehensive of the three in terms of the variables considered. The variables considered in ILLICON and the PCA and ACPA/AASHTO methods are shown in Table 17.

Because of the differences in variables that can be evaluated in each program, the experimental designs completed for the PCA and ACPA/AASHTO methods are somewhat different from the design completed for the Illinois DOT method. (*32*)

### 3.2.1 Design Life

The design life was assumed to be 30 years for all design programs.

### 3.2.2 Truck Traffic and Axle Load Spectra

Daily truck traffic volumes of 8,750 trucks per day and 17,500 trucks per day in the design truck lane were included in the experiment. Daily traffic of 8,750 trucks in the design lane corresponds to an Average Daily Truck Traffic (ADTT) of 17,500 for a facility with one truck lane in each direction or an ADTT of 35,000 for a facility with two truck lanes in each direction.

Some of the greatest numbers of trucks per day per lane for the LLPRS candidate project in the 1996 Caltrans PMS database are shown in Table 18.

**Table 17 Variables Considered in ILLICON, ACPA/AASHTO, and PCA Design Methods.**

| Variable | | Factor Levels | ILLICON | ACPA/ AASHTO | PCA |
|---|---|---|---|---|---|
| System Type | 1 | Unbonded Base | ⊗ | | |
| | 2 | Unbonded Base | ⊗ | | |
| Shoulder Type | 1 | Asphalt concrete | ⊗ | × | × |
| | 2 | Tied concrete, LTE = 50% | ⊗ | | |
| | 3 | Tied concrete, LTE = 90% | ⊗ | × | × |
| | 4 | Widened 0.3 m | ⊗ | | |
| | 5 | Widened 0.6 m | ⊗ | | |
| Dowels | 1 | No | × | × | × |
| | 2 | No | × | × | |
| | 3 | Yes | × | × | |
| | 4 | Yes | × | × | × |
| Concrete Strength Gain | | Strength versus curing time | ⊗ | | |
| Subgrade/base support value (k) | 1 | 100mm CTB, 150mm ASB | ⊗ | × | × |
| | 2 | 150mm CTB, 150mm ASB | ⊗ | × | × |
| | 3 | 250mm AB | ⊗ | × | × |
| Climate | | Temperature, rainfall | ⊗ | × | |
| Traffic | 1 | ESALs | ⊗ | ⊗ | |
| | 2 | Axle Load Spectra (average) | ⊗ | ⊗ | ⊗ |

⊗ = Full consideration
× = Limited consideration
LTE = Load Transfer Efficiency

**Table 18 Caltrans Facilities with Highest Daily Truck Traffic Volumes in Design Lane (Assuming Even Distribution of Trucks Between All Truck Lanes).**

| Location | Post-miles | 1996 ADTT | Truck Lanes in Each Direction | Number of Trucks Per Day in Design Lane | Percent of Trucks with 5 or More Axles |
|---|---|---|---|---|---|
| I-60, Los Angeles County | 23 to 25 | 39,900 | 2 | 9,975 | 55.0 |
| I-710, Los Angeles County | 6.8 to 15 | 38,239 | 2 | 9.560 | 69.4 |
| I-5, Los Angeles County | 16 to 24 | 28,320 | 2 | 7,080 | 40.0 |

The lower value for daily trucks in the design lane of 8,750 is similar to the maximum values currently existing in the Caltrans network. The upper value of 17,500 was selected to provide information for much greater levels of truck traffic, which may represent average traffic over the 30-year design life for LLPRS pavements. It can be seen that these facilities have large percentages of trucks with five or more axles, indicating semi-tractor trailer combinations that typically carry heavy loads.

It is valuable to consider the throughput associated with the levels of truck traffic included in the experiment. Assuming idealized conditions of a uniform distribution of trucks across 24 hours per day and 365 days per year, no cars in the truck lanes, a uniform truck length of 30 m (5 axle trucks, single trailer, semi-tractor), and a constant speed of 50 kph, these truck traffic levels result in the headways and clear space between trucks shown in Table 19.

**Table 19 Headways and Clearances Between Trucks for Design Truck Traffics at 50 kph.**

| Trucks per day in design lane | Headway Between Trucks | Clear Space Between Trucks |
|---|---|---|
| 8,750 | 9.87 seconds | 106 m |
| 17,500 | 4.94 seconds | 38 m |

The peaking of truck traffic during certain hours of the day will result in considerably lower headways and clearances between trucks, as will the presence of cars in the truck lanes, and stop and start trafficking caused by entry and exit of vehicles into the truck lanes. A typical assumption is that 75 percent of the truck traffic occurs in the daylight half of the day. (*32*) The effect on headways and clear spaces with this assumption, and maintaining all other previous assumptions, is shown in Table 20.

**Table 20 Daytime Headways and Clearances Between Trucks for Design Truck Traffics at 50 kph, Assuming 75 Percent of Trucks Pass in Daylight Half of Day.**

| Trucks per day in design lane | Daytime Headway Between Trucks | Daytime Clear Space Between Trucks |
|---|---|---|
| 8,750 | 6.58 seconds | 61 m |
| 17,500 | 3.29 seconds | 16 m |

Even under the assumed idealized conditions of Table 19, it can be seen that a volume of 17,500 trucks per day in the design lane results in relatively small headways and clearances between trucks. The calculations for daylight peaking shown in Table 20 indicate that an increase in freight throughput on a facility without increasing the number of truck lanes will require heavier axle loads, and/or the implementation of vehicle control systems to safely permit the decreased headways and clear spaces between vehicles.

Three axle load spectra are included in the experiment. The first is a composite developed by the PCA to represent “very heavy” traffic. The second and third are averages of several years of data in the 1990s from the FHWA Long-Term Pavement Performance (LTPP) data base. (*33*) One is from Interstate 5 in San Joaquin county, and the other is from Interstate 15 in San Diego county. The three spectra are shown in Table 21.

As is evident in Figure 37, the three spectra have similar trends. However, the San Joaquin and San Diego spectra have a very small percentage of very heavy single and tandem

**Table 21 PCA "Very Heavy," I-5 San Joaquin and I-215 San Diego Axle Load Spectra.**

| Single | Axles per 1000 Trucks | | | Tandem | Axles per 1000 Trucks | | |
|---|---|---|---|---|---|---|---|
| Axle Loads kips (kN) | I-15 San Diego | I-5 San Joaquin | PCA very heavy | Axle Loads kips (kN) | I-15 San Diego | I-5 San Joaquin | PCA very heavy |
| 42 (187) | 0 | 0.0002 | 0 | 80 (356) | 0 | 0.0018 | 0 |
| 40 (177) | 0.0074 | 0.0072 | 0 | 76 (338) | 0.0017 | 0.0033 | 0 |
| 38 (169) | 0.0080 | 0.0075 | 0 | 72 (320) | 0.0057 | 0.0068 | 0 |
| 36 (160) | 0.0084 | 0.0036 | 0 | 68 (302) | 0.0121 | 0.0081 | 0 |
| 34 (151) | 0.0160 | 0.0109 | 0.1900 | 64 (285) | 0.0095 | 0.0226 | 0 |
| 32 (142) | 0.0299 | 0.0215 | 0.5400 | 60 (267) | 0.0548 | 0.0467 | 0.5700 |
| 30 (133) | 0.0440 | 0.0383 | 0.6300 | 56 (249) | 0.0712 | 0.1052 | 1.0700 |
| 28 (125) | 0.061 | 0.097 | 1.780 | 52 (231) | 0.170 | 0.225 | 1.790 |
| 26 (116) | 0.254 | 0.449 | 3.520 | 48 (214) | 0.390 | 0.056 | 3.030 |
| 24 (107) | 0.668 | 4.028 | 4.160 | 44 (196) | 1.604 | 2.843 | 3.520 |
| 22 (98) | 2.9 | 31.6 | 9.7 | 40 (178) | 7.2 | 40.1 | 20.3 |
| 20 (89) | 19.7 | 117.6 | 41.8 | 36 (160) | 69.4 | 213.1 | 78.2 |
| 18 (80) | 58.1 | 207.5 | 68.3 | 32 (142) | 148.5 | 196.8 | 109.5 |
| 16 (71) | 75.0 | 169.2 | 57.1 | 28 (125) | 103.6 | 80.6 | 95.8 |
| 14 (62) | 75.1 | 152.5 | NA | 24 (107) | 118.5 | 75.9 | 71.2 |
| 12 (53) | 293.9 | 418.9 | NA | 20 (89) | 123.5 | 85.3 | NA |
| 10 (44) | 451.5 | 436.8 | NA | 16 (71) | 176.1 | 133.7 | NA |
| 8 (36) | 294.3 | 227.3 | NA | 12 (53) | 185.7 | 171.5 | NA |
| 6 (27) | 253.9 | 228.2 | NA | 8 (36) | 34.8 | 60.0 | NA |
| 4 (18) | 190.5 | 133.0 | NA | 4 (18) | 26.1 | 18.8 | NA |
| 2 (9) | 126.4 | 66.9 | NA | | | | |

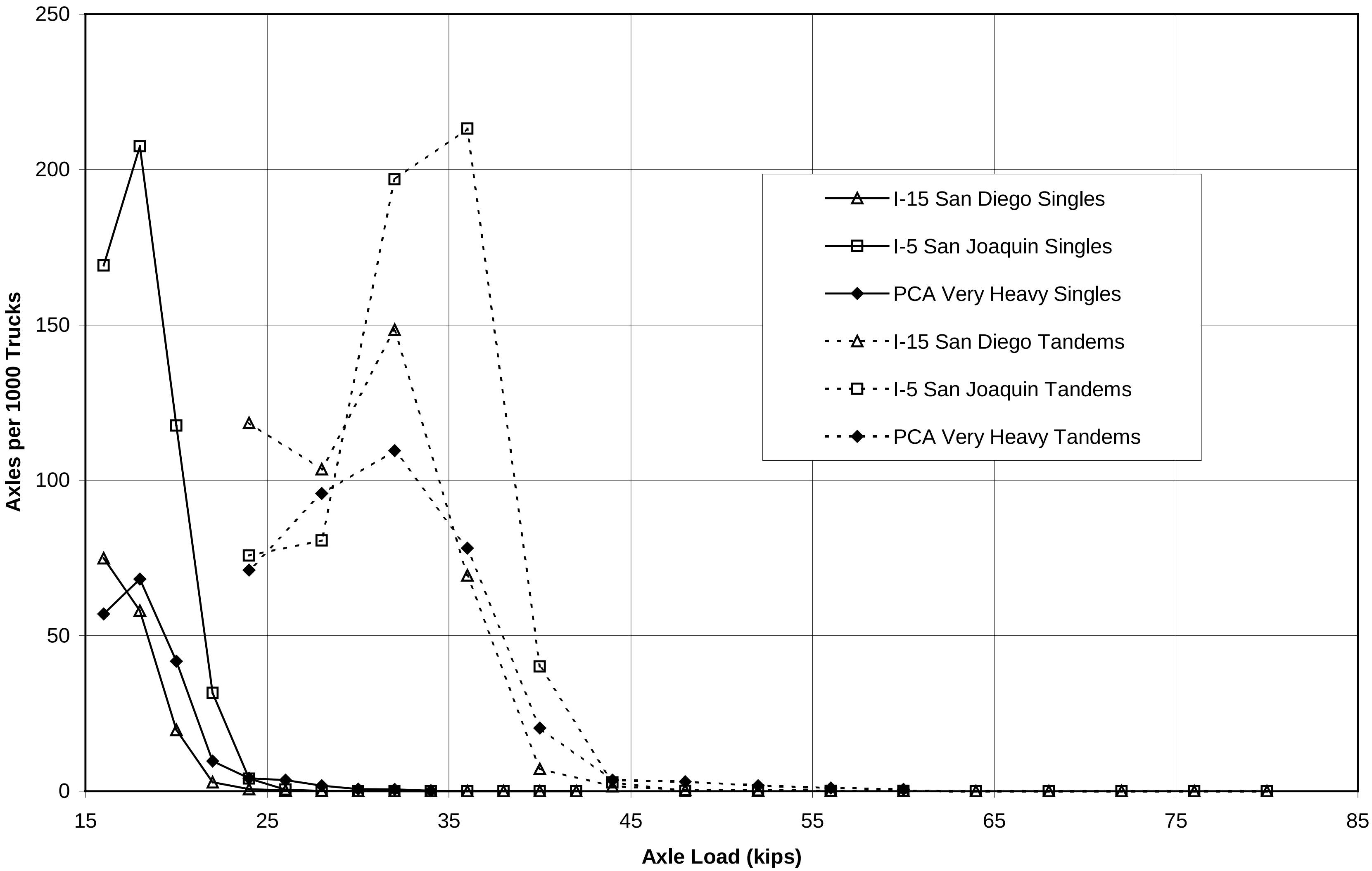



**Figure 37. Comparison of PCA "very heavy," I-5 San Joaquin County, and I-215 San Diego County axle load spectra.**

axle loads that are not included in the PCA spectrum, as shown in Figure 38. Despite accounting for only a few percent of the total axle loads, these very overloaded axles are responsible for a significant portion of the damage to concrete pavements, particularly fatigue cracking because of the very high stress to modulus of rupture ratios. Single axle load distributions were truncated at 151 kN (34 kips) and tandem axle loads at 267 kN (60 kips) because of limitations on the number of axle load categories that can be included in the ACPA/AASHTO and PCA software analyses.

Additional traffic variables are considered in the Illinois DOT method, as shown in Table 22.

**Table 22 Summary of Assumed Values for Variables Included in Illinois DOT Method and Not Considered in PCA and ACPA/AASHTO Methods.**

| Variable | Assumed Values |
|---|---|
| Slab to Base Bonding | Unbonded |
| Concrete Elastic Modulus | 4,000,000 psi |
| Base Elastic Modulus | 500,000 psi |
| Concrete Poisson Ratio | 0.15 |
| Dowel Diameter | 37 mm (1.5 inches) |
| Modulus of Rupture Test Method | 3$^{rd}$ Point Loading |
| Truck Traffic Daily Distribution | 75 percent of Trucks in Daylight Hours |
| Average Distance Slab Edge to Edge of Wheel | 456 mm (18 in.) |
| Standard Deviation of Lateral Wheel Location | 300 mm (12 in.) |
| Fatigue Model | Beams |
| Method to Include About 90 percent Reliability | Multiply axle load repetitions by 2.5 |

### 3.2.3 Subgrade/Base Support

The support provided to the concrete slabs by the subgrade, subbase, and base is used in terms of the modulus of subgrade reaction, or k, in all three methods. The modulus of subgrade reaction is essentially a linear spring constant in which the distance that the spring compresses is

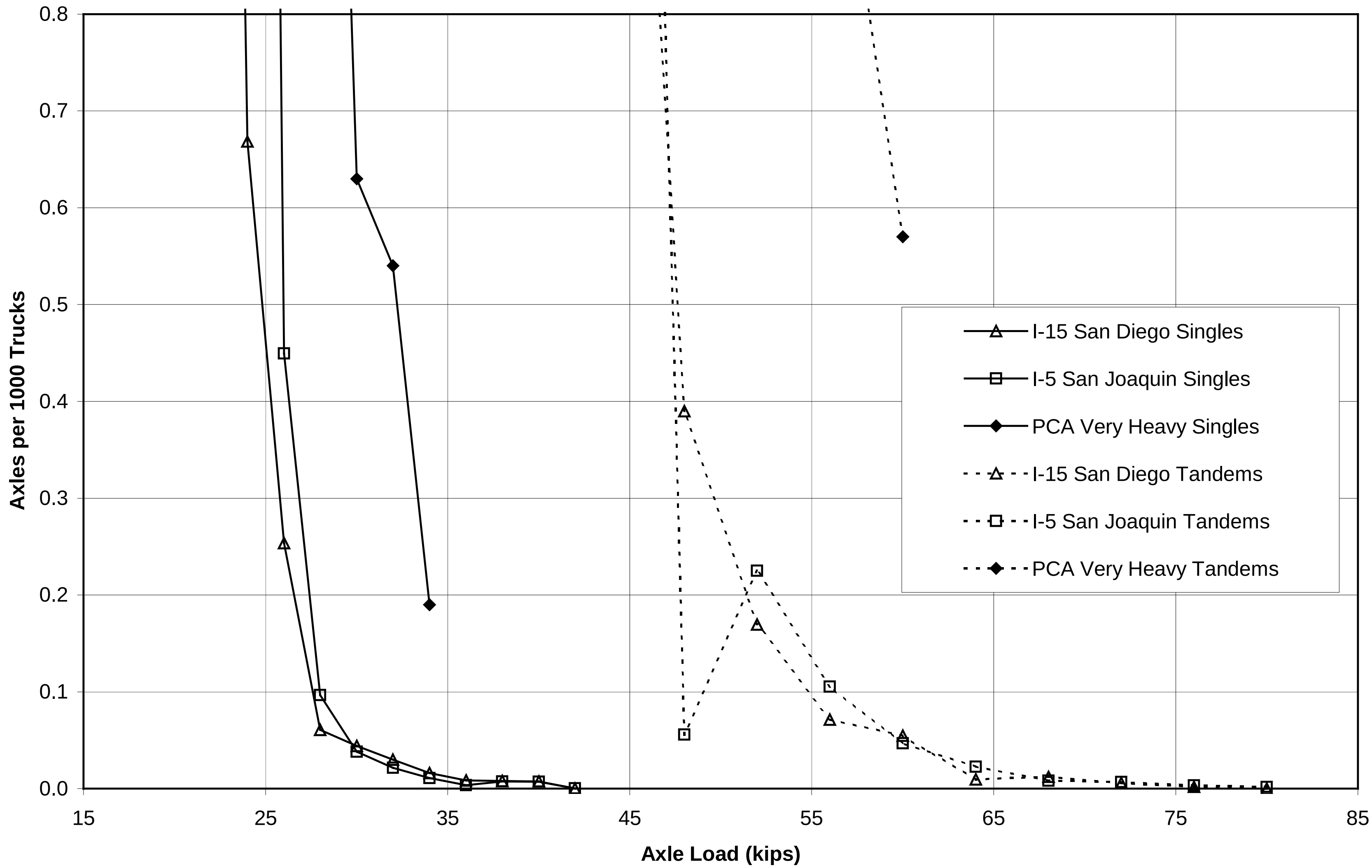



**Figure 38. Comparison of heaviest loads from PCA "very heavy," I-5 San Joaquin County, and I-215 San Diego County axle load spectra.**

a function of the stress applied. The software for all three design methods considered use English units, so the units are psi/in.

The method for estimating a composite k-value for structures that have base layers between the slab and the subgrade is different for the PCA and ACPA/AASHTO methods. The PCA method explicitly considers loss of support and fatigue in determining slab thickness. The ACPA/AASHTO method considers loss of serviceability to the user, which does not distinguish between distresses. Two subgrade k-values likely in California, 100 and 200 psi/in. (27.1 MPa/m and 54.3 MPa/m), and three base structures were initially considered for inclusion in the experimental design. Based on recommendations in the two design methods, composite k-values were selected for the three base structures and two subgrade k-values, as shown in Table 23.

**Table 23 Composite base/subgrade k-values for PCA and ACPA/AASHTO methods for various subgrade and base structures.**

| **Design Method** | **PCA** | | **ACPA/AASHTO** | |
|---|---|---|---|---|
| Subgrade k psi/in. (MPa/m) | 100 (27.1) | 200 (54.3) | 100 (27.1) | 200 (54.3) |
| 150 mm CTB, 150 mm ASB k value | 400 | <u>640</u> | 258 | <u>457</u> |
| 100 mm CTB, 150 mm ASB k value | 200 | <u>350</u> | 192 | <u>353</u> |
| 250 mm AB k value | <u>170</u> | 290 | <u>100</u> | 200 |

To limit the size of the experiment, only the six underlined composite k-values were used for the PCA and ACPA/AASHTO methods.

In the Illinois DOT method, the effect of the base layers on fatigue performance is considered by transforming the base in an equivalent thickness of concrete surfacing. There is no top of the base k-value required, only subgrade k-values. Subgrade k-values of 100, 250 and 500 psi/in. were included in the experiment. The Illinois DOT method calculates slab thickness based only on fatigue criteria (i.e., formation of transverse cracking). Distresses such as faulting, corner cracking, and pumping associated with loss of support or erosion are not mechanistically modeled. All subgrades were considered to be A4 to A7 soils by the AASHTO classification method.

### 3.2.4 Concrete Flexural Strength

Concrete 28-day moduli of rupture (MR) of 3.45, 4.48, and 5.52 MPa (500, 650 and 800 psi, respectively) were included in the experiment. These MR values are based on third-point loading for all three design methods. Caltrans currently specifies a concrete MR of 3.79 MPa (550 psi) at 14 days for Portland cement concrete using a center-point loading configuration. The special provisions for many LLPRS projects require a concrete MR of 2.8 MPa at 8 hours, and 4.1 MPa at 7 days. Caltrans uses center-point loading (CT 523) instead of third-point loading (ASTM C78), which typically produces MR values approximately 5 percent greater than those from third-point loading and with a greater variance. Many other states also use center-point loading.

The elastic modulus of the concrete is required for the ACPA/AASHTO and Illinois DOT methods. For the ACPA/AASHTO method, the elastic modulus was estimated based on the MR, with elastic modulus values of $3.375\times10^6$, $4.388\times10^6$, and $5.400\times10^6$ psi corresponding to MR values of 500, 650, and 800 psi (3.45, 4.48, and 5.51 MPa) respectively. For the Illinois DOT, an elastic modulus of $4.0\times10^6$ psi was used.

### 3.2.5 Design Features

The design features included in the long life rigid pavement rehabilitation strategies (LLPRS-Rigid) to extend the life of rigid pavements are dowels in the transverse joints, tied concrete shoulders, and widened truck lanes. Doweled transverse joints and tied concrete shoulders were evaluated using the three design methods. Characterization of the pavement structure for these features is different in the three methods. The PCA method does not consider widened truck lanes, although for practical purposes wide tied concrete shoulders perform much the same function as widened truck lanes.

In the PCA method, the use of dowels or aggregate interlock to obtain transverse joint load transfer, and tied concrete shoulders or asphalt concrete (AC) shoulders, is considered by means of different performance equations.

In the ACPA/AASHTO method, load transfer at the transverse joints and shoulders is characterized by the "J factor." Guidelines are given in the method for selecting J factors for combinations of doweled or aggregate interlock transverse joints, and tied concrete shoulders or AC shoulders. Widened truck lanes were treated as tied concrete shoulders. The J factors selected for this experiment to represent these permutations of joint load transfer are shown in Table 24. These factors fall within the ranges recommended by ACPA/AASHTO.

**Table 24 Joint Load Transfer, "J factors," Selected for Use with ACPA/AASHTO Method.**

| | **Doweled Transverse Joints** | **Aggregate Interlock Transverse Joints** |
|---|---|---|
| Tied Concrete Shoulders/ Widened Truck Lanes | 2.7 | 3.6 |
| AC Shoulders/ Normal Lane Widths | 3.2 | 4.3 |

The Illinois DOT method requires characterization of the joint stiffness in terms of dimensionless coefficients for doweled and undoweled (aggregate interlock) transverse joints. For the undoweled joints, the joint stiffness was 50 percent where AGG is a spring stiffness in $F/L^2$, k = subgrade modulus of reaction, and l = radius of relative stiffness. For doweled joint, the joint stiffness was equal to 90 percent. The dowel diameter was 1.25 in. Shoulder types considered in the Illinois DOT method included asphalt concrete, tied concrete shoulder with a high degree of load transfer (90 percent LTE), tied concrete shoulder with a low degree of load transfer (50 percent LTE), and truck lanes widened 0.3 and 0.6 m beyond the standard 3.7-m width.

Unlike the ACPA/AASHTO and PCA methods, the Illinois method considers slab length, which is a key consideration for transverse fatigue cracking. Slab lengths considered in the ILLICON experiment were 4.57 and 5.79 m (15 and 19 ft.).

### 3.2.6 Safety Factors/Reliability

The three design methods considered use very different procedures to include reliability into the structural design. An attempt was made in the experiment to include design reliability appropriate for heavy-duty interstate pavements, and to include similar reliability across the three methods.

The PCA method includes reliability by applying a Load Safety Factor (LSF) to each load in the axle load spectrum. An LSF for interstate pavements of 1.2 was used in the experiment.

The ACPA/AASHTO method explicitly considers reliability in the design equation. An overall reliability of 95 percent was used for the experiment. The standard deviation of the concrete strength was assumed to be 10 percent of the average strength. The initial serviceability in terms of the Present Serviceability Index (PSI) was assumed to be 4.5, and the terminal PSI was assumed to be 2.5.

The Illinois DOT method considers design reliability. The ILLICON program is used as a design check and does not include reliability factors. Designs are for average performance in terms of percent of slabs cracked. To introduce a design reliability of approximately 90 to 95 percent into the calculations, traffic repetitions were multiplied by a factor of 2.5. The Illinois

DOT assumes that most of the variability of pavement performance occurs because of variability in estimating axle loading over the design life.

### 3.2.7 Climate and Drainage

The PCA method does not directly consider climate or drainage.

The ACPA/AASHTO method considers climate and drainage together with the coefficient of drainage, Cd. Coefficients of drainage of 0.80 and 1.20 were included in this experiment. A Cd of 0.80 corresponds to poor drainage, with underlying soils layers subject to saturation more than 25 percent of the time. A Cd of 1.20 corresponds to excellent drainage, with underlying soils layers subject to saturation from one to five percent of the time.

The Illinois DOT method considers climate in terms of both rainfall and temperature. The Integrated Climate Model (ICM) is used to calculate pavement temperatures and water infiltration from air temperature, wind speed, precipitation, and cloud cover data available from the National Oceanographic and Aeronautic Administration (NOAA), and from information about the pavement structure. (*34*) For this experiment, the ICM model was run for one city in each of the climatic regions shown in Table 25.

**Table 25 Locations Used for Integrated Climate Model Analysis.**

| Location | Pavement Design Climatic Region |
|---|---|
| Daggett | Desert |
| Los Angeles | South Coast |
| Fresno | Valley |
| Reno | Mountain |
| San Francisco | Bay Area |

During initial pavement analyses, it was found that there was no difference between the Los Angeles and San Francisco climates, and so those two locations were then combined. The Reno calculations were not included in this report because of time constraints.

3.2.8 Failure Modes

It is important to understand that different failure criteria are used in each of the three design methods.

The PCA method considers failure to occur by either transverse fatigue cracking or "erosion." Erosion includes all distresses caused by loss of support to the concrete slab, including faulting, corner cracking, and potentially longitudinal cracking. Each thickness design is evaluated for both fatigue cracking and erosion, and the failure mode that requires the thickest slab is considered critical. In the tables of experiment results included in Appendices B-D, the mode of failure found to be critical is identified for each case.

Failure is not identified by distress in the ACPA/AASHTO method. Instead, pavement life is evaluated in terms of "serviceability," a composite measure of pavement condition dependent primarily on user perception, and therefore primarily on ride quality. The design equations are mostly based on the results of the AASHO Road Test of 1958 to 1960, and are restricted in many ways to the subgrade conditions and climate in central Illinois during those years. In particular, rigid pavement distress development caused by loss of support to the concrete slabs is highly related to the "pumpable" and "erodable" subgrade materials at the AASHO Road Test. For this reason, some adjustments were made to the J factors used in the ACPA version of the AASHTO design method. These adjustments were used in this experiment and are described in detail in notes that accompany the ACPA design method. (*35*)

The failure mode considered in the Illinois DOT method is transverse fatigue cracking. This method considers slab thickness to be the primary variable that determines a pavement's potential for fatigue cracking. The IDOT method uses past experience to justify other design features such as base type. This approach is justifiable considering that faulting and other distresses caused by loss of support to the concrete slabs are not significantly affected by slab thickness if slab thickness is appropriately designed for resistance to fatigue cracking.

### 3.3 Evaluation of Design Lives Using the PCA Method

Concrete slab thicknesses determined by the PCA method for the experiment variables are shown in Table 26. The results are summarized in terms of the mode of failure, fatigue or erosion, and shown on a case by case basis in Appendix B. The program output is in inches and so the results are reported in inches.

For the proposed rigid pavement strategies, which include retention of 100 mm of CTB and 150 mm of ASB, assuming a subgrade k-value of 200 psi/in., the required slab thicknesses are between 7.5 and 14 inches (191 and 356 mm). Slab thickness is dependent primarily upon the inclusion of dowels and/or tied shoulder and concrete flexural strength, and to a lesser extent upon axle load spectra and truck traffic.

Average, minimum and maximum slab thicknesses for each variable and factor level are shown in Table 27. Also shown is the proportion of cases for which fatigue or erosion is identified as critical by the design method. Overall, 16 percent of the cases were identified as failing by fatigue, and 84 percent by erosion. The maximum permitted slab thickness in the PCA method is 14 inches (356 mm). When a thicker slab is required, the software calls for a slab "> 14 inches." For the purposes of preparing Table 27, slab thicknesses greater than 14 inches (356 mm) were calculated as 14.5 inches (368 mm). The maximum of 14 inches (356 mm) is an indication of the maximum extent to which the PCA wishes to extrapolate its method, which was exceeded for many of the cases in this experiment, especially when dowels and tied concrete shoulders were not employed.

## Table 26 Concrete Slab Thicknesses from PCA Method, in. (cm).

| | | **Dowels and Tied Shoulders** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture psi (MPa)** | | | | | | | | |
| **Axle Loads Spectrum** | **Daily Trucks Design Lane** | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| | | **Subgrade/Base k psi/in. (kPa/cm)** | | | | | | | | |
| | | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** |
| PCA | 8,750 | 11 (27.9) | 10 (24.1) | 9.5 (24.1) | 9 (22.9) | 8.5 (21.6) | 8 (20.3) | 9 (22.9) | 8.5 (21.6) | 8 (20.3) |
| PCA | 17,500 | 11.5 (29.2) | 10.5 (26.7) | 10 (24.1) | 9.5 (24.1) | 9 (22.9) | 8.5 (21.6) | 9.5 (24.1) | 9 (22.9) | 8.5 (21.6) |
| San Diego | 8,750 | 10 (24.1) | 9 (22.9) | 8.5 (21.6) | 8.5 (21.6) | 7.5 (19.1) | 7 (17.8) | 8 (20.3) | 7.5 (19.1) | 7 (17.8) |
| San Diego | 17,500 | 10.5 (26.7) | 9.5 (24.1) | 9 (22.9) | 8.5 (21.6) | 8 (20.3) | 7.5 (19.1) | 8.5 (21.6) | 7.5 (19.1) | 7.5 (19.1) |
| San Joaquin | 8,750 | 10 (24.1) | 9 (22.9) | 8.5 (21.6) | 8.5 (21.6) | 8 (20.3) | 7.5 (19.1) | 8.5 (21.6) | 8 (20.3) | 7.5 (19.1) |
| San Joaquin | 17,500 | 10.5 (26.7) | 9.5 (24.1) | 9 (22.9) | 9 (22.9) | 8 (20.3) | 8 (20.3) | 9 (22.9) | 8 (20.3) | 8 (20.3) |
| | | **Dowels and No Tied Shoulders** | | | | | | | | |
| | | **PCC Modulus of Rupture psi (MPa)** | | | | | | | | |
| **Axle Loads Spectrum** | **Daily Trucks Design Lane** | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| | | **Subgrade/Base k psi/in. (kPa/cm)** | | | | | | | | |
| | | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** |
| PCA | 8,750 | 12.5 (31.8) | 11.5 (29.2) | 10.5 (26.7) | 10.5 (26.7) | 10 (24.1) | 10 (24.1) | 10.5 (26.7) | 10 (24.1) | 10 (24.1) |
| PCA | 17,500 | 13 (33.0) | 12 (30.5) | 11 (27.9) | 11.5 (29.2) | 10.5 (26.7) | 10.5 (26.7) | 11.5 (29.2) | 10.5 (26.7) | 10.5 (26.7) |
| San Diego | 8,750 | 11.5 (29.2) | 10.5 (26.7) | 9.5 (24.1) | 10 (24.1) | 9.5 (24.1) | 9 (22.9) | 10 (24.1) | 9.5 (24.1) | 9 (22.9) |
| San Diego | 17,500 | 12 (30.5) | 10.5 (26.7) | 10 (24.1) | 10.5 (26.7) | 10 (24.1) | 9.5 (24.1) | 10.5 (26.7) | 10 (24.1) | 9.5 (24.1) |
| San Joaquin | 8,750 | 11.5 (29.2) | 10.5 (26.7) | 10 (24.1) | 11 (27.9) | 10.5 (26.7) | 10 (24.1) | 11 (27.9) | 10.5 (26.7) | 10 (24.1) |
| San Joaquin | 17,500 | 12 (30.5) | 11 (27.9) | 10.5 (26.7) | 11.5 (29.2) | 11 (27.9) | 10.5 (26.7) | 11.5 (29.2) | 11 (27.9) | 10.5 (26.7) |

*(Table 26 continued)*

| | | No Dowels and Tied Shoulders | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture psi (MPa)** | | | | | | | | |
| **Axle Loads Spectrum** | **Daily Trucks Design Lane** | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| | | **Subgrade/Base k psi/in. (kPa/cm)** | | | | | | | | |
| | | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** |
| PCA | 8,750 | 11.5 (29.2) | 10.5 (26.7) | 9.5 (24.1) | 11.5 (29.2) | 10.5 (26.7) | 9.5 (24.1) | 11.5 (29.2) | 10.5 (26.7) | 9.5 (24.1) |
| PCA | 17,500 | 12.5 (31.8) | 11 (27.9) | 10.5 (26.7) | 12.5 (31.8) | 11 (27.9) | 10.5 (26.7) | 12.5 (31.8) | 11 (27.9) | 10.5 (26.7) |
| San Diego | 8,750 | 10.5 (26.7) | 9 (22.9) | 8.5 (21.6) | 10.5 (26.7) | 9 (22.9) | 8.5 (21.6) | 10.5 (26.7) | 9 (22.9) | 8.5 (21.6) |
| San Diego | 17,500 | 11 (27.9) | 9.5 (24.1) | 9 (22.9) | 11 (27.9) | 9.5 (24.1) | 9 (22.9) | 11 (27.9) | 9.5 (24.1) | 9 (22.9) |
| San Joaquin | 8,750 | 11 (27.9) | 10 (24.1) | 9.5 (24.1) | 11 (27.9) | 10 (24.1) | 9.5 (24.1) | 11 (27.9) | 10 (24.1) | 9.5 (24.1) |
| San Joaquin | 17,500 | 11.5 (29.2) | 10 (24.1) | 9.5 (24.1) | 11 (27.9) | 10 (24.1) | 9.5 (24.1) | 11.5 (29.2) | 10 (24.1) | 9.5 (24.1) |
| | | **No Dowels and No Tied Shoulders** | | | | | | | | |
| | | **PCC Modulus of Rupture psi (MPa)** | | | | | | | | |
| **Axle Loads Spectrum** | **Daily Trucks Design Lane** | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| | | **Subgrade/Base k psi/in. (kPa/cm)** | | | | | | | | |
| | | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** | **170 (461)** | **350 (950)** | **640 (1737)** |
| PCA | 8,750 | >>14 (35.6) | 12.5 (31.8) | 12 (30.5) | >>14 (35.6) | 12.5 (31.8) | 12 (30.5) | >>14 (35.6) | 12.5 (31.8) | 12 (30.5) |
| PCA | 17,500 | >>14 (35.6) | 13.5 (34.3) | 12.5 (31.8) | >>14 (35.6) | 13.5 (34.3) | 12.5 (31.8) | >>14 (35.6) | 13.5 (34.3) | 12.5 (31.8) |
| San Diego | 8,750 | 13.5 (34.3) | 12 (30.5) | 11 (27.9) | 13.5 (34.3) | 12 (30.5) | 11 (27.9) | 13.5 (34.3) | 12 (30.5) | 11 (27.9) |
| San Diego | 17,500 | >>14 (35.6) | 12.5 (31.8) | 11.5 (29.2) | >>14 (35.6) | 12.5 (31.8) | 11.5 (29.2) | >>14 (35.6) | 12.5 (31.8) | 11.5 (29.2) |
| San Joaquin | 8,750 | >>14 (35.6) | 13 (33.0) | 12 (30.5) | >>14 (35.6) | 13 (33.0) | 12 (30.5) | >>14 (35.6) | 13 (33.0) | 12 (30.5) |
| San Joaquin | 17,500 | >>14 (35.6) | 14 (35.6) | 12.5 (31.8) | >>14 (35.6) | 14 (35.6) | 12.5 (31.8) | >>14 (35.6) | 14 (35.6) | 12.5 (31.8) |

**Table 27 Average Concrete Slab Thicknesses and Failure Modes for Each Variable Factor Level. PCA Method.**

| Variable | Factor Level | Required Slab Thickness in. (cm) | | | Failure Mode (percent) | |
|---|---|---|---|---|---|---|
| | | Average | Minimum | Maximum | Fatigue | Erosion |
| Subgrade k psi/in (kPa/cm) | 170 (461) | 11.6 (29.4) | 8.0 (20.3) | 14.5 (36.8) | 19 | 81 |
| | 350 (950) | 10.5 (26.7) | 7.5 (19.1) | 14.0 (35.6) | 17 | 83 |
| | 640 (1737) | 9.9 (25.1) | 7.0 (17.8) | 12.5 (31.8) | 14 | 86 |
| Axle Load Spectra | PCA "very heavy" | 11.1 (28.2) | 8.0 (20.3) | 14.5 (36.8) | 18 | 82 |
| | San Diego | 10.1 (25.7) | 7.0 17.8) | 14.5 (36.8) | 22 | 78 |
| | San Joaquin | 10.8 (27.3) | 7.5 (19.1) | 14.5 (36.8) | 10 | 90 |
| Daily Trucks In Design Lane | 8,750 | 10.4 (26.4) | 7.0 17.8) | 14.5 (36.8) | 18 | 82 |
| | 17,500 | 10.9 (27.7) | 7.5 (19.1) | 14.5 (36.8) | 16 | 84 |
| Concrete Flexural Strength psi (MPa) | 500 (3.45) | 11.0 (28.0) | 8.5 (21.6) | 14.5 (36.8) | 43 | 57 |
| | 650 (4.48) | 10.5 (26.6) | 7.0 17.8) | 14.5 (36.8) | 7 | 93 |
| | 800 (5.52) | 10.5 (26.6) | 7.0 17.8) | 14.5 (36.8) | 0 | 100 |
| Design Features | No Dowels, AC Shoulders | 13.0 (33.1) | 11.0 (28.0) | 14.5 (36.8) | 0 | 100 |
| | No Dowels, Tied Shoulders | 10.3 (26.0) | 8.5 (21.6) | 12.5 (31.8) | 0 | 100 |
| | Dowels, AC Shoulders | 10.6 (26.9) | 9.0 (22.9) | 13.0 (33.0) | 24 | 76 |
| | Dowels, Tied Shoulders | 8.7 (22.2) | 7.0 17.8) | 11.5 (29.2) | 43 | 57 |

The range of subgrade/base support values resulted in an average change of one to two inches (25-51 mm) of concrete thickness. For the primary strategy proposed for LLPRS, which involves retention of 100 mm of CTB where possible (subgrade k = 350 pci), required slab thicknesses ranged between 7.5 and 14 inches (191 and 356 mm).

The effect of different axle load spectra is fairly minimal, for the limited number of spectra available when this experiment was performed. The PCA spectrum generally results in thicker concrete slabs than do the two spectra from the LTPP data base. There is some difference in the mode of failure between the San Diego and San Joaquin spectra, with the San

Joaquin spectrum more critical for fatigue and the San Diego spectrum more critical for erosion. The San Joaquin spectrum has a greater number of heavy single axle loads, which are critical for fatigue, while the San Diego spectrum has a greater number of heavy tandem axle loads, which are critical for erosion according to the PCA method.

The effect of traffic repetitions is less important than axle load spectrum. The effect of heavier loads is more important than the effect of more truck traffic in determining slab thickness.

Low concrete flexural strength and load transfer conditions at joints and shoulders affect the mode of failure and required concrete slab thickness. When concrete flexural strength is 3.45 MPa (500 psi) and doweled joints are included, the thickness is typically controlled by fatigue. When concrete flexural strength is 4.48 or 5.52 MPa (650 and 800 psi), the typical mode of failure is erosion.

Inclusion of dowels and tied shoulders or widened truck lanes has strong effects on required slab thickness and on the mode of failure. Inclusion of dowels and tied shoulders reduces the average slab thickness required from 13 inches to 8.7 inches (330 to 221 mm), and minimum slab thicknesses for the most critical cases of concrete flexural strength and subgrade support from 14.5 to 11.5 inches (368 to 292 mm).

The use of dowels reduces the proportion of failures caused by erosion from 100 percent to 76 percent. When dowels are used with tied shoulders, erosion failures are reduced to 57 percent. Erosion failure, or loss of support, is the most widespread distress in the Caltrans network, manifested primarily as joint faulting and corner cracking.

An assessment of required slab thicknesses assuming the use of dowels and tied shoulders or widened truck lanes is shown in Table 28.

**Table 28 Average Concrete Slab Thicknesses and Failure Modes for Each Variable Factor Level, Assuming Use of Dowels and Tied Concrete Shoulders or Widened Truck Lanes.**

| | | Required Slab Thickness in. (cm) | | | Failure Mode (percent) | |
|---|---|---|---|---|---|---|
| **Variable** | **Factor Level** | **Average** | **Minimum** | **Maximum** | **Fatigue** | **Erosion** |
| Subgrade k value psi/in. (kPa/cm) | 170 (461) | 9.4 (23.8) | 8.0 (20.3) | 11.5 (29.2) | 50 | 50 |
| | 350 (950) | 8.6 (21.9) | 7.5 (19.1) | 10.5 (26.7) | 44 | 56 |
| | 640 (1737) | 8.2 (20.8) | 7.0 (17.8) | 10.0 (25.4) | 33 | 67 |
| Axle Load Spectra | PCA "very heavy" | 9.3 (23.6) | 8.0 (20.3) | 11.5 (29.2) | 39 | 61 |
| | San Diego | 8.3 (21.1) | 7.5 (19.1) | 10.5 (26.7) | 56 | 44 |
| | San Joaquin | 8.6 (21.8) | 7.0 (17.8) | 10.5 (26.7) | 33 | 67 |
| Daily Trucks in Design Lane | 8,750 | 8.5 (21.6) | 7.0 (17.8) | 11.0 (27.9) | 44 | 56 |
| | 17,500 | 8.9 (22.7) | 7.5 (19.1) | 11.5 (29.2) | 41 | 59 |
| Concrete Flexural Strength psi (MPa) | 500 (3.45) | 9.8 (24.8) | 8.0 (20.3) | 11.5 (29.2) | 100 | 0 |
| | 650 (4.48) | 8.3 (21.0) | 7.0 (17.8) | 9.5 (24.1) | 28 | 72 |
| | 800 (5.52) | 8.2 (20.8) | 7.0 (17.8) | 9.5 (24.1) | 0 | 100 |

For the proposed LLPRS strategy of retention of 100 mm of CTB and 150 mm of ASB, and assuming a subgrade k-value of 200 pci (combined support value of 350 pci), the required slab thicknesses are between 7.5 and 10.5 inches (191 and 267 mm).

Required slab thicknesses are between 7 and 9.5 inches (178 and 241 mm) across all subgrade/base support values if concrete flexural strengths are maintained above 4.48 MPa (650 psi). If a flexural strength of 3.45 MPa (500 psi) is permitted, the maximum required slab thickness moves to 11.5 inches (292 mm).

Differences in axle load spectra and truck traffic have more limited effects on required slab thicknesses when dowels and tied concrete shoulders are utilized.

## 3.4 Evaluation of Design Lives Using the ACPA/AASHTO Method

Concrete slab thicknesses determined by the ACPA/AASHTO method for the experiment variables are shown in Table 29. The results are shown on a case by case basis in Appendix C.

The slab thicknesses are given in inches because these are the units used by the software. The maximum slab thickness permitted in the ACPA/AASHTO method is 20 inches, as opposed to 14.5 inches in the PCA method. The 20-inch maximum thickness is an indication of the maximum extent to which the design method is intended to be extrapolated. Many cases resulted in the design method calling for this maximum thickness.

Table 29 shows that with 100 mm of CTB and 150 mm of ASB, slab thicknesses range between 13.2 and 20 inches (335 and 508 mm), assuming a subgrade k-value of 200 pci (combined k value of 353 pci). This would be the concrete thicknesses required using this procedure if Caltrans decided not to disturb the existing CTB and ASB. Slab thickness is dependent primarily upon the drainage coefficient, inclusion of dowels and tied concrete shoulders, truck traffic level, and concrete flexural strength. It is dependent to a lesser extent upon axle load spectra and subgrade/base support.

Table 30 includes average, minimum, and maximum slab thicknesses for each variable and factor level.

Drainage condition has a significant effect on the required slab thicknesses. Between drainage coefficients of 0.8 and 1.2, the average slab thickness decreases from 17.9 to 15 inches (455 to 381 mm). Drainage condition is not considered in the calculation of slab thickness in the PCA method.

The addition of dowels and tied shoulders reduces required slab thickness by about 3 inches (76 mm) on average, compared to aggregate interlock joints and asphalt concrete shoulders. The inclusion of dowels alone on average reduces slab thickness by about 2 inches (51 mm). The inclusion of tied shoulders alone on average reduces slab thickness by about 1 inch (25 mm).

**Table 29 Concrete Slab Thicknesses from ACPA/AASHTO Method, in. (cm).**

| ***Coefficient of Drainage = 0.8*** | | ***Dowels and Tied Shoulders J = 2.7*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture psi (MPa)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **3,375,000** | | | **4,388,000** | | | **5,400,000** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 17.2 (43.7) | 16.5 (41.9) | 16.4 (41.7) | 15.2 (38.6) | 14.6 (37.1) | 14.5 (36.8) | 13.8 (35.1) | 13.2 (33.5) | 13.1 (33.3) |
| PCA | 17,500 | 19.0 (48.3) | 18.4 (46.7) | 18.2 (4.2) | 16.8 (42.7) | 16.2 (41.1) | 16.0 (40.6) | 15.2 (38.6) | 14.7 (37.3) | 14.5 (36.8) |
| San Diego | 8,750 | 17.2 (43.7) | 16.5 (41.9) | 16.4 (41.7) | 15.2 (38.6) | 14.6 (37.1) | 14.4 (36.6) | 13.7 (34.8) | 13.2 (33.5) | 13.0 (33.0) |
| San Diego | 17,500 | 19.0 (48.3) | 18.4 (46.7) | 18.2 (46.2) | 16.8 (42.7) | 16.2 (41.1) | 16.0 (40.6) | 15.2 (38.6) | 14.7 (37.3) | 14.5 (36.8) |
| San Joaquin | 8,750 | 19.2 (48.8) | 18.5 (47.0) | 18.5 (47.0) | 16.9 (42.9) | 16.3 (41.4) | 16.2 (41.1) | 15.3 (38.9) | 14.8 (37.6) | 14.6 (37.1) |
| San Joaquin | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 18.7 (47.5) | 18.1 (46.0) | 18.0 (45.7) | 17.0 (43.2) | 16.4 (41.7) | 16.3 (41.4) |
| ***Coefficient of Drainage = 0.8*** | | ***Dowels and No Tied Shoulders J = 3.2*** | | | | | | | | |
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **3,375,000** | | | **4,388,000** | | | **5,400,000** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 18.7 (47.5) | 18.1 (46.0) | 17.9 (45.5) | 16.5 (41.9) | 16.0 (40.6) | 15.8 (40.1) | 15.0 (38.1) | 14.4 (36.6) | 14.3 (36.3) |
| PCA | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 19.9 (50.5) | 18.3 (46.5) | 17.7 (45.0) | 17.5 (44.5) | 16.6 (42.2) | 16.0 (40.6) | 15.9 (40.1) |
| San Diego | 8,750 | 18.7 (47.5) | 18.1 (46.0) | 17.9 (45.5) | 16.5 (41.9) | 15.9 (40.1) | 15.8 (40.1) | 15.0 (38.1) | 14.4 (36.6) | 14.3 (36.3) |
| San Diego | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 19.9 (50.5) | 18.3 (46.5) | 17.7 (45.0) | 17.5 (44.5) | 16.5 (41.9) | 16.0 (40.6) | 15.9 (40.1) |
| San Joaquin | 8,750 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 18.4 (46.7) | 17.8 (45.2) | 17.7 (45.0) | 16.7 (42.4) | 16.1 (40.9) | 16.0 (40.6) |
| San Joaquin | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.8 (50.3) | 19.6 (49.8) | 18.4 (46.7) | 17.9 (45.5) | 17.7 (45.0) |

*Table 29 continued*

| ***Coefficient of Drainage = 0.8*** | | ***No Dowels and Tied Shoulders J = 3.6*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| | | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **3,375,000** | | | **4,388,000** | | | **5,400,000** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 19.8 (50.3) | 19.2 (48.8) | 19.0 (48.3) | 17.5 (44.5) | 17.0 (43.2) | 16.8 (42.7) | 15.9 (40.4) | 15.4 (39.1) | 15.2 (38.6) |
| PCA | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.4 (49.3) | 18.8 (47.8) | 18.6 (47.2) | 17.5 (44.5) | 17.0 (43.2) | 16.8 (42.7) |
| San Diego | 8,750 | 19.8 (50.3) | 19.2 (48.8) | 19.0 (48.3) | 17.5 (44.5) | 16.9 (42.9) | 16.8 (42.7) | 15.9 (40.4) | 15.3 (38.9) | 15.2 (38.6) |
| San Diego | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.4 (49.3) | 18.8 (47.8) | 18.6 (47.2) | 17.5 (44.5) | 17.0 (43.2) | 16.8 (42.7) |
| San Joaquin | 8,750 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.5 (49.5) | 18.9 (48.0) | 18.8 (47.8) | 17.7 (45.0) | 17.1 (43.4) | 17.0 (43.2) |
| San Joaquin | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.5 (49.5) | 19.0 (48.3) | 18.8 (47.8) |

| ***Coefficient of Drainage = 0.8*** | | ***No Dowels and No Tied Shoulders J = 4.3*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **3,375,000** | | | **4,388,000** | | | **5,400,000** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.1 (48.5) | 18.6 (47.2) | 18.4 (46.7) | 17.4 (44.2) | 16.8 (42.7) | 16.7 (42.4) |
| PCA | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.2 (48.8) | 18.6 (47.2) | 18.5 (47.0) |
| San Diego | 8,750 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.1 (48.5) | 18.5 (47.0) | 18.4 (46.7) | 17.3 (43.9) | 16.8 (42.7) | 16.6 (42.2) |
| San Diego | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.1 (48.5) | 18.6 (47.2) | 18.5 (47.0) |
| San Joaquin | 8,750 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.3 (49.0) | 18.8 (47.8) | 18.6 (47.2) |
| San Joaquin | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) |

*Table 29 continued*

| *Coefficient of Drainage = 1.2* | | *Dowels and Tied Shoulders J = 2.7* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **$3.375 \times 10^6$** | | | **$4.388 \times 10^6$** | | | **$5.400 \times 10^6$** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 14.0 (35.6) | 13.4 (34.0) | 13.2 (33.5) | 12.4 (31.5) | 11.8 (30.0) | 11.6 (29.5) | 11.2 (28.4) | 10.6 (26.9) | 10.5 (26.7) |
| PCA | 17,500 | 15.5 (39.4) | 14.9 (37.8) | 14.7 (37.3) | 13.7 (34.8) | 13.1 (33.3) | 13.0 (33.0) | 12.4 (31.5) | 11.9 (30.2) | 11.7 (29.7) |
| San Diego | 8,750 | 14.0 (35.6) | 13.4 (34.0) | 13.2 (33.5) | 12.4 (31.5) | 11.8 (30.0) | 11.6 (29.5) | 11.2 (28.4) | 10.6 (26.9) | 10.5 (26.7) |
| San Diego | 17,500 | 15.5 (39.4) | 14.9 (37.8) | 14.7 (37.3) | 13.7 (34.8) | 13.1 (33.3) | 12.9 (32.8) | 12.4 (31.5) | 11.8 (30.0) | 11.7 (29.7) |
| San Joaquin | 8,750 | 15.7 (39.9) | 15.0 (38.1) | 14.8 (37.6) | 13.8 (35.1) | 13.2 (33.5) | 13.1 (33.3) | 12.5 (31.8) | 12.0 (30.5) | 11.8 (30.0) |
| San Joaquin | 17,500 | 17.3 (43.9) | 16.7 (42.4) | 16.5 (41.9) | 15.3 (38.9) | 14.7 (37.3) | 14.5 (36.8) | 13.9 (35.3) | 13.3 (33.8) | 13.2 (33.5) |
| *Coefficient of Drainage = 1.2* | | *Dowels and No Tied Shoulders J = 3.2* | | | | | | | | |
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **$3.375 \times 10^6$** | | | **$4.388 \times 10^6$** | | | **$5.400 \times 10^6$** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 15.3 (38.9) | 14.6 (37.1) | 14.5 (36.8) | 13.5 (34.3) | 12.9 (32.8) | 12.7 (32.3) | 12.2 (31.0) | 11.6 (29.5) | 11.5 (29.2) |
| PCA | 17,500 | 16.9 (42.9) | 16.3 (41.4) | 16.1 (40.9) | 14.9 (37.8) | 14.3 (36.3) | 14.2 (36.1) | 13.5 (34.3) | 13.0 (33.0) | 12.8 (32.5) |
| San Diego | 8,750 | 15.3 (38.9) | 14.6 (37.1) | 14.5 (36.8) | 13.5 (34.3) | 12.9 (32.8) | 12.7 (32.3) | 12.2 (31.0) | 11.6 (29.5) | 11.5 (29.2) |
| San Diego | 17,500 | 16.9 (42.9) | 16.3 (41.4) | 16.1 (40.9) | 14.9 (37.8) | 14.3 (36.3) | 14.2 (36.1) | 13.5 (34.3) | 13.0 (33.0) | 12.8 (32.5) |
| San Joaquin | 8,750 | 17.0 (43.2) | 16.4 (41.7) | 16.2 (41.1) | 15.0 (38.1) | 14.5 (36.8) | 14.3 (36.3) | 13.6 (34.5) | 13.1 (33.3) | 12.9 (32.8) |
| San Joaquin | 17,500 | 18.9 (48.0) | 18.2 (46.2) | 18.0 (45.7) | 16.6 (42.2) | 16.1 (40.9) | 15.9 (40.4) | 15.1 (38.4) | 14.5 (36.8) | 14.4 (36.6) |

*Table 29 continued*

| ***Coefficient of Drainage = 1.2*** | | ***No Dowels and Tied Shoulders J = 3.6*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **$3.375 \times 10^6$** | | | **$4.388 \times 10^6$** | | | **$5.400 \times 10^6$** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 16.2 (41.1) | 15.6 (39.6) | 15.4 (39.1) | 14.3 (36.3) | 13.7 (34.8) | 13.6 (34.5) | 13.0 (33.0) | 12.4 (31.5) | 12.2 (31.0) |
| PCA | 17,500 | 17.9 (45.5) | 17.3 (43.9) | 17.1 (43.4) | 15.8 (40.1) | 15.2 (38.6) | 15.1 (38.4) | 14.3 (36.3) | 13.8 (35.1) | 13.6 (34.5) |
| San Diego | 8,750 | 16.2 (41.1) | 15.6 (39.6) | 15.4 (39.1) | 14.3 (36.3) | 13.7 (34.8) | 13.5 (34.3) | 13.0 (33.0) | 12.4 (31.5) | 12.2 (31.0) |
| San Diego | 17,500 | 17.9 (45.5) | 17.3 (43.9) | 17.1 (43.4) | 15.8 (40.1) | 15.2 (38.6) | 15.1 (38.4) | 14.3 (36.3) | 13.8 (35.1) | 13.6 (34.5) |
| San Joaquin | 8,750 | 18.1 (46.0) | 17.4 (44.2) | 17.3 (43.9) | 16.0 (40.6) | 15.4 (39.1) | 15.2 (38.6) | 14.5 (36.8) | 13.9 (35.3) | 13.8 (35.1) |
| San Joaquin | 17,500 | 20.0 (50.8) | 19.3 (49.0) | 19.2 (48.8) | 17.7 (45.0) | 17.1 (43.4) | 16.9 (42.9) | 16.0 (40.6) | 15.4 (39.1) | 15.3 (38.9) |
| ***Coefficient of Drainage = 1.2*** | | ***No Dowels and No Tied Shoulders J = 4.3*** | | | | | | | | |
| | | **PCC Modulus of Rupture (psi)** | | | | | | | | |
| ***Reliability = 95%*** | | **500 (3.45)** | | | **650 (4.48)** | | | **800 (5.52)** | | |
| **Axle Loads Location** | **Trucks in Design Lane per Day** | **Concrete Modulus of Elasticity $E_{pcc}$ (psi)** | | | | | | | | |
| | | **$3.375 \times 10^6$** | | | **$4.388 \times 10^6$** | | | **$5.400 \times 10^6$** | | |
| | | **Subgrade/Base k (psi/in.)** | | | | | | | | |
| | | **100** | **353** | **457** | **100** | **353** | **457** | **100** | **353** | **457** |
| PCA | 8,750 | 17.7 (45.0) | 17.1 (43.4) | 16.9 (42.9) | 15.6 (39.6) | 15.0 (38.1) | 14.9 (37.8) | 14.2 (36.1) | 13.6 (34.5) | 13.5 (34.3) |
| PCA | 17,500 | 19.6 (49.8) | 18.9 (48.0) | 18.8 (47.8) | 17.3 (43.9) | 16.7 (42.4) | 16.6 (42.2) | 15.7 (39.9) | 15.1 (38.4) | 15.0 (38.1) |
| San Diego | 8,750 | 17.7 (45.0) | 17.1 (43.4) | 16.9 (42.9) | 15.6 (39.6) | 15.0 (38.1) | 14.9 (37.8) | 14.2 (36.1) | 13.6 (34.5) | 13.5 (34.3) |
| San Diego | 17,500 | 19.6 (49.8) | 18.9 (48.0) | 18.8 (47.8) | 17.3 (43.9) | 16.7 (42.4) | 16.5 (41.9) | 15.7 (39.9) | 15.1 (38.4) | 15.0 (38.1) |
| San Joaquin | 8,750 | 19.8 (50.3) | 19.1 (48.5) | 18.9 (48.0) | 17.4 (44.2) | 16.8 (42.7) | 16.7 (42.4) | 15.8 (40.1) | 15.2 (38.6) | 15.1 (38.4) |
| San Joaquin | 17,500 | 20.0 (50.8) | 20.0 (50.8) | 20.0 (50.8) | 19.3 (49.0) | 18.7 (47.5) | 18.5 (47.0) | 17.5 (44.5) | 16.9 (42.9) | 16.8 (42.7) |

**Table 30 Average Concrete Slab Thicknesses for Each Variable Factor Level, ACPA/AASHTO Method.**

| Variable | Factor Level | Required Slab Thickness in. (cm) | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| Subgrade k psi/in. (kPa/cm) | 100 (271) | 16.8 (42.7) | 14.0 (35.6) | 20.0 (50.8) |
| | 353 (958) | 16.3 (41.4) | 10.6 (27.0) | 20.0 (50.8) |
| | 457 (1240) | 16.2 (41.1) | 10.5 (26.6) | 20.0 (50.8) |
| Axle Load Spectra | PCA | 16.0 (40.6) | 10.5 (26.6) | 20.0 (50.8) |
| | San Diego | 15.9 (40.4) | 10.5 (26.6) | 20.0 (50.8) |
| | San Joaquin | 17.4 (44.2) | 11.8 (30.0) | 20.0 (50.8) |
| Daily Trucks in Design Lane | 8,750 | 15.7 (39.9) | 10.5 (26.6) | 20.0 (50.8) |
| | 17,500 | 17.2 (43.6) | 11.7 (29.7) | 20.0 (50.8) |
| Concrete Flexural Strength psi (MPa) | 500 (3.45) | 18.0 (45.8) | 13.2 (33.5) | 20.0 (50.8) |
| | 650 (4.48) | 16.4 (41.6) | 11.6 (29.4) | 20.0 (50.8) |
| | 800 (5.52) | 14.9 (37.9) | 10.5 (26.6) | 20.0 (50.8) |
| Design Features J factor | 2.7 | 14.8 (37.6) | 10.5 (26.6) | 20.0 (50.8) |
| | 3.2 | 16.1 (40.8) | 11.5 (29.2) | 20.0 (50.8) |
| | 3.6 | 16.9 (42.9) | 12.2 (31.1) | 20.0 (50.8) |
| | 4.3 | 18.0 (45.8) | 13.5 (34.2) | 20.0 (50.8) |
| Coefficient of Drainage | 0.8 | 17.9 (45.5) | 13.0 (33.1) | 20.0 (50.8) |
| | 1.2 | 15.0 (38.0) | 10.5 (26.6) | 20.0 (50.8) |

The support provided to the slab by the subgrade and base does not have much effect on slab thickness, typically changing slab thickness by less than 1 inch (25 mm). On the other hand, required slab thickness is fairly sensitive to concrete flexural strength, with average slab thickness reduced by about 3 inches by increasing the modulus of rupture from 3.45 to 5.52 MPa (500 to 800 psi).

The daily truck traffic in the design lane has about the same effect on average required slab thickness as do the different axle load spectra. Doubling the daily truck traffic from 8,750 to 17,500 increases average slab thickness by about 1.5 inches (38 mm). The San Joaquin axle load spectrum requires slabs that are about 1.8 inches (46 mm) thicker than those required by the other two spectra.

An assessment of required slab thicknesses assuming the use of dowels and tied shoulders or wide truck lanes is shown in Table 31.

**Table 31 Average Concrete Slab Thicknesses and Failure Modes for Each Variable Factor Level, Assuming Use of Dowels and Tied Concrete Shoulders or Widened Truck Lanes, ACPA/AASHTO Method.**

| Variable | Factor Level | Required Slab Thickness (in.) | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| Subgrade k psi/in. (kPa/cm) | 100 (271) | 15.2 (38.7) | 13.9 (35.2) | 20.0 (50.8) |
| | 353 (958) | 14.6 (37.2) | 10.6 (27.0) | 20.0 (50.8) |
| | 457 (1240) | 14.5 (36.8) | 10.5 (26.6) | 20.0 (50.8) |
| Axle Load Spectra | PCA | 14.2 (36.2) | 11.7 (29.7) | 19.0 (48.3) |
| | San Diego | 14.2 (36.2) | 10.5 (26.6) | 19.0 (48.3) |
| | San Joaquin | 15.9 (40.4) | 11.8 (30.0) | 20.0 (50.8) |
| Daily Trucks in Design Lane | 8,750 | 14.0 (35.6) | 10.5 (26.6) | 19.2 (48.7) |
| | 17,500 | 15.5 (39.5) | 11.7 (29.7) | 20.0 (50.8) |
| Concrete Flexural Strength psi (MPa) | 500 (3.45) | 16.5 (42.0) | 14.0 (35.6) | 20.0 (50.8) |
| | 650 (4.48) | 14.6 (37.1) | 11.6 (29.4) | 18.7 (47.5) |
| | 800 (5.52) | 13.2 (33.6) | 10.5 (26.6) | 17.0 (43.1) |
| Coefficient of Drainage | 0.8 | 16.3 (41.5) | 13.0 (33.1) | 20.0 (50.8) |
| | 1.2 | 13.3 (33.7) | 10.5 (26.6) | 17.3 (44.0) |

With dowels and tied concrete shoulders, required slab thickness are between 13 and 20 inches (330 and 508 mm) for poor drainage conditions, and between 10.5 and 17.3 inches (267 and 439 mm) for good drainage conditions for the variables and factor levels included in this experiment. For the proposed LLPRS-Rigid strategy of retaining the 100 mm CTB and 150 mm aggregate base layers (subgrade/base k value of 353 pci), required slab thicknesses are between 13.2 and 20 inches (335 and 508 mm) for poor drainage conditions, and between 10.6 and 16.7 inches (269 and 424 mm) for good drainage conditions.

## 3.5 Evaluation of Design Lives Using ILLICON

The effects of base type, concrete coefficient of thermal expansion (alpha), inclusion of dowels and dowel size, and an increase of loads in each axle load spectrum of 20 percent, were explored in preliminary experimental factorials. These experiments were used to eliminate several variables from the larger factorial.

### 3.5.1 Base Type

Base type was found not to be an important factor in the ILLICON analyses, as shown in Table 32. Subgrade stiffness is much more important than base structure in ILLICON because base stiffnesses and thicknesses are much smaller than the cube of concrete slab thickness times the concrete elastic modulus.

**Table 32 Effect of Base Type on Required Slab Thickness for South Coast Climate, AC Shoulders, No Dowels, 5.79 m Slabs, San Joaquin Axle Load Spectrum.**

| Axle Load Spectrum | Base Type | Slab Thickness (inches) for Various Combinations of Subgrade Stiffness and Concrete MR. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | k=100 pci | | | k=250 pci | | | k=500 pci | | |
| | | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa) | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa) | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa) |
| Very High PCA | Aggregate Base | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (28.0) | 9 (22.9) | 14 (35.6) | 11 (28.0) | 8.5 (21.6) |
| | CTB + ASB | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (28.0) | 9 (22.9) | 14 (35.6) | 11 (28.0) | 8.5 (21.6) |
| | LCB | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (28.0) | 9 (22.9) | 14 (35.6) | 11 (28.0) | 8.5 (21.6) |
| San Diego LTPP | Aggregate Base | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 10.5 (26.7) | 9 (22.9) | 14 (35.6) | 10.5 (26.7) | 8.5 (21.6) |
| | CTB + ASB | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 10.5 (26.7) | 9 (22.9) | 14 (35.6) | 10.5 (26.7) | 8.5 (21.6) |
| | LCB | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 10.5 (26.7) | 9 (22.9) | 14 (35.6) | 10.5 (26.7) | 8.5 (21.6) |
| San Joaquin LTPP | Aggregate Base | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (28.0) | 9 (22.9) | 14 (35.6) | 11 (28.0) | 8.5 (21.6) |
| | CTB + ASB | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (28.0) | 9 (22.9) | 14 (35.6) | 11 (28.0) | 8.5 (21.6) |
| | LCB | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (28.0) | 9 (22.9) | 14 (35.6) | 11 (28.0) | 8.5 (21.6) |

3.5.2 Concrete Coefficient of Thermal Expansion

The coefficient of thermal expansion (alpha) of the concrete has a significant effect on required slab thickness, as shown in Table 33. Thermal contraction and curling produce large tensile stresses in the slab, particularly in climates where there are large day-to-night temperature changes. The effects shown in Table 33 would be expected to be even larger for the Desert environment in which day to night temperature changes are larger than they are in the South Coast environment.

**Table 33 Effect of Concrete Coefficient of Thermal Expansion (alpha) on Required Slab Thickness for South Coast Climate, AC Shoulders, 5.79 m Slabs, San Joaquin Axle Load Spectrum.**

| Concrete Coefficient of Thermal Expansion in./in./°F | Slab Thickness for Various Combinations of Subgrade Stiffness and Concrete MR [in. (cm)] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | k=100 pci | | | k=250 pci | | | k=500 pci | | |
| | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa) | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa) | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa) |
| alpha=3E-6 | 12 (30.5) | 10 (25.4) | 8.5 (21.6) | 12 (30.5) | 9.5 (24.1) | 8 (20.3) | 12 (30.5) | 9 (22.9) | 7 (17.8) |
| alpha=5.55E-6 | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| alpha=8E-6 | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 15 (38.1) | 12.5 (31.8) |

The average slab thicknesses for concrete coefficient of thermal expansions (in./in./°F) of $3\times10^{-6}$, $5.55\times10^{-6}$, and $8\times10^{-6}$ are 9.8, 12.3, and 14.3 in. (24.9, 31.2, and 36.3 cm), respectively.

The assumed coefficient of thermal expansion for ordinary Portland cement concrete is $5.55 \times 10^{-6}$ in./in./°F. Cement manufacturers who have submitted materials to the University of California, Berkeley for laboratory tests have not supplied coefficient of thermal expansion data. Traditionally, the coefficient of thermal expansion for concrete has been found to be highly dependent on the aggregate type. There is no standard ASTM or AASHTO test for coefficient of thermal expansion. Information published by the US Army Corps of Engineers suggests that some calcium sulfoaluminate cements may have larger coefficients than Portland cement, however the corresponding data for concrete mixes was not included. (*36*)

The negative effects of a large coefficient of thermal expansion are made worse by stiffer subgrades, which do not deform much when the slab curls. The result is that the slab is unsupported by the curling, resulting in larger tensile stresses. Use of base materials that will deform with the concrete slab when it curls, but that are not erodable under the effects of joint movement and the presence of water, appears to be the best option.

### 3.5.3 Dowel Size

Dowel size and its effect on bearing stress at the concrete/dowel interface have significant effects on the development of faulting, as is presented in Section 3.7 of this report. However, the effects of dowels, and dowel size, on transverse fatigue cracking are relatively minor according to the sensitivity study performed using ILLICON, as shown in Table 34. The transverse joints, where dowels provide load transfer, are not the critical load locations for fatigue cracking and are far enough away from the slab edge not to affect the maximum bending stress.

### 3.5.4 Increased Axle Loads

The effect of an increase of all axle loads in the San Joaquin spectrum was evaluated for 4.57- and 5.79-m (15- and 19-ft.) slab lengths. The San Joaquin spectrum included the full set of axle loads shown in Table 21, not the truncated spectrum. All axle loads were increased 20 percent. The number of repetitions was not increased, as shown in Table 35.

**Table 34 Effect of Dowel Size on Required Slab Thickness Based on Fatigue Cracking Criterion, for South Coast Climate, AC Shoulders, 5.79-m Slabs, San Joaquin Axle Load Spectrum.**

| *1.5-inch (38 mm) Dowels* | **Slab Thickness [inches (cm)] for Various Combinations of Subgrade Stiffness and Concrete MR** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **k=100 pci** | | | **k=250 pci** | | | **k=500 pci** | | |
| | **Concrete Modulus of Rupture** | | | | | | | | |
| | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** |
| Very High PCA | 14 (35.6) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12.5 (31.8) | 10.5 (26.7) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| San Diego LTPP | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14.5 (36.8) | 10.5 (26.7) | 9.5 (24.1) | 15.5 (39.4) | 12 (30.5) | 9.5 (24.1) |
| San Joaquin LTPP | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| *1.25-inch (31.8 mm) Dowels* | **Slab Thickness [inches (cm)] for Various Combinations of Subgrade Stiffness and Concrete MR** | | | | | | | | |
| | **k=100 pci** | | | **k=250 pci** | | | **k=500 pci** | | |
| | **Concrete Modulus of Rupture** | | | | | | | | |
| | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** |
| Very High PCA | 14 (35.6) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12.5 (31.8) | 10.5 (26.7) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| San Diego LTPP | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14.5 (36.8) | 10.5 (26.7) | 9.5 (24.1) | 15.5 (39.4) | 12 (30.5) | 9.5 (24.1) |
| San Joaquin LTPP | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| *No Dowels* | **Slab Thickness [inches (cm)] for Various Combinations of Subgrade Stiffness and Concrete MR** | | | | | | | | |
| | **k=100 pci** | | | **k=250 pci** | | | **k=500 pci** | | |
| | **Concrete Modulus of Rupture** | | | | | | | | |
| | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa)** |
| Very High PCA | 14 (35.6) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12.5 (31.8) | 10.5 (26.7) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| San Diego LTPP | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14.5 (36.8) | 10.5 (26.7) | 9.5 (24.1) | 15.5 (39.4) | 12 (30.5) | 9.5 (24.1) |
| San Joaquin LTPP | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |

**Table 35 Current San Joaquin Axle Load Spectrum, and With 20 Percent Increase in Loads.**

| Current Axle Loads | | | | With 20 Percent Increase in Loads | | | |
|---|---|---|---|---|---|---|---|
| Axles per 1000 Trucks | | | | Axles per 1000 Trucks | | | |
| **Single Axle Loads kips (kN)** | **I-5 San Joaquin** | **Tandem Axle Loads kips (kN)** | **I-5 San Joaquin** | **Single Axle Loads kips (kN)** | **I-5 San Joaquin** | **Tandem Axle Loads kips (kN)** | **I-5 San Joaquin** |
| 42 (187) | 0.0002 | 80 (356) | 0.0018 | 50.4 (224) | 0.0002 | 96.0 (427) | 0.0018 |
| 40 (178) | 0.0072 | 76 (338) | 0.0033 | 48.0 (214) | 0.0072 | 91.2 (406) | 0.0033 |
| 38 (169) | 0.0075 | 72 (320) | 0.0068 | 45.6 (203) | 0.0075 | 86.4 (384) | 0.0068 |
| 36 (160) | 0.0036 | 68 (302) | 0.0081 | 43.2 (192) | 0.0036 | 81.6 (363) | 0.0081 |
| 34 (151) | 0.0109 | 64 (285) | 0.0226 | 40.8 (181) | 0.0109 | 76.8 (342) | 0.0226 |
| 32 (142) | 0.0215 | 60 (267) | 0.0467 | 38.4 (171) | 0.0215 | 72.0 (320) | 0.0467 |
| 30 (133) | 0.0383 | 56 (249) | 0.1052 | 36.0 (160) | 0.0383 | 67.2 (299) | 0.1052 |
| 28 (125) | 0.097 | 52 (231) | 0.225 | 33.6 (149) | 0.097 | 62.4 (278) | 0.225 |
| 26 (116) | 0.449 | 48 (214) | 0.056 | 31.2 (139) | 0.449 | 57.6 (256) | 0.056 |
| 24 (106) | 4.028 | 44 (196) | 2.843 | 28.8 (128) | 4.028 | 52.8 (235) | 2.843 |
| 22 (97.9) | 31.6 | 40 (178) | 40.1 | 26.4 (117) | 31.6 | 48 (214) | 40.1 |
| 20 (89.0) | 117.6 | 36 (160) | 213.1 | 24.0 (106) | 117.6 | 43.2 (192) | 213.1 |
| 18 (80.1) | 207.5 | 32 (142) | 196.8 | 21.6 (96.1) | 207.5 | 38.4 (171) | 196.8 |
| 16 (71.2) | 169.2 | 28 (125) | 80.6 | 19.2 (85.4) | 169.2 | 33.6 (149) | 80.6 |
| 14 (62.3) | 152.5 | 24 (107) | 75.9 | 16.8 (74.7) | 152.5 | 28.8 (128) | 75.9 |
| 12 (53.4) | 418.9 | 20 (89.0) | 85.3 | 14.4 (64.1) | 418.9 | 24.0 (106) | 85.3 |
| 10 (44.5) | 436.8 | 16 (71.2) | 133.7 | 12.0 (53.4) | 436.8 | 19.2 (85.4) | 133.7 |
| 8 (35.6) | 227.3 | 12 (53.4) | 171.5 | 9.6 (42.7) | 227.3 | 14.4 (64.1) | 171.5 |
| 6 (26.7) | 228.2 | 8 (35.6) | 60.0 | 7.2 (32.0) | 228.2 | 9.6 (42.7) | 60.0 |
| 4 (17.8) | 133.0 | 4 (17.8) | 18.8 | 4.8 (21.4) | 133.0 | 4.8 (21.4) | 18.8 |
| 2 (8.9) | 66.9 | | | 2.4 (10.7) | 66.9 | | |

It can be seen in Table 36 that the increased load spectrum resulted in increases of required slab thickness of about 0.5 to 1.0 inches (1.3 to 2.5 cm), with an average increase of 0.7 inches (1.8 cm) for the entire table. The number of repetitions and loads of the heaviest axles are critical for transverse fatigue cracking. The effects of the axle load increase are not evaluated with respect to faulting in ILLICON.

**Table 36 Effect on Required Slab Thickness of Increasing All Axle Loads by 20 Percent for 19 and 15 ft. (5.79 and 4.57 m) Slab Lengths, South Coast Climate, No Dowels, ILLICON method, [in. (cm)].**

| | | **k=100pci** | | | **k=250pci** | | | **k=500pci** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Concrete Modulus of Rupture psi (MPa)** | | | | | | | | |
| ***19 ft. (5.79 m) slabs*** | **Load** | **500 (3.45)** | **650 (4.48)** | **800 (5.52)** | **500 (3.45)** | **650 (4.48)** | **800 (5.52)** | **500 (3.45)** | **650 (4.48)** | **800 (5.52)** |
| AC | Original Loads | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| Shoulder | Increased by 20% | 14.5 (36.8) | 12 (30.5) | 10.5 (26.7) | 15.5 (39.4) | 13 (33.0) | 11 (27.9) | 16.5 (41.9) | 13.5 (34.3) | 11 (27.9) |
| Tied Concrete | Original Loads | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| Shoulder Low LTE | Increased by 20% | 14 (35.6) | 12 (30.5) | 10.5 (26.7) | 15.5 (39.4) | 13 (33.0) | 10.5 (26.7) | 16.5 (41.9) | 13.5 (34.3) | 10.5 (26.7) |
| Tied Concrete | Original Loads | 11.5 (29.2) | 9.5 (24.1) | 8 (20.3) | 13.5 (34.3) | 10.5 (26.7) | 8 (20.3) | 14.5 (36.8) | 11 (27.9) | 7.5 (19.1) |
| Shoulder High LTE | Increased by 20% | 12.5 (31.8) | 10 (25.4) | 8.5 (21.6) | 14 (35.6) | 11 (27.9) | 8.5 (21.6) | 15 (38.1) | 11.5 (29.2) | 8 (20.3) |
| 0.3 m Widened | Original Loads | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14 (35.6) | 11.5 (29.2) | 9.5 (24.1) | 15 (38.1) | 11.5 (29.2) | 9 (22.9) |
| Truck Lane | Increased by 20% | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 14.5 (36.8) | 12 (30.5) | 10 (25.4) | 15.5 (39.4) | 12.5 (31.8) | 9.5 (24.1) |
| 0.6 m Widened | Original Loads | 11.5 (29.2) | 9 (22.9) | 7.5 (19.1) | 12.5 (31.8) | 9.5 (24.1) | 7 (17.8) | 14 (35.6) | 9 (22.9) | 5.5 (14.0) |
| Truck Lane | Increased by 20% | 12 (30.5) | 10 (25.4) | 8 (20.3) | 13 (33.0) | 10 (25.4) | 7.5 (19.1) | 14.5 (36.8) | 10 (25.4) | 6.5 (16.5) |
| ***15 ft. (4.57 m) slabs*** | | | | | | | | | | |
| AC | Original Loads | 11.5 (29.2) | 10 (25.4) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| Shoulder | Increased by 20% | 12.5 (31.8) | 11 (27.9) | 9.5 (24.1) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14 (35.6) | 11.5 (29.2) | 9.5 (24.1) |
| Tied Concrete | Original Loads | 11.5 (29.2) | 10 (25.4) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| Shoulder Low LTE | Increased by 20% | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) |
| Tied Concrete | Original Loads | 10 (25.4) | 8.5 (21.6) | 7 (17.8) | 11 (27.9) | 9 (22.9) | 7 (17.8) | 11.5 (29.2) | 9 (22.9) | 7 (17.8) |
| Shoulder High LTE | Increased by 20% | 10.5 (26.7) | 9 (22.9) | 7.5 (19.1) | 11.5 (29.2) | 9.5 (24.1) | 7.5 (19.1) | 12 (30.5) | 9.5 (24.1) | 7.5 (19.1) |
| 0.3 m Widened | Original Loads | 11 (27.9) | 9.5 (24.1) | 8.5 (21.6) | 12 (30.5) | 10 (25.4) | 8.5 (21.6) | 12.5 (31.8) | 10 (25.4) | 8.5 (21.6) |
| Truck Lane | Increased by 20% | 12 (30.5) | 10 (25.4) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| 0.6 m Widened | Original Loads | 9.5 (24.1) | 8 (20.3) | 7 (17.8) | 10 (25.4) | 8 (20.3) | 6.5 (16.5) | 11 (27.9) | 8 (20.3) | 6 (15.2) |
| Truck Lane | Increased by 20% | 10.5 (26.7) | 8.5 (21.6) | 7.5 (19.1) | 10.5 (26.7) | 8.5 (21.6) | 7 (17.8) | 11.5 (29.2) | 8.5 (21.6) | 6.5 (16.5) |

### 3.5.5 Overall Results from ILLICON factorial

The results from determination of required slab thicknesses for the experiment variables are shown in Tables 37-42. The complete results are included on a case by case basis in Appendix D. Base type and transverse joint load transfer type were eliminated from the full factorial based on the preliminary analyses.

Required slab thicknesses range between 5.5 and 17.5 inches for the experimental factorial, depending primarily on slab length, shoulder type, climatic region and concrete flexural strength. Slab length and climatic region were not considered in the PCA and ACPA/AASHTO methods.

For the South Coast climate, it is apparent from the results that tied concrete shoulders with a high degree of load transfer or truck lanes widened to 4.0 m, with concrete flexural strengths of 800 psi (5.52 MPa), are necessary if slab thicknesses of less than 9 inches (229 mm) are to provide fatigue lives of at least 30 years. Alternatively, truck lanes widened to 4.3 m can be used with concrete flexural strengths of 650 psi (4.48 MPa) and still maintain a slab thickness of 9 inches (229 mm).

For the Desert (Daggett) and Valley (Fresno) climates, slab thicknesses of 9.5 to 13 inches (241 to 330 mm) are required. The use of asphalt concrete shoulders and/or concrete flexural strengths of 500 psi (3.45 MPa) require slab thicknesses of about 11.5 to 13 inches (292 to 330 mm) in the South Coast climate, and 12.5 to 17 inches (318 to 432 mm) in the Valley and Desert climates. Average, minimum and maximum slab thicknesses for each variable are summarized in Table 43.

**Table 37 Concrete Slab Thicknesses [in. (cm)] from Illinois DOT Method for 15 ft. (4.57 m) Slabs in Los Angeles Climate.**

| | **k=100pci** | | | **k=250pci** | | | **k=500pci** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Concrete Modulus of Rupture** | | | | | | | | |
| | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** |
| ***Asphalt Concrete Shoulder, No Dowels*** | | | | | | | | | |
| Very High PCA | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11 (27.9) | 9 (22.9) |
| San Diego LTPP | 11.5 (29.2) | 10 (25.4) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 10.5 (26.7) | 8.5 (21.6) |
| San Joaquin LTPP | 11.5 (29.2) | 10 (25.4) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| ***Tied Concrete Shoulder (50% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| San Diego LTPP | 11.5 (29.2) | 10 (25.4) | 8.5 (21.6) | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 10 (25.4) | 8.5 (21.6) |
| San Joaquin LTPP | 11.5 (29.2) | 10 (25.4) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| ***Tied Concrete Shoulder (90% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 10 (25.4) | 8.5 (21.6) | 7.5 (19.1) | 11 (27.9) | 9 (22.9) | 7.5 (19.1) | 11.5 (29.2) | 9 (22.9) | 7 (17.8) |
| San Diego LTPP | 9.5 (24.1) | 8 (20.3) | 7 (17.8) | 10.5 (26.7) | 8.5 (21.6) | 7 (17.8) | 11.5 (29.2) | 8.5 (21.6) | 6.5 (16.5) |
| San Joaquin LTPP | 10 (25.4) | 8.5 (21.6) | 7 (17.8) | 11 (27.9) | 9 (22.9) | 7 (17.8) | 11.5 (29.2) | 9 (22.9) | 7 (17.8) |
| ***0.3m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 11.5 (29.2) | 10 (25.4) | 9 (22.9) | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 8.5 (21.6) |
| San Diego LTPP | 11 (27.9) | 9.5 (24.1) | 8.5 (21.6) | 11.5 (29.2) | 10 (25.4) | 8.5 (21.6) | 12 (30.5) | 10 (25.4) | 8 (20.3) |
| San Joaquin LTPP | 11 (27.9) | 9.5 (24.1) | 8.5 (21.6) | 12 (30.5) | 10 (25.4) | 8.5 (21.6) | 12.5 (31.8) | 10 (25.4) | 8.5 (21.6) |
| ***0.6m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 10 (25.4) | 8.5 (21.6) | 7 (17.8) | 10.5 (26.7) | 8.5 (21.6) | 6.5 (16.5) | 11 (27.9) | 8 (20.3) | 6 (15.2) |
| San Diego LTPP | 9.5 (24.1) | 8 (20.3) | 6.5 (16.5) | 10 (25.4) | 8 (20.3) | 6 (15.2) | 10.5 (26.7) | 7.5 (19.1) | 5.5 (14.0) |
| San Joaquin LTPP | 9.5 (24.1) | 8 (20.3) | 7 (17.8) | 10 (25.4) | 8 (20.3) | 6.5 (16.5) | 11 (27.9) | 8 (20.3) | 6 (15.2) |

**Table 38 Concrete Slab Thicknesses [in. (cm)] from Illinois DOT Method for 19 ft. (5.79 m) Slabs in Los Angeles Climate.**

| | **k=100pci** | | | **k=250pci** | | | **k=500pci** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Concrete Modulus of Rupture** | | | | | | | | |
| | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** |
| ***Asphalt Concrete Shoulder, No Dowels*** | | | | | | | | | |
| Very High PCA | 14 (35.6) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12.5 (31.8) | 10.5 (26.7) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| San Diego LTPP | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14.5 (36.8) | 12 (30.5) | 10 (25.4) | 15.5 (39.4) | 12 (30.5) | 9.5 (24.1) |
| San Joaquin LTPP | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| ***Tied Concrete Shoulder (50% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| San Diego LTPP | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14.5 (36.8) | 11.5 (29.2) | 9.5 (24.1) | 15.5 (39.4) | 12 (30.5) | 9.5 (24.1) |
| San Joaquin LTPP | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15 (38.1) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 12.5 (31.8) | 10 (25.4) |
| ***Tied Concrete Shoulder (90% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 12 (30.5) | 10 (25.4) | 8 (20.3) | 13 (33.0) | 10.5 (26.7) | 8 (20.3) | 14.5 (36.8) | 10.5 (26.7) | 7.5 (19.1) |
| San Diego LTPP | 11.5 (29.2) | 9.5 (24.1) | 7.5 (19.1) | 13 (33.0) | 10 (25.4) | 7.5 (19.1) | 14 (35.6) | 10 (25.4) | 7 (17.8) |
| San Joaquin LTPP | 11.5 (29.2) | 9.5 (24.1) | 8 (20.3) | 13.5 (34.3) | 10.5 (26.7) | 8 (20.3) | 14.5 (36.8) | 11 (27.9) | 7.5 (19.1) |
| ***0.3m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14 (35.6) | 11.5 (29.2) | 9.5 (24.1) | 15 (29.2) | 11.5 (29.2) | 9 (22.9) |
| San Diego LTPP | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13.5 (34.3) | 11 (27.9) | 9 (22.9) | 14.5 (36.8) | 11 (27.9) | 8.5 (21.6) |
| San Joaquin LTPP | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 14 (35.6) | 11.5 (29.2) | 9.5 (24.1) | 15 (29.2) | 11.5 (29.2) | 9 (22.9) |
| ***0.6m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 11.5 (29.2) | 9.5 (24.1) | 7.5 (19.1) | 12.5 (31.8) | 9.5 (24.1) | 7 (17.8) | 13.5 (34.3) | 9 (22.9) | 6 (15.2) |
| San Diego LTPP | 11 (27.9) | 9 (22.9) | 7.5 (19.1) | 12.5 (31.8) | 9 (22.9) | 6.5 (16.5) | 13.5 (34.3) | 8.5 (21.6) | 5.5 (14.0) |
| San Joaquin LTPP | 11.5 (29.2) | 9 (22.9) | 7.5 (19.1) | 12.5 (31.8) | 9.5 (24.1) | 7 (17.8) | 14 (35.6) | 9 (22.9) | 5.5 (14.0) |

**Table 39 Concrete Slab Thicknesses [in. (cm)] from Illinois DOT Method for 15 ft. (4.57 m) Slabs in Fresno Climate.**

| | k=100pci | | | k=250pci | | | k=500pci | | |
|---|---|---|---|---|---|---|---|---|---|
| | Concrete Modulus of Rupture | | | | | | | | |
| | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa |
| ***Asphalt Concrete Shoulder, No Dowels*** | | | | | | | | | |
| Very High PCA | 13 (33.0) | 11 (27.9) | 10 (25.4) | 13.5 (34.3) | 12 (30.5) | 10.5 (26.7) | 14 (35.6) | 12 (30.5) | 10 (25.4) |
| San Diego LTPP | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) |
| San Joaquin LTPP | 12.5 (31.8) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 10.5 (26.7) | 14 (35.6) | 12 (30.5) | 10 (25.4) |
| ***Tied Concrete Shoulder (50% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 12.5 (31.8) | 11 (27.9) | 10 (25.4) | 13.5 (34.3) | 12 (30.5) | 10.5 (26.7) | 14 (35.6) | 11.5 (29.2) | 10 (25.4) |
| San Diego LTPP | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) |
| San Joaquin LTPP | 12.5 (31.8) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 14 (35.6) | 12 (30.5) | 10 (25.4) |
| ***Tied Concrete Shoulder (90% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 11 (27.9) | 9.5 (24.1) | 8.5 (21.6) | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) |
| San Diego LTPP | 11 (27.9) | 9.5 (24.1) | 8 (20.3) | 12 (30.5) | 10 (25.4) | 8.5 (21.6) | 12.5 (31.8) | 10.5 (26.7) | 8.5 (21.6) |
| San Joaquin LTPP | 11 (27.9) | 9.5 (24.1) | 8.5 (21.6) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) |
| ***0.3m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) |
| San Diego LTPP | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) |
| San Joaquin LTPP | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) |
| ***0.6m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 11 (27.9) | 9.5 (24.1) | 8 (20.3) | 12 (30.5) | 10 (25.4) | 8.5 (21.6) | 12 (30.5) | 10 (25.4) | 8 (20.3) |
| San Diego LTPP | 10.5 (26.7) | 9 (22.9) | 8 (20.3) | 11.5 (29.2) | 9.5 (24.1) | 8 (20.3) | 12 (30.5) | 10 (25.4) | 8 (20.3) |
| San Joaquin LTPP | 11 (27.9) | 9 (22.9) | 8 (20.3) | 12 (30.5) | 10 (25.4) | 8.5 (21.6) | 12 (30.5) | 10 (25.4) | 8.5 (21.6) |

**Table 40 Concrete Slab Thicknesses [in. (cm)] from Illinois DOT Method for 19-ft. (5.79-m) Slabs in Fresno Climate.**

| | k=100pci | | | k=250pci | | | k=500pci | | |
|---|---|---|---|---|---|---|---|---|---|
| | Concrete Modulus of Rupture | | | | | | | | |
| | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa |
| ***Asphalt Concrete Shoulder, No Dowels*** | | | | | | | | | |
| Very High PCA | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 14.5 (36.8) | 12.5 (31.8) |
| San Diego LTPP | 15 (38.1) | 12.5 (31.8) | 11 (27.9) | 16.5 (41.9) | 14 (35.6) | 12 (30.5) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) |
| San Joaquin LTPP | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 14.5 (36.8) | 12.5 (31.8) |
| ***Tied Concrete Shoulder (50% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) |
| San Diego LTPP | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16.5 (41.9) | 14 (35.6) | 12 (30.5) | 17 (43.2) | 14.5 (36.8) | 12 (30.5) |
| San Joaquin LTPP | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 14.5 (36.8) | 12.5 (31.8) |
| ***Tied Concrete Shoulder (90% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15.5 (39.4) | 13 (33.0) | 11 (27.9) | 16.5 (41.9) | 13.5 (34.3) | 11 (27.9) |
| San Diego LTPP | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15.5 (39.4) | 13 (33.0) | 11 (27.9) | 16 (40.6) | 13.5 (34.3) | 11 (27.9) |
| San Joaquin LTPP | 14 (35.6) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 13.5 (34.3) | 11.5 (29.2) | 16.5 (41.9) | 14 (35.6) | 11.5 (29.2) |
| ***0.3m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16 (40.6) | 13.5 (34.3) | 11.5 (29.2) | 16.5 (41.9) | 14 (35.6) | 11.5 (29.2) |
| San Diego LTPP | 14 (35.6) | 12 (30.5) | 10.5 (26.7) | 16 (40.6) | 13.5 (34.3) | 11.5 (29.2) | 16.5 (41.9) | 13.5 (34.3) | 11.5 (29.2) |
| San Joaquin LTPP | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16.5 (41.9) | 13.5 (34.3) | 11.5 (29.2) | 17 (43.2) | 14 (35.6) | 12 (30.5) |
| ***0.6m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) | 15.5 (39.4) | 12.5 (31.8) | 10.5 (26.7) | 16 (40.6) | 13 (33.0) | 10.5 (26.7) |
| San Diego LTPP | 13.5 (34.3) | 11 (27.9) | 9.5 (24.1) | 15.5 (39.4) | 12.5 (31.8) | 10 (25.4) | 16 (40.6) | 13 (33.0) | 10.5 (26.7) |
| San Joaquin LTPP | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) | 15.5 (39.4) | 13 (33.0) | 10.5 (26.7) | 16 (40.6) | 13.5 (34.3) | 11 (27.9) |

**Table 41 Concrete Slab Thicknesses [in. (cm)] from Illinois DOT Method for 15 ft. (4.57 m) Slabs in Daggett Climate.**

| | K=100pci | | | k=250pci | | | k=500pci | | |
|---|---|---|---|---|---|---|---|---|---|
| | Concrete Modulus of Rupture | | | | | | | | |
| | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa | 500 psi (3.45 MPa) | 650 psi (4.48 MPa) | 800 psi (5.52 MPa |
| ***Asphalt Concrete Shoulder, No Dowels*** | | | | | | | | | |
| Very High PCA | 13 (33.0) | 11 (27.9) | 10 (25.4) | 14 (35.6) | 12 (30.5) | 10.5 (26.7) | 14 (35.6) | 12 (30.5) | 10.5 (26.7) |
| San Diego LTPP | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) |
| San Joaquin LTPP | 12.5 (31.8) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 10.5 (26.7) | 14 (35.6) | 12 (30.5) | 10.5 (26.7) |
| ***Tied Concrete Shoulder (50% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 12.5 (31.8) | 11 (27.9) | 10 (25.4) | 13.5 (34.3) | 12 (30.5) | 10.5 (26.7) | 14 (35.6) | 12 (30.5) | 10 (25.4) |
| San Diego LTPP | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) |
| San Joaquin LTPP | 12.5 (31.8) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 14 (35.6) | 12 (30.5) | 10 (25.4) |
| ***Tied Concrete Shoulder (90% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 11 (27.9) | 9.5 (24.1) | 8.5 (24.1) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) |
| San Diego LTPP | 11 (27.9) | 9.5 (24.1) | 8 (22.9) | 12 (30.5) | 10 (25.4) | 8.5 (24.1) | 12.5 (31.8) | 10.5 (26.7) | 8.5 (24.1) |
| San Joaquin LTPP | 11 (27.9) | 9.5 (24.1) | 8.5 (24.1) | 12.5 (31.8) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9 (22.9) |
| ***0.3m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 12.5 (31.8) | 10.5 (26.7) | 9.5 (24.1) | 13 (33.0) | 11.5 (29.2) | 10 (25.4) | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) |
| San Diego LTPP | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) |
| San Joaquin LTPP | 12 (30.5) | 10.5 (26.7) | 9 (22.9) | 13 (33.0) | 11 (27.9) | 9.5 (24.1) | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) |
| ***0.6m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 11 (27.9) | 9.5 (24.1) | 8 (22.9) | 12 (30.5) | 10 (25.4) | 8.5 (24.1) | 12 (30.5) | 10 (25.4) | 8 |
| San Diego LTPP | 10.5 (26.7) | 9 (22.9) | 7.5 (19.1) | 11.5 (29.2) | 9.5 (24.1) | 8 | 12 (30.5) | 10 (25.4) | 8 |
| San Joaquin LTPP | 11 (27.9) | 9 (22.9) | 8 (22.9) | 12 (30.5) | 10 (25.4) | 8.5 (24.1) | 12 (30.5) | 10 (25.4) | 8.5 (24.1) |

**Table 42 Concrete Slab Thicknesses [in. (cm)] from Illinois DOT Method for 19 ft. (5.79 m) Slabs in Daggett Climate.**

| | **K=100pci** | | | **k=250pci** | | | **k=500pci** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Concrete Modulus of Rupture** | | | | | | | | |
| | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** | **500 psi (3.45 MPa)** | **650 psi (4.48 MPa)** | **800 psi (5.52 MPa** |
| ***Asphalt Concrete Shoulder, No Dowels*** | | | | | | | | | |
| Very High PCA | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 14.5 (36.8) | 12.5 (31.8) |
| San Diego LTPP | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16.5 (41.9) | 14 (35.6) | 12 (30.5) | 17 (43.2) | 14.5 (36.8) | 12 (30.5) |
| San Joaquin LTPP | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 15 (38.1) | 12.5 (31.8) |
| ***Tied Concrete Shoulder (50% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12 (30.5) | 17.5 (44.5) | 14.5 (36.8) | 12.5 (31.8) |
| San Diego LTPP | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16.5 (41.9) | 14 (35.6) | 12 (30.5) | 17 (43.2) | 14.5 (36.8) | 12 (30.5) |
| San Joaquin LTPP | 15 (38.1) | 13 (33.0) | 11.5 (29.2) | 17 (43.2) | 14.5 (36.8) | 12.5 (31.8) | 17.5 (44.5) | 14.5 (36.8) | 12.5 (31.8) |
| ***Tied Concrete Shoulder (90% LTE), No Dowels*** | | | | | | | | | |
| Very High PCA | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15.5 (39.4) | 13 (33.0) | 11 (27.9) | 16.5 (41.9) | 13.5 (34.3) | 11 (27.9) |
| San Diego LTPP | 13.5 (34.3) | 11.5 (29.2) | 10 (25.4) | 15.5 (39.4) | 13 (33.0) | 11 (27.9) | 16 (40.6) | 13.5 (34.3) | 11 (27.9) |
| San Joaquin LTPP | 14 (35.6) | 12 (30.5) | 10 (25.4) | 16 (40.6) | 13.5 (34.3) | 11 (27.9) | 16.5 (41.9) | 14 (35.6) | 11.5 (29.2) |
| ***0.3m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16 (40.6) | 13.5 (34.3) | 11.5 (29.2) | 16.5 (41.9) | 14 (35.6) | 11.5 (29.2) |
| San Diego LTPP | 14 (35.6) | 12 (30.5) | 10.5 (26.7) | 16 (40.6) | 13.5 (34.3) | 11.5 (29.2) | 16.5 (41.9) | 13.5 (34.3) | 11.5 (29.2) |
| San Joaquin LTPP | 14.5 (36.8) | 12.5 (31.8) | 11 (27.9) | 16.5 (41.9) | 13.5 (34.3) | 11.5 (29.2) | 17 (43.2) | 14 (35.6) | 12 (30.5) |
| ***0.6m Widened Truck Lane, No Dowels*** | | | | | | | | | |
| Very High PCA | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) | 15.5 (39.4) | 12.5 (31.8) | 10.5 (26.7) | 16 (40.6) | 13 (33.0) | 10.5 (26.7) |
| San Diego LTPP | 13.5 (34.3) | 11 (27.9) | 9.5 (24.1) | 15.5 (39.4) | 12.5 (31.8) | 10 (25.4) | 16 (40.6) | 13 (33.0) | 10.5 (26.7) |
| San Joaquin LTPP | 13.5 (34.3) | 11.5 (29.2) | 9.5 (24.1) | 15.5 (39.4) | 13 (33.0) | 10.5 (26.7) | 16 (40.6) | 13.5 (34.3) | 11 (27.9) |

**Table 43 Average Concrete Slab Thicknesses, Each Variable Factor Level, Illinois DOT Method.**

| | | Required slab thickness [in. (cm)] | | |
|---|---|---|---|---|
| | | **Average** | **Minimum** | **Maximum** |
| Climatic region | LA (South Coast) | 10.4 (26.4) | 5.5 (14.0) | 16 (40.6) |
| | Fresno (Valley) | 12.1 (30.8) | 8 (20.3) | 17.5 (44.5) |
| | Daggett (Desert) | 12.1 (30.8) | 7.5 (19.1) | 17.5 (44.5) |
| Slab length | 15 ft. | 10.5 (26.6) | 5.5 (14.0) | 14.0 (35.6) |
| | 19 ft. | 12.6 (32.1) | 5.5 (14.0) | 17.5 (44.5) |
| Shoulder type | Asphalt Concrete | 12.4 (31.5) | 8.5 (21.6) | 17.5 (44.5) |
| | Tied, Concrete (50% LTE) | 12.3 (31.3) | 8.5 (21.6) | 17.5 (44.5) |
| | Tied, Concrete (90% LTE) | 10.9 (27.7) | 6.5 (16.5) | 16.5 (41.9) |
| | Widened Lane 4.0 m | 11.8 (29.9) | 8.0 (20.3) | 17.0 (43.2) |
| | Widened Lane 4.3 m | 10.4 (26.3) | 5.5 (14.0) | 16.0 (40.6) |
| Axle load spectra | PCA | 11.7 (29.7) | 6 (15.2) | 17.5 (44.5) |
| | San Diego | 11.3 (29.8) | 5.5 (14.0) | 17 (43.2) |
| | San Joaquin | 11.6 (29.6) | 5.5 (14.0) | 17.5 (44.5) |
| Concrete MR | 500 psi (3.45 MPa) | 13.6 (34.7) | 9.5 (24.1) | 17.5 (44.5) |
| | 650 psi (4.48 MPa) | 11.4 (28.9) | 7.5 (19.1) | 15 (38.1) |
| | 800 psi (5.52 MPa) | 9.6 (24.4) | 5.5 (14.0) | 12.5 |
| Subgrade support | 100 psi/in. | 10.9 (27.7) | 6.5 (16.5) | 15 (38.1) |
| | 250 psi/in. | 11.8 (29.9) | 6 (15.2) | 17 (43.2) |
| | 500 psi/in. | 12.0 (30.4) | 5.5 (14.0) | 17.5 (44.5) |

LTE = Load Transfer Efficiency across shoulder/slab joint

Traffic loads passing on the edge of the slab are critical for transverse fatigue cracking because they cause very large tensile bending stresses. The tensile stresses are greatly reduced when there is load transfer across the longitudinal joint at the slab edge, or when the loads are moved to a location away from the slab edge. Compared to asphalt concrete shoulders, tied concrete shoulders with high load transfer efficiency (90 percent LTE) reduce required slab thickness by 2 inches (51 mm).

Slab lengths of new concrete slabs on LLPRS projects will need to match those of the existing adjacent lanes in order to prevent volunteer cracking at mismatched transverse joints. Those slab lengths vary between about 12 and 19 ft. (3.66 and 5.79). On average, 19-ft. (5.79 m) slab lengths required about 2 inches (51 mm) greater slab thickness because of the larger bending stresses that occur on longer slabs. This indicates that slab thickness will need to depend on the joint spacing of the adjacent lanes, which depends upon when those lanes where built, even when all other factors are the same.

Increasing concrete flexural strength from 500 psi to 650 psi (3.45 MPa to 4.48MPa) or from 650 psi to 800 psi (4.48 MPa to 5.52 MPa) results in a decrease in the required slab thickness of about 2 in. (51 mm). This indicates that slab thicknesses may not need to be increased for 19-ft. (5.79-m) joints, provided the concrete has sufficiently high flexural strength.

Climate region has a significant effect on required slab thickness because of the tensile stresses caused by temperature curling. The Valley and Desert environments experience large changes in day to night temperature, and on average require slabs that are almost 2 inches (51 mm) thicker than those in more moderate Coastal climates.

An increase in subgrade support from 100 to 500 pci (factor of 5) results in an average decrease in required slab thickness of about 1 inch (25 mm). Subgrade support is not sensitive to load stress analysis but is more sensitive for curling stress analysis.

The effect of axle load spectrum on required slab thickness is relatively minor for the three spectra included in the experiment.

## 3.6 Comparison Across Design Methods

The ACPA/AASHTO requires greater slabs thicknesses compared to the PCA and Illinois DOT methods, regardless of the transverse or longitudinal joint load transfer, as shown in Table 44. The ACPA/AASHTO method probably requires very thick slabs because the empirical relation included in the method must be extrapolated from less than 10,000,000 ESALs to more than 100,000,000 ESALs for LLPRS projects. Both the PCA and Illinois DOT methods indicate that slabs must be thicker than 8 to 10.5 inches unless dowels and tied shoulders or widened truck lanes are used.

**Table 44 Comparison of Slab Thickness Versus Inclusion of Dowels and Tied Concrete Shoulders or Wide Truck Lanes Across All Three Design Methods for LLPRS Base Structure, South Coast Environment, San Joaquin Axle Load Spectrum, 17,500 Trucks Per Day in Design Lane, 650 psi (4.48 MPa) Concrete Flexural Strength.**

| **Method** | | **Slab Thickness** | | |
|---|---|---|---|---|
| | | **No Dowels, AC Shoulder** | **Dowels, Tied Shoulder** | **Dowels, 4.3 m Wide Truck Lane** |
| PCA | | 14 in. (356 mm) | 8 in. (203 mm) | NA |
| ACPA/AASHTO [1] | | 18.7 in. (475 mm) | 14.7 in. (373 mm) | NA |
| Illinois DOT | 19-foot (5.79-m) joint spacing | 12 in. (305 mm) | 10.5 in. (267 mm) | 9.5 in. (241 mm) |
| | 15-foot (4.57-m) joint spacing | 10.5 in. (267 mm) | 9 in. (229 mm) | 8 in. (203 mm) |

[1] ACPA/AASHTO method results used a drainage coefficient of 1.2.

All three methods indicate that flexural strengths of at least 650 psi (4.48 MPa) are necessary to reduce slab thickness, as shown in Table 45. Flexural strength of 800 psi (5.52 MPa) results in greater required slab thicknesses, although all three methods indicate that the thickness reduction is not as great as when strengths are increased from 500 to 650 psi (3.45 to 4.48 MPa). Flexural strengths of 650 to 800 psi (4.48 to 5.52 MPa) are necessary to reduce slab thickness to less than about 10 inches (254 mm).

Comparison of the required slab thickness for the proposed LLPRS strategy, and assuming 650 psi (4.48 MPa) concrete flexural strength and inclusion of dowels and tied shoulders, indicates that there is disagreement between the three methods, as shown in Table 46. For the very large traffic levels anticipated on the LLPRS projects, the more mechanistic based PCA and Illinois DOT methods are more appropriate than the ACPA/AASHTO method. It appears that 8- and 9-inch (203- and 229-mm) slabs may be barely adequate for 30-year design

**Table 45 Comparison of Slab Thickness Versus Concrete Flexural Strength Across All Three Design Methods for LLPRS Base Structure, South Coast Environment, San Joaquin Axle Load Spectrum, 17,500 Trucks Per Day in Design Lane, Dowels and Tied Concrete Shoulders.**

| | | Slab Thickness | | |
|---|---|---|---|---|
| | | **Flexural Strength = 500 psi (3.45 MPa)** | **Flexural Strength = 650 psi (4.48 MPa)** | **Flexural Strength = 800 psi (5.52 MPa)** |
| PCA | | 9.5 in. (241 mm) | 8 in. (203 mm) | 8 in. (203 mm) |
| ACPA/AASHTO [1] | | 16.7 in. (424 mm) | 14.7 in. (373 mm) | 13.3 in. (338 mm) |
| Illinois DOT | 19-foot (5.79-m) joints | 13.5 in. (343 mm) | 10.5 in. (267 mm) | 8 in. (203 mm) |
| Illinois DOT | 15-foot (4.57 m) joints | 11 in. (279 mm) | 9 in. (229 mm) | 7 in. (178 mm) |

[1] ACPA/AASHTO method results used a drainage coefficient of 1.2.

**Table 46 Comparison of Slab Thickness Versus Daily Trucks in the Design Lane Across All Three Design Methods for LLPRS Base Structure, 650 psi (4.48 MPa) Concrete Flexural Strength, South Coast Environment, San Joaquin Axle Load Spectrum, Dowels and Tied Concrete Shoulders.**

| | | Daily Truck Traffic in the Design Lane | |
|---|---|---|---|
| | | **8,750** | **17,500** |
| PCA | | 8 in. (203 mm) | 8 in. (203 mm) |
| ACPA/AASHTO [1] | | 13.2 in. (335 mm) | 14.7 in. (373 mm) |
| Illinois DOT | 19-foot (5.79 m) joints | 10.5 in. (267 mm) | 10.5 in. (267 mm) |
| Illinois DOT | 15-foot (4.57 m) joints | 9 in. (229 mm) | 9 in. (229 mm) |

[1] ACPA/AASHTO method results used a drainage coefficient of 1.2.

lives. If longer joint spacings are used, the Illinois DOT method indicates that thicker slabs are required. The PCA method recommends joint spacings of 15 ft. (4.57 m) or less.

## 3.7 Effect of Dowel Size on Bearing Stress and Faulting

A short study was performed to determine the effectiveness of dowels in the reduction of joint faulting in PCC pavements and to explore the maximum size dowel that can be placed in 200- to 225-mm thick concrete slabs (i.e., typical thickness) of the currently proposed LLPRS strategy. A performance model based on field sections and several mechanistic variables was recently published by the FHWA. (*6*) This model was used to analyze faulting under a number of conditions. Currently, no good mechanistic-empirical faulting model is available. The selected conditions represent those typically found in California and, in particular, at the site of the LLPRS candidate projects. Local environmental and traffic variables were included, as were possible pavement design parameters, such as joint spacing and base type.

### 3.7.1 Determination of Bearing Stress Values

Because faulting in doweled pavements is affected by the bearing stress of the dowel on the concrete, it was first necessary to determine the dowel/concrete bearing stress. If the bearing stress is high, the tight fit between the dowel and the slab deteriorates, and the effectiveness of the dowel in transmitting loads across the transverse joint is diminished.

Bearing stress was calculated using a mechanistic model. Bearing stress depends on several variables as given on pages 12 and 13 of the FHWA report. (*6*) In this analysis, the values of the variables used are shown in Table 47. It should be noted that the elastic moduli used correspond to moduli of rupture of 500, 650, and 800 psi (3.45, 4.48, and 5.52 MPa). Dowel spacing was not considered in this model because pavements were only surveyed after their construction. Furthermore, the mechanistic-based dowel analysis only looks at the load transferred across one dowel and its effects on concrete stresses.

**Table 47 Experiment Design for Analysis of Bearing Stress at Dowel/Concrete Interface.**

| Variable | Values |
|---|---|
| Dowel Diameter | 1, 1.25, 1.5 in.<br>(25, 32, 38 mm) |
| Modulus of Elasticity | 3,375; 4,388; 5,400 million ksi<br>(23,269; 29,909; 37,231 MPa) |
| Slab Thickness | 8, 10, 12 in.<br>(203, 254, 305 mm) |
| Modulus of Subgrade Reaction | 100, 250, 500 pci |
| Thermal Coefficient, alpha | $3\times10^{-6}$, $5.55\times10^{-6}$, $8\times10^{-6}$ |

Examination of the results of this analysis, shown in Table 48, demonstrates that bearing stresses are sensitive to slab thickness, subgrade stiffness, concrete modulus of elasticity, and dowel diameter, while not sensitive to the thermal coefficient. Resulting bearing stresses ranged from 1100 psi (7.58 MPa), for a 12-inch (305-mm) thick slab with a subgrade k value of 100 pci, and 1.5-inch (38-mm) diameter dowels, to 3816 psi (26.3 MPa), for an 8-inch (203-mm) slab with a subgrade value of 500 pci and 1-inch (25-mm) dowels.

Figure 39 shows that larger dowels, and to a lesser extent thicker concrete slabs, reduce bearing stress. The model results shown in Figure 40 indicates that stiffer subgrades increase bearing stresses on the concrete.

Bearing stress values of 1500, 2500 and 3500 psi (10.34, 17.24, and 24.13 MPa) were selected as representative values for poor, moderate, and good conditions, and were used in the analysis of faulting in doweled pavements presented in the following sections.

**Table 48 Results of Bearing Stress Analysis Experiment.**

| **E=4.388×10^6 psi (30,253 MPa)** | | | **Bearing Stress [psi (MPa)]** | | |
|---|---|---|---|---|---|
| **Slab thickness, in. (cm)** | **k (pci)** | **alpha (in./in./°F)** | **1-in. (25-mm) dowel diameter** | **1.25-in. (32-mm) dowel diameter** | **1.5-in. (38-mm) dowel diameter** |
| 8 (20.3) | 100 | 3.00E-06 | 2840 (19.6) | 1920 (13.3) | 1400 (9.6) |
| | | 5.55E-06 | 2850 (19.7) | 1930 (13.3) | 1400 (9.7) |
| | | 8.00E-06 | 2860 (19.7) | 1930 (13.3) | 1400 (9.7) |
| 8 (20.3) | 250 | 3.00E-06 | 3360 (23.2) | 2270 (15.7) | 1650 (11.4) |
| | | 5.55E-06 | 3370 (23.3) | 2280 (15.7) | 166 (11.4) |
| | | 8.00E-06 | 3380 (23.3) | 2290 (15.8) | 1660 (11.4) |
| 8 (20.3) | 500 | 3.00E-06 | 3790 (26.1) | 2560 (17.7) | 1860 (12.8) |
| | | 5.55E-06 | 3800 (26.2) | 2570 (17.7) | 1870 (12.9) |
| | | 8.00E-06 | 3820 (26.3) | 2580 (17.8) | 1870 (12.9) |
| 10 (25.4) | 100 | 3.00E-06 | 2500 (17.2) | 1690 (11.7) | 1230 (8.46) |
| | | 5.55E-06 | 2510 (17.3) | 1690 (11.7) | 1230 (8.48) |
| | | 8.00E-06 | 2510 (17.3) | 1700 (11.7) | 1230 (8.50) |
| 10 (25.4) | 250 | 3.00E-06 | 2980 (20.5) | 2010 (13.9) | 1460 (10.1) |
| | | 5.55E-06 | 2990 (20.6) | 2020 (13.9) | 1470 (10.1) |
| | | 8.00E-06 | 3000 (20.7) | 2020 (14.0) | 1470 (10.1) |
| 10 25.4) | 500 | 3.00E-06 | 3380 (20.3) | 2280 (15.7) | 1660 (11.4) |
| | | 5.55E-06 | 3390 (23.4) | 2290 (15.8) | 1660 (11.5) |
| | | 8.00E-06 | 3400 (23.4) | 2300 (15.8) | 1670 (11.5) |
| 12 (30.5) | 100 | 3.00E-06 | 2240 (15.4) | 1520 (10.4) | 1100 (7.59) |
| | | 5.55E-06 | 2250 (15.5) | 1520 (10.5) | 1100 (7.61) |
| | | 8.00E-06 | 2250 (15.5) | 1520 (10.5) | 1110 (7.62) |
| 12 (30.5) | 250 | 3.00E-06 | 2680 (18.5) | 1820 (12.5) | 1320 (9.09) |
| | | 5.55E-06 | 2690 (18.6) | 1820 (12.6) | 1320 (9.11) |
| | | 8.00E-06 | 2700 (18.6) | 1830 (12.6) | 1330 (9.14) |
| 12 (30.5) | 500 | 3.00E-06 | 3060 (21.1) | 2070 (14.3) | 1500 (10.4) |
| | | 5.55E-06 | 3070 (21.2) | 2070 (14.3 | 1510 (10.4) |
| | | 8.00E-06 | 3080 (21.2) | 2080 (14.3) | 1510 (10.4) |

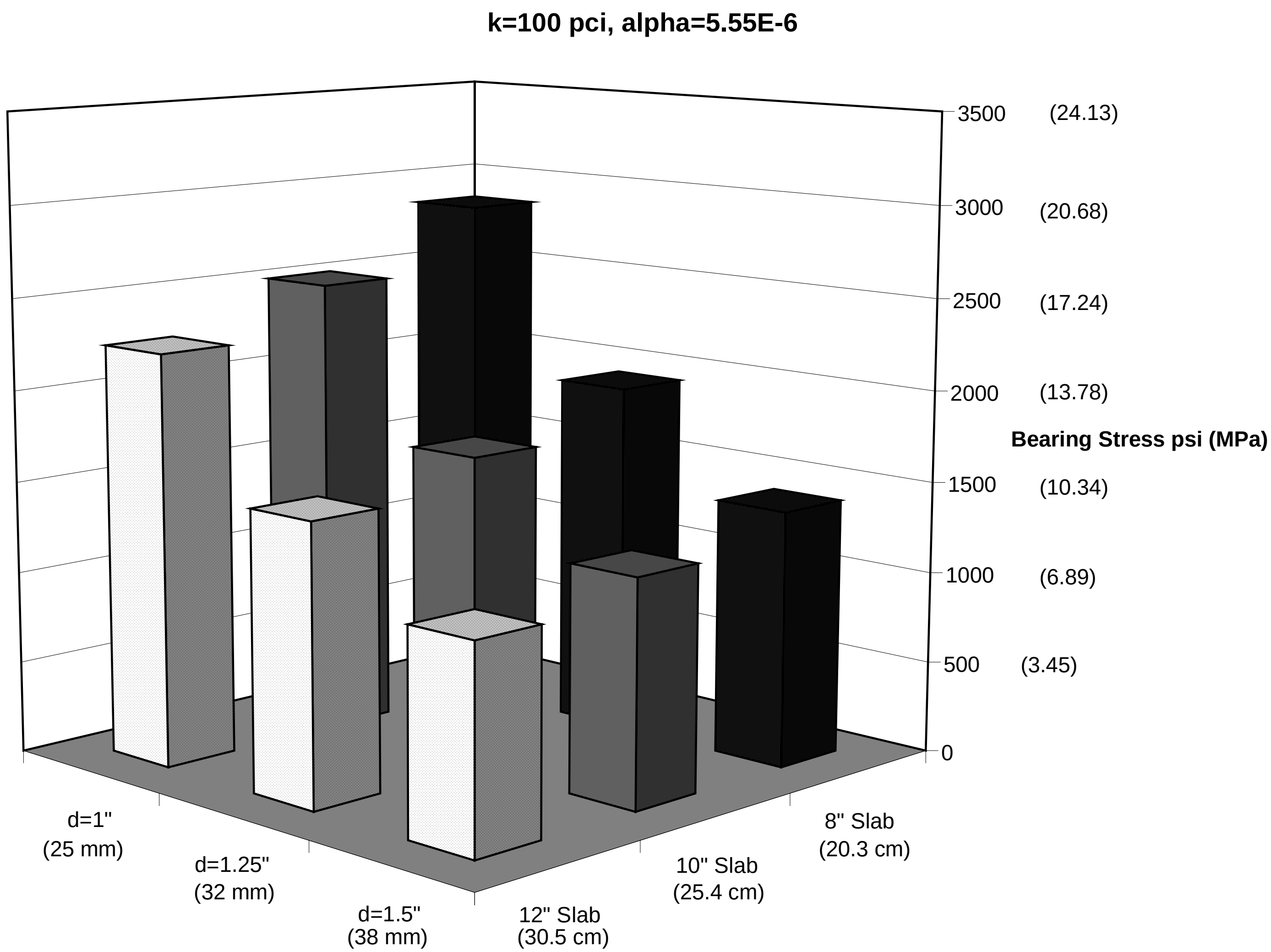



**Figure 39. Dowel/Concrete Bearing Stress Versus Dowel Size and Concrete Slab Thickness.**

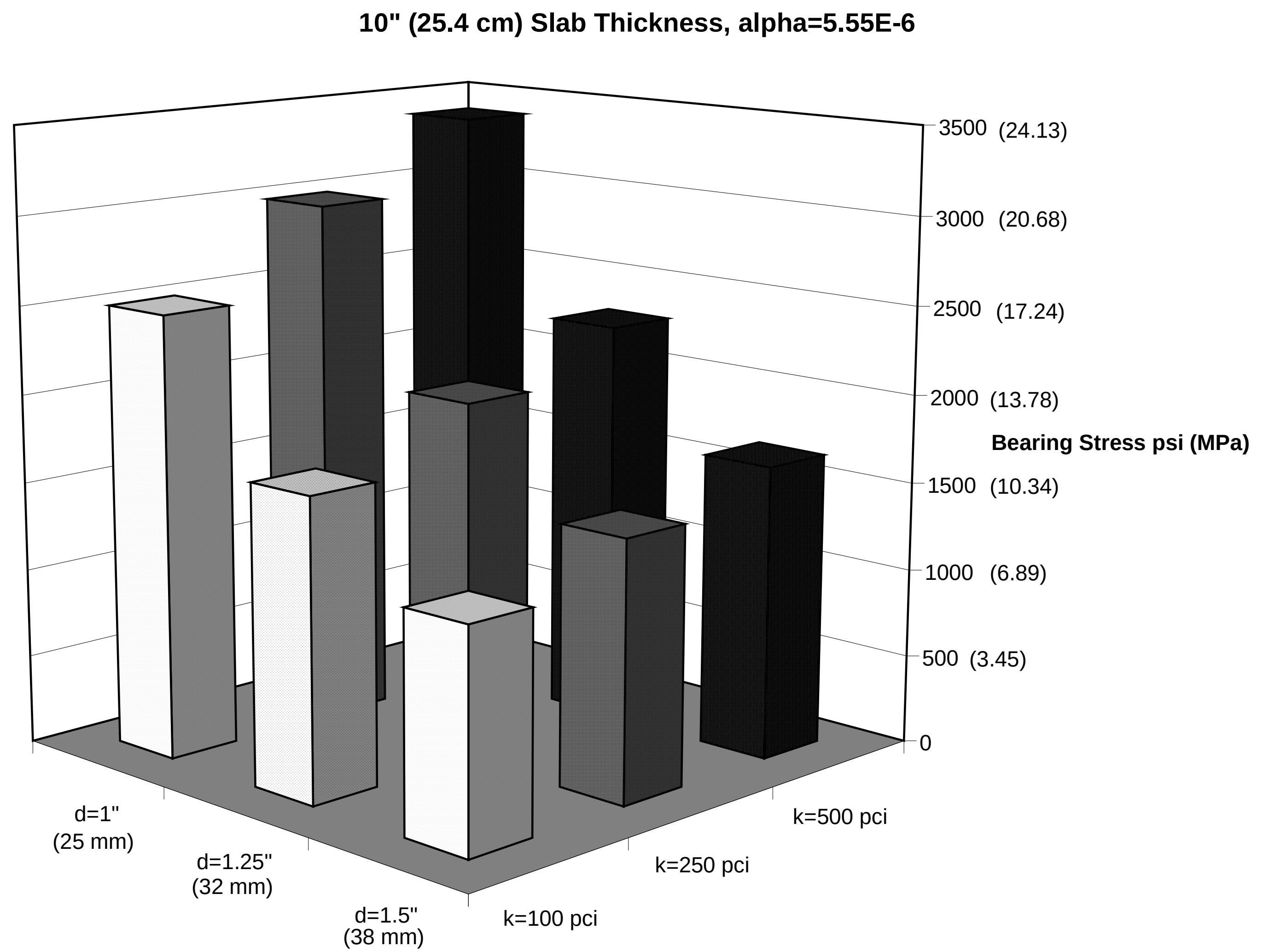



**Figure 40. Dowel/Concrete Bearing Stress Versus Dowel Size and Subgrade Stiffness.**

### 3.7.2 Variables Considered

#### *3.7.2.1 Doweled Pavements*

Having established reasonable values of bearing stress, faulting performance was calculated using the following model (*6*):

$$FaultD = CESAL^{0.25} * [0.0628 - 0.0628 * C_d + 0.3673 * 10^{-8} * Bstress^2 + 0.4116 * 10^{-5} * Jtspace^2 + 0.7466 * 10^{-9} * FI^2 * Precip^{0.5} - 0.009503 * Basetype - 0.01917 * Widenlane + 0.0009217 * Age]$$

where:

| | | |
|---|---|---|
| CESAL | = | Cumulative 18-kip (80-kN) equivalent single axle loads, millions |
| Bstress | = | Maximum dowel/concrete bearing stress, lb./in.$^2$ |
| Jtspace | = | Mean transverse joint spacing, ft. |
| Basetype | = | Base type (0 = nonstabilized base; 1 = stabilized base) |
| Widenlane | = | Widened lane (0 = not widened, 1 = widened) |
| $C_d$ | = | Modified AASHTO drainage coefficient, calculated from database information |
| FI | = | Mean annual freezing index, degree-days |
| Precip | = | Mean annual precipitation |
| Age | = | Pavement age, years |

The model was empirically determined from long term observation of many plain jointed pavements across the country, including a large number in California.

The model incorporates several different variables, the values of which are shown in Table 44. In the model, the quantity of precipitation has no bearing on the degree of faulting when the freezing index was assumed to be zero. Also, the faulting performance depends on both the age of the pavement and on the cumulative amount of traffic in terms of ESALs.

The traffic volumes used were obtained by converting LTPP axle spectra data from the San Diego and San Joaquin stations into ESALs using Caltrans procedures, assuming 17,500 trucks per day in the design lane and assuming no increase in the annual traffic volume. The axle load spectra were not truncated for this study as they were for the comparison of design methods, as discussed in Section 3.2.2. The experiment design for evaluating faulting performance as a function of dowel size is shown in Table 49. It should be noted that this model was developed for pavements with less than 20 million ESALs.

**Table 49 Experiment Design for Evaluation of Faulting Performance versus Dowel Size.**

| **Variable** | **Values** |
|---|---|
| Traffic, cumulative ESALs | 5.0 million (San Diego) and 10.8 million (San Joaquin) ESALs/yr. |
| Bearing Stress | 1500, 2500, 3500 psi (10.34, 17.24, 24.13 MPa) |
| Joint Spacing | 15, 19 feet (4.57, 5.79 m) |
| Base Type | Granular, Stabilized |
| Widened Lanes | Yes, No |
| ACPA/AASHTO Drainage Coefficient, Cd | 0.8, 1.2 |
| Freezing Index | 0 |
| Precipitation | N/A due to value of freezing index |
| Age | 10, 20, 30 years |

### *3.7.2.2 Undoweled Pavements*

Calculation of faulting in undoweled pavements was performed in a similar manner to that of doweled pavements. The following equation for faulting prediction of undoweled pavements is also from Reference (*6*):

$$\text{Corner Deflection} = P * (1.2 - 0.88 * 1.4142 * a/\ell^2) / (\text{Kstatic} * \ell^2)$$

where:

P = Applied wheel load, set to 9000 lbs. (40 kN)
$\ell$ = Radius of relative stiffness
a = Radius of the applied load, set to 5.64 in. (143 mm), assuming a tire pressure of 90 lbs./in$^2$ (621 kPa)
Kstatic = Static backcalculated k-value, lbs./in.$^2$/in.

The undoweled model uses many of the same variables as the doweled model, with the exception of bearing stress and age, although traffic is cumulative over the life of the pavement, as shown in Table 50.

**Table 50 Experiment Design for Evaluation of Faulting Performance for Undoweled Pavements.**

| Variable | Values |
|---|---|
| Traffic, cumulative ESALs | 5.0 million (San Diego) and 10.8 million (San Joaquin) ESALs/yr. |
| Joint Spacing | 15, 19 feet (4.57, 5.79 m) |
| Slab Thickness | 8, 10, 12 in. (203, 254, 305 mm) |
| Base Type | Granular (0), Stabilized (1) |
| Widened Lanes | Yes, No |
| ACPA/AASHTO Drainage Coefficient, Cd | 0.8, 1.2 |
| Freezing Index | 0 |
| Precipitation | N/A due to value of freezing index |
| Number of Days with Temperatures over 90 °F (32°C) | 0, 90, 120 |

The undoweled model also incorporates slab thickness and the average number of days per year on which temperatures exceed 90°F (32°C). The latter variable was determined from hourly temperature data from the National Climatic Data Center. This data was analyzed for four cities in California: San Francisco, Los Angeles, Fresno, and Daggett. These four cities were assumed to be typical of the Bay Area, South Coast, Valley, and Desert climates, respectively.

### 3.7.3 Results

Although the model was used to calculate fault heights for all combinations of the variables shown in Tables 49 and 50, only several were selected for preliminary examination of the results.

Development of faults is shown for the San Diego and San Joaquin traffic distributions and 8-inch (203-mm) slabs in Tables 51 and 52, and for 12-inch (305-mm) slabs in Tables 53 and 54, respectively. The tables show the faulting for doweled pavements with bearing stresses of 1500, 2500 and 3500 psi (10.34, 17.24, and 24.13 MPa), and for undoweled pavements as a function of 10, 20 and 30 years of traffic. Lower bearing stresses are associated with larger dowels, thicker slabs, greater concrete flexural strength, and less stiff subgrades.

Joint spacing was found to have little effect on the degree of faulting, thus a joint spacing of 15 ft. (4.57 m) was assumed for further analyses. The model was found to be sensitive to the number of days of high temperature, but little difference was found between the Valley and Desert climates, or between the Bay Area and South Coast climates. Therefore, Tables 51-54 reflect values for South Coast and Desert climates only.

Base type, lane widening, and drainage coefficients are all very influential in determining faulting performance. The results are less sensitive to slab thickness. It should be noted that the model calculated negative values for joint faulting in some cases; these negative values were assumed to equal zero.

Plots were generated from the 8-inch (20.3-cm) slab results to show general trends in the data. The first, Figure 41, shows that faulting increases with age and with bearing stress. Additionally, faulting is substantially greater in undoweled pavements. Figure 42 shows the degree of faulting in doweled and undoweled pavements for several combinations of base type and lane width. Both lane widening and base stabilization can contribute to the reduction of joint faulting. Figure 43 shows that higher drainage coefficients can reduce joint faulting, but that the effect varies with climatic region. Effective drainage reduces faulting of undoweled pavements much more significantly in hot climates than in mild, and this effect can surpass the benefit of doweling according to this model.

**Table 51 Calculated Faulting Histories for Doweled and Undoweled Pavements, San Diego Axle Load Spectrum, 15-ft. (4.57-m) Joint Spacing, 8-in. (20.3-cm) Slab Thickness.**

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13) MPa) | Undoweled Fault Depth [in. (mm)] |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | NO | 0.8 | 10 | 0.08 (2.09) | 0.12 (3.09) | 0.18 (4.58) | 0.28 (7.12) |
| 0 | 0 | NO | 0.8 | 20 | 0.13 (3.23) | 0.17 (4.41) | 0.24 (6.18) | 0.33 (8.46) |
| 0 | 0 | NO | 0.8 | 30 | 0.17 (4.4) | 0.22 (5.7) | 0.3 (7.66) | 0.37 (9.37) |
| 120 | 0 | NO | 0.8 | 10 | 0.08 (2.09) | 0.12 (3.09) | 0.18 (4.58) | 0.21 (5.29) |
| 120 | 0 | NO | 0.8 | 20 | 0.13 (3.23) | 0.17 (4.41) | 0.24 (6.18) | 0.25 (6.28) |
| 120 | 0 | NO | 0.8 | 30 | 0.17 (4.4) | 0.22 (5.7) | 0.3 (7.66) | 0.27 (6.95) |

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | NO | 0.8 | 10 | 0.06 (1.45) | 0.1 (2.44) | 0.15 (3.93) | 0.25 (6.35) |
| 0 | 1 | NO | 0.8 | 20 | 0.1 (2.47) | 0.14 (3.65) | 0.21 (5.42) | 0.3 (7.54) |
| 0 | 1 | NO | 0.8 | 30 | 0.14 (3.55) | 0.19 (4.86) | 0.27 (6.82) | 0.33 (8.34) |
| 120 | 1 | NO | 0.8 | 10 | 0.06 (1.45) | 0.1 (2.44) | 0.15 (3.93) | 0.18 (4.51) |
| 120 | 1 | NO | 0.8 | 20 | 0.1 (2.47) | 0.14 (3.65) | 0.21 (5.42) | 0.21 (5.36) |
| 120 | 1 | NO | 0.8 | 30 | 0.14 (3.55) | 0.19 (4.86) | 0.27 (6.82) | 0.23 (5.93) |

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | YES | 0.8 | 10 | 0.03 (0.8) | 0.07 (1.79) | 0.13 (3.28) | 0.17 (4.32) |
| 0 | 0 | YES | 0.8 | 20 | 0.07 (1.69) | 0.11 (2.87) | 0.18 (4.64) | 0.2 (5.13) |
| 0 | 0 | YES | 0.8 | 30 | 0.11 (2.69) | 0.16 (4.0) | 0.23 (5.96) | 0.22 (5.68) |
| 120 | 0 | YES | 0.8 | 10 | 0.03 (0.8) | 0.07 (1.79) | 0.13 (3.28) | 0.1 (2.48) |
| 120 | 0 | YES | 0.8 | 20 | 0.07 (1.69) | 0.11 (2.87) | 0.18 (4.64) | 0.12 (2.95) |
| 120 | 0 | YES | 0.8 | 30 | 0.11 (2.69) | 0.16 (4.0) | 0.23 (5.96) | 0.13 (3.26) |

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | YES | 0.8 | 10 | 0.01 (0.16) | 0.05 (1.15) | 0.1 (2.64) | 0.14 (3.54) |
| 0 | 1 | YES | 0.8 | 20 | 0.04 (0.93) | 0.08 (2.11) | 0.15 (3.88) | 0.17 (4.2) |
| 0 | 1 | YES | 0.8 | 30 | 0.07 (1.84) | 0.12 (3.15) | 0.2 (5.11) | 0.18 (4.65) |
| 120 | 1 | YES | 0.8 | 10 | 0.01 (0.16) | 0.05 (1.15) | 0.1 (2.64) | 0.07 (1.71) |
| 120 | 1 | YES | 0.8 | 20 | 0.04 (0.93) | 0.08 (2.11) | 0.15 (3.88) | 0.08 (2.02) |
| 120 | 1 | YES | 0.8 | 30 | 0.07 (1.84) | 0.12 (3.15) | 0.2 (5.11) | 0.09 (2.24) |

*Table 51 continued*

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 0 | NO | 1.2 | 10 | 0.02 (0.4) | 0.05 (1.39) | 0.11 (2.88) | 0.12 (3.03) |
| 0 | 0 | NO | 1.2 | 20 | 0.05 (1.21) | 0.09 (2.39) | 0.16 (4.16) | 0.14 (3.59) |
| 0 | 0 | NO | 1.2 | 30 | 0.09 (2.16) | 0.14 (3.47) | 0.21 (5.43) | 0.16 (3.97) |
| 120 | 0 | NO | 1.2 | 10 | 0.02 (0.4) | 0.05 (1.39) | 0.11 (2.88) | 0.05 (1.19) |
| 120 | 0 | NO | 1.2 | 20 | 0.05 (1.21) | 0.09 (2.39) | 0.16 (4.16) | 0.06 (1.41) |
| 120 | 0 | NO | 1.2 | 30 | 0.09 (2.16) | 0.14 (3.47) | 0.21 (5.43) | 0.06 (1.56) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | NO | 1.2 | 10 | 0 (0) | 0.03 (0.75) | 0.09 (2.24) | 0.09 (2.25) |
| 0 | 1 | NO | 1.2 | 20 | 0.02 (0.45) | 0.06 (1.63) | 0.13 (3.4) | 0.1 (2.67) |
| 0 | 1 | NO | 1.2 | 30 | 0.05 (1.31) | 0.1 (2.62) | 0.18 (4.58) | 0.12 (2.95) |
| 120 | 1 | NO | 1.2 | 10 | 0 (0) | 0.03 (0.75) | 0.09 (2.24) | 0.02 (0.41) |
| 120 | 1 | NO | 1.2 | 20 | 0.02 (0.45) | 0.06 (1.63) | 0.13 (3.4) | 0.02 (0.48) |
| 120 | 1 | NO | 1.2 | 30 | 0.05 (1.31) | 0.1 (2.62) | 0.18 (4.58) | 0.02 (0.53) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.09) | 0.06 (1.58) | 0.01 (0.22) |
| 0 | 0 | YES | 1.2 | 20 | 0 (0) | 0.03 (0.85) | 0.1 (2.62) | 0.01 (0.25) |
| 0 | 0 | YES | 1.2 | 30 | 0.02 (0.45) | 0.07 (1.76) | 0.15 (3.72) | 0.01 (0.28) |
| 120 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.09) | 0.06 (1.58) | 0 (0) |
| 120 | 0 | YES | 1.2 | 20 | 0 (0) | 0.03 (0.85) | 0.1 (2.62) | 0 (0) |
| 120 | 0 | YES | 1.2 | 30 | 0.02 (0.45) | 0.07 (1.76) | 0.15 (3.72) | 0 (0) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04(0.94) | 0 (0) |
| 0 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.09) | 0.07 (1.86) | 0 (0) |
| 0 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (0.92) | 0.11 (2.88) | 0 (0) |
| 120 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (0.94) | 0 (0) |
| 120 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.09) | 0.07 (1.86) | 0 (0) |
| 120 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (0.92) | 0.11 (2.88) | 0 (0) |

**Table 52 Calculated Faulting Histories for Doweled and Undoweled Pavements, San Joaquin Axle Load Spectrum, 15-ft. (4.57-m) Joint Spacing, 8-in. (20.3-cm) Slab Thickness.**

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth [in. (mm)] |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13) MPa) | |
| 0 | 0 | NO | 0.8 | 10 | 0.1 (2.53) | 0.15 (3.74) | 0.22 (5.54) | 0.34 (8.61) |
| 0 | 0 | NO | 0.8 | 20 | 0.15 (3.91) | 0.21 (5.34) | 0.29 (7.48) | 0.4 (10.24) |
| 0 | 0 | NO | 0.8 | 30 | 0.21 (5.32) | 0.27 (6.9) | 0.37 (9.27) | 0.45 (11.34) |
| 120 | 0 | NO | 0.8 | 10 | 0.1 (2.53) | 0.15 (3.74) | 0.22 (5.54) | 0.25 (6.39) |
| 120 | 0 | NO | 0.8 | 20 | 0.15 (3.91) | 0.21 (5.34) | 0.29 (7.48) | 0.3 (7.6) |
| 120 | 0 | NO | 0.8 | 30 | 0.21 (5.32) | 0.27 (6.9) | 0.37 (9.27) | 0.33 (8.41) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | NO | 0.8 | 10 | 0.07 (1.76) | 0.12 (2.96) | 0.19 (4.76) | 0.3 (7.67) |
| 0 | 1 | NO | 0.8 | 20 | 0.12 (2.99) | 0.17 (4.41) | 0.26 (6.56) | 0.36 (9.13) |
| 0 | 1 | NO | 0.8 | 30 | 0.17 (4.3) | 0.23 (5.88) | 0.32 (8.25) | 0.4 (10.1) |
| 120 | 1 | NO | 0.8 | 10 | 0.07 (1.76) | 0.12 (2.96) | 0.19 (4.76) | 0.21 (5.45) |
| 120 | 1 | NO | 0.8 | 20 | 0.12 (2.99) | 0.17 (4.41) | 0.26 (6.56) | 0.26 (6.48) |
| 120 | 1 | NO | 0.8 | 30 | 0.17 (4.3) | 0.23 (5.88) | 0.32 (8.25) | 0.28 (7.18) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 0 | YES | 0.8 | 10 | 0.04 (0.97) | 0.09 (2.17) | 0.16 (3.97) | 0.21 (5.22) |
| 0 | 0 | YES | 0.8 | 20 | 0.08 (2.04) | 0.14 (3.47) | 0.22 (5.62) | 0.24 (6.21) |
| 0 | 0 | YES | 0.8 | 30 | 0.13 (3.26) | 0.19 (4.84) | 0.28 (7.21) | 0.27 (6.87) |
| 120 | 0 | YES | 0.8 | 10 | 0.04 (0.97) | 0.09 (2.17) | 0.16 (3.97) | 0.12 (3) |
| 120 | 0 | YES | 0.8 | 20 | 0.08 (2.04) | 0.14 (3.47) | 0.22 (5.62) | 0.14 (3.57) |
| 120 | 0 | YES | 0.8 | 30 | 0.13 (3.26) | 0.19 (4.84) | 0.28 (7.21) | 0.16 (3.95) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | YES | 0.8 | 10 | 0.01 (0.19) | 0.05 (1.39) | 0.13 (3.19) | 0.17 (4.28) |
| 0 | 1 | YES | 0.8 | 20 | 0.04 (1.12) | 0.1 (2.55) | 0.18 (4.69) | 0.2 (5.09) |
| 0 | 1 | YES | 0.8 | 30 | 0.09 (2.23) | 0.15 (3.81) | 0.24 (6.19) | 0.22 (5.63) |
| 120 | 1 | YES | 0.8 | 10 | 0.01 (0.19) | 0.05 (1.39) | 0.13 (3.19) | 0.08 (2.06) |
| 120 | 1 | YES | 0.8 | 20 | 0.04 (1.12) | 0.1 (2.55) | 0.18 (4.69) | 0.1 (2.45) |
| 120 | 1 | YES | 0.8 | 30 | 0.09 (2.23) | 0.15 (3.81) | 0.24 (6.19) | 0.11 (2.71) |

*Table 52 continued*

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 0 | NO | 1.2 | 10 | 0.02 (0.48) | 0.07 (1.68) | 0.14 (3.48) | 0.14 (3.65) |
| 0 | 0 | NO | 1.2 | 20 | 0.06 (1.47) | 0.11 (2.9) | 0.2 (5.04) | 0.17 (4.34) |
| 0 | 0 | NO | 1.2 | 30 | 0.1 (2.61) | 0.17 (4.2) | 0.26 (6.57) | 0.19 (4.81) |
| 120 | 0 | NO | 1.2 | 10 | 0.02 (0.48) | 0.07 (1.68) | 0.14 (3.48) | 0.06 (1.43) |
| 120 | 0 | NO | 1.2 | 20 | 0.06 (1.47) | 0.11 (2.9) | 0.2 (5.04) | 0.07 (1.7) |
| 120 | 0 | NO | 1.2 | 30 | 0.1 (2.61) | 0.17 (4.2) | 0.26 (6.57) | 0.07 (1.88) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | NO | 1.2 | 10 | 0 (0) | 0.04 (0.9) | 0.11 (2.71) | 0.11 (2.71) |
| 0 | 1 | NO | 1.2 | 20 | 0.02 (0.54) | 0.08 (1.97) | 0.16 (4.11) | 0.13 (3.23) |
| 0 | 1 | NO | 1.2 | 30 | 0.06 (1.59) | 0.12 (3.17) | 0.22 (5.55) | 0.14 (3.57) |
| 120 | 1 | NO | 1.2 | 10 | 0 (0) | 0.04 (0.9) | 0.11 (2.71) | 0.02 (0.49) |
| 120 | 1 | NO | 1.2 | 20 | 0.02 (0.54) | 0.08 (1.97) | 0.16 (4.11) | 0.02 (0.58) |
| 120 | 1 | NO | 1.2 | 30 | 0.06 (1.59) | 0.12 (3.17) | 0.22 (5.55) | 0.03 (0.65) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.11) | 0.08 (1.92) | 0.01 (0.26) |
| 0 | 0 | YES | 1.2 | 20 | 0 (0) | 0.04 (1.03) | 0.12 (3.17) | 0.01 (0.31) |
| 0 | 0 | YES | 1.2 | 30 | 0.02 (0.55) | 0.08 (2.13) | 0.18 (4.51) | 0.01 (0.34) |
| 120 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.11) | 0.08 (1.92) | 0 (0) |
| 120 | 0 | YES | 1.2 | 20 | 0 (0) | 0.04 (1.03) | 0.12 (3.17) | 0 (0) |
| 120 | 0 | YES | 1.2 | 30 | 0.02 (0.55) | 0.08 (2.13) | 0.18 (4.51) | 0 (0) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (1.14) | 0 (0) |
| 0 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.11) | 0.09 (2.25) | 0 (0) |
| 0 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (1.11) | 0.14 (3.48) | 0 (0) |
| 120 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (1.14) | 0 (0) |
| 120 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.11) | 0.09 (2.25) | 0 (0) |
| 120 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (1.11) | 0.14 (3.48) | 0 (0) |

**Table 53 Calculated Faulting Histories for Doweled and Undoweled Pavements, San Diego Axle Load Spectrum, 15-ft. (4.57-m) Joint Spacing, 12-in. (30.5-cm) Slab Thickness.**

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth [in. (mm)] |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13) MPa) | |
| 0 | 0 | NO | 0.8 | 10 | 0.08 (2.09) | 0.12 (3.09) | 0.18 (4.58) | 0.25 (6.44) |
| 0 | 0 | NO | 0.8 | 20 | 0.13 (3.23) | 0.17 (4.41) | 0.24 (6.18) | 0.3 (7.65) |
| 0 | 0 | NO | 0.8 | 30 | 0.17 (4.4) | 0.22 (5.7) | 0.3 (7.66) | 0.33 (8.46) |
| 120 | 0 | NO | 0.8 | 10 | 0.08 (2.09) | 0.12 (3.09) | 0.18 (4.58) | 0.18 (4.6) |
| 120 | 0 | NO | 0.8 | 20 | 0.13 (3.23) | 0.17 (4.41) | 0.24 (6.18) | 0.22 (5.47) |
| 120 | 0 | NO | 0.8 | 30 | 0.17 (4.4) | 0.22 (5.7) | 0.3 (7.66) | 0.24 (6.05) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | NO | 0.8 | 10 | 0.06 (1.45) | 0.1 (2.44) | 0.15 (3.93) | 0.22 (5.66) |
| 0 | 1 | NO | 0.8 | 20 | 0.1 (2.47) | 0.14 (3.65) | 0.21 (5.42) | 0.26 (6.72) |
| 0 | 1 | NO | 0.8 | 30 | 0.14 (3.55) | 0.19 (4.86) | 0.27 (6.82) | 0.29 (7.44) |
| 120 | 1 | NO | 0.8 | 10 | 0.06 (1.45) | 0.1 (2.44) | 0.15 (3.93) | 0.15 (3.82) |
| 120 | 1 | NO | 0.8 | 20 | 0.1 (2.47) | 0.14 (3.65) | 0.21 (5.42) | 0.18 (4.54) |
| 120 | 1 | NO | 0.8 | 30 | 0.14 (3.55) | 0.19 (4.86) | 0.27 (6.82) | 0.2 (5.03) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 0 | YES | 0.8 | 10 | 0.03 (0.8) | 0.07 (1.79) | 0.13 (3.28) | 0.14 (3.63) |
| 0 | 0 | YES | 0.8 | 20 | 0.07 (1.69) | 0.11 (2.87) | 0.18 (4.64) | 0.17 (4.31) |
| 0 | 0 | YES | 0.8 | 30 | 0.11 (2.69) | 0.16 (4) | 0.23 (5.96) | 0.19 (4.77) |
| 120 | 0 | YES | 0.8 | 10 | 0.03 (0.8) | 0.07 (1.79) | 0.13 (3.28) | 0.07 (1.8) |
| 120 | 0 | YES | 0.8 | 20 | 0.07 (1.69) | 0.11 (2.87) | 0.18 (4.64) | 0.08 (2.13) |
| 120 | 0 | YES | 0.8 | 30 | 0.11 (2.69) | 0.16 (4) | 0.23 (5.96) | 0.09 (2.36) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | YES | 0.8 | 10 | 0.01 (0.16) | 0.05 (1.15) | 0.1 (2.64) | 0.11 (2.85) |
| 0 | 1 | YES | 0.8 | 20 | 0.04 (0.93) | 0.08 (2.11) | 0.15 (3.88) | 0.13 (3.39) |
| 0 | 1 | YES | 0.8 | 30 | 0.07 (1.84) | 0.12 (3.15) | 0.2 (5.11) | 0.15 (3.75) |
| 120 | 1 | YES | 0.8 | 10 | 0.01 (0.16) | 0.05 (1.15) | 0.1 (2.64) | 0.04 (1.02) |
| 120 | 1 | YES | 0.8 | 20 | 0.04 (0.93) | 0.08 (2.11) | 0.15 (3.88) | 0.05 (1.2) |
| 120 | 1 | YES | 0.8 | 30 | 0.07 (1.84) | 0.12 (3.15) | 0.2 (5.11) | 0.05 (1.33) |

*Table 53 continued*

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 0 | NO | 1.2 | 10 | 0.02 (0.4) | 0.05 (1.39) | 0.11 (2.88) | 0.09 (2.34) |
| 0 | 0 | NO | 1.2 | 20 | 0.05 (1.21) | 0.09 (2.39) | 0.16 (4.16) | 0.11 (2.77) |
| 0 | 0 | NO | 1.2 | 30 | 0.09 (2.16) | 0.14 (3.47) | 0.21 (5.43) | 0.12 (3.07) |
| 120 | 0 | NO | 1.2 | 10 | 0.02 (0.4) | 0.05 (1.39) | 0.11 (2.88) | 0.02 (0.5) |
| 120 | 0 | NO | 1.2 | 20 | 0.05 (1.21) | 0.09 (2.39) | 0.16 (4.16) | 0.02 (0.59) |
| 120 | 0 | NO | 1.2 | 30 | 0.09 (2.16) | 0.14 (3.47) | 0.21 (5.43) | 0.03 (0.65) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane?** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | NO | 1.2 | 10 | 0 (0) | 0.03 (0.75) | 0.09 (2.24) | 0.06 (1.56) |
| 0 | 1 | NO | 1.2 | 20 | 0.02 (0.45) | 0.06 (1.63) | 0.13 (3.4) | 0.07 (1.85) |
| 0 | 1 | NO | 1.2 | 30 | 0.05 (1.31) | 0.1 (2.62) | 0.18 (4.58) | 0.08 (2.05) |
| 120 | 1 | NO | 1.2 | 10 | 0 (0) | 0.03 (0.75) | 0.09 (2.24) | 0 (0) |
| 120 | 1 | NO | 1.2 | 20 | 0.02 (0.45) | 0.06 (1.63) | 0.13 (3.4) | 0 (0) |
| 120 | 1 | NO | 1.2 | 30 | 0.05 (1.31) | 0.1 (2.62) | 0.18 (4.58) | 0 (0) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane?** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.09) | 0.06 (1.58) | 0 (0) |
| 0 | 0 | YES | 1.2 | 20 | 0 (0) | 0.03 (0.85) | 0.1 (2.62) | 0 (0) |
| 0 | 0 | YES | 1.2 | 30 | 0.02 (0.45) | 0.07 (1.76) | 0.15 (3.72) | 0 (0) |
| 120 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.09) | 0.06 (1.58) | 0 (0) |
| 120 | 0 | YES | 1.2 | 20 | 0 (0) | 0.03 (0.85) | 0.1 (2.62) | 0 (0) |
| 120 | 0 | YES | 1.2 | 30 | 0.02 (0.45) | 0.07 (1.76) | 0.15 (3.72) | 0 (0) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (0.94) | 0 (0) |
| 0 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.09) | 0.07 (1.86) | 0 (0) |
| 0 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (0.92) | 0.11 (2.88) | 0 (0) |
| 120 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (0.94) | 0 (0) |
| 120 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.09) | 0.07 (1.86) | 0 (0) |
| 120 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (0.92) | 0.11 (2.88) | 0 (0) |

**Table 54 Calculated Faulting Histories for Doweled and Undoweled Pavements, San Joaquin Axle Load Spectrum, 15-ft. (4.57-m) Joint Spacing, 12-in. (30.5-cm) Slab Thickness.**

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth [in. (mm)] |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13) MPa) | |
| 0 | 0 | NO | 0.8 | 10 | 0.1 (2.53) | 0.15 (3.74) | 0.22 (5.54) | 0.31 (7.78) |
| 0 | 0 | NO | 0.8 | 20 | 0.15 (3.91) | 0.21 (5.34) | 0.29 (7.48) | 0.36 (9.26) |
| 0 | 0 | NO | 0.8 | 30 | 0.21 (5.32) | 0.27 (6.9) | 0.37 (9.27) | 0.4 (10.24) |
| 120 | 0 | NO | 0.8 | 10 | 0.1 (2.53) | 0.15 (3.74) | 0.22 (5.54) | 0.22 (5.56) |
| 120 | 0 | NO | 0.8 | 20 | 0.15 (3.91) | 0.21 (5.34) | 0.29 (7.48) | 0.26 (6.61) |
| 120 | 0 | NO | 0.8 | 30 | 0.21 (5.32) | 0.27 (6.9) | 0.37 (9.27) | 0.29 (7.32) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | NO | 0.8 | 10 | 0.07 (1.76) | 0.12 (2.96) | 0.19 (4.76) | 0.27 (6.84) |
| 0 | 1 | NO | 0.8 | 20 | 0.12 (2.99) | 0.17 (4.41) | 0.26 (6.56) | 0.32 (8.14) |
| 0 | 1 | NO | 0.8 | 30 | 0.17 (4.3) | 0.23 (5.88) | 0.32 (8.25) | 0.35 (9) |
| 120 | 1 | NO | 0.8 | 10 | 0.07 (1.76) | 0.12 (2.96) | 0.19 (4.76) | 0.18 (4.62) |
| 120 | 1 | NO | 0.8 | 20 | 0.12 (2.99) | 0.17 (4.41) | 0.26 (6.56) | 0.22 (5.5) |
| 120 | 1 | NO | 0.8 | 30 | 0.17 (4.3) | 0.23 (5.88) | 0.32 (8.25) | 0.24 (6.08) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 0 | YES | 0.8 | 10 | 0.04 (0.97) | 0.09 (2.17) | 0.16 (3.97) | 0.17 (4.39) |
| 0 | 0 | YES | 0.8 | 20 | 0.08 (2.04) | 0.14 (3.47) | 0.22 (5.62) | 0.21 (5.22) |
| 0 | 0 | YES | 0.8 | 30 | 0.13 (3.26) | 0.19 (4.84) | 0.28 (7.21) | 0.23 (5.77) |
| 120 | 0 | YES | 0.8 | 10 | 0.04 (0.97) | 0.09 (2.17) | 0.16 (3.97) | 0.09 (2.17) |
| 120 | 0 | YES | 0.8 | 20 | 0.08 (2.04) | 0.14 (3.47) | 0.22 (5.62) | 0.1 (2.58) |
| 120 | 0 | YES | 0.8 | 30 | 0.13 (3.26) | 0.19 (4.84) | 0.28 (7.21) | 0.11 (2.85) |
| **Number of days per year with temperatures >90 °F (32 °C)** | **Base Type** | **Widened Lane** | **Cd** | **Age (years)** | **Fault Depth with Dowels [in. (mm)]** | | | **Undoweled Fault Depth in. (mm)** |
| | | | | | **1500 psi (10.34 MPa)** | **2500 psi (17.24 MPa)** | **3500 psi (24.13 MPa)** | |
| 0 | 1 | YES | 0.8 | 10 | 0.01 (0.19) | 0.05 (1.39) | 0.13 (3.19) | 0.14 (3.45) |
| 0 | 1 | YES | 0.8 | 20 | 0.04 (1.12) | 0.1 (2.55) | 0.18 (4.69) | 0.16 (4.1) |
| 0 | 1 | YES | 0.8 | 30 | 0.09 (2.23) | 0.15 (3.81) | 0.24 (6.19) | 0.18 (4.54) |
| 120 | 1 | YES | 0.8 | 10 | 0.01 (0.19) | 0.05 (1.39) | 0.13 (3.19) | 0.05 (1.23) |
| 120 | 1 | YES | 0.8 | 20 | 0.04 (1.12) | 0.1 (2.55) | 0.18 (4.69) | 0.06 (1.46) |
| 120 | 1 | YES | 0.8 | 30 | 0.09 (2.23) | 0.15 (3.81) | 0.24 (6.19) | 0.06 (1.61) |

*Table 54 Continued*

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 0 | NO | 1.2 | 10 | 0.02 (0.48) | 0.07 (1.68) | 0.14 (3.48) | 0.11 (2.82) |
| 0 | 0 | NO | 1.2 | 20 | 0.06 (1.47) | 0.11 (2.9) | 0.2 (5.04) | 0.13 (3.36) |
| 0 | 0 | NO | 1.2 | 30 | 0.1 (2.61) | 0.17 (4.2) | 0.26 (6.57) | 0.15 (3.71) |
| 120 | 0 | NO | 1.2 | 10 | 0.02 (0.48) | 0.07 (1.68) | 0.14 (3.48) | 0.02 (0.6) |
| 120 | 0 | NO | 1.2 | 20 | 0.06 (1.47) | 0.11 (2.9) | 0.2 (5.04) | 0.03 (0.71) |
| 120 | 0 | NO | 1.2 | 30 | 0.1 (2.61) | 0.17 (4.2) | 0.26 (6.57) | 0.03 (0.79) |

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 1 | NO | 1.2 | 10 | 0 (0) | 0.04 (0.9) | 0.11 (2.71) | 0.07 (1.88) |
| 0 | 1 | NO | 1.2 | 20 | 0.02 (0.54) | 0.08 (1.97) | 0.16 (4.11) | 0.09 (2.24) |
| 0 | 1 | NO | 1.2 | 30 | 0.06 (1.59) | 0.12 (3.17) | 0.22 (5.55) | 0.1 (2.48) |
| 120 | 1 | NO | 1.2 | 10 | 0 (0) | 0.04 (0.9) | 0.11 (2.71) | 0 (0) |
| 120 | 1 | NO | 1.2 | 20 | 0.02 (0.54) | 0.08 (1.97) | 0.16 (4.11) | 0 (0) |
| 120 | 1 | NO | 1.2 | 30 | 0.06 (1.59) | 0.12 (3.17) | 0.22 (5.55) | 0 (0) |

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.11) | 0.08 (1.92) | 0 (0) |
| 0 | 0 | YES | 1.2 | 20 | 0 (0) | 0.04 (1.03) | 0.12 (3.17) | 0 (0) |
| 0 | 0 | YES | 1.2 | 30 | 0.02 (0.55) | 0.08 (2.13) | 0.18 (4.51) | 0 (0) |
| 120 | 0 | YES | 1.2 | 10 | 0 (0) | 0 (0.11) | 0.08 (1.92) | 0 (0) |
| 120 | 0 | YES | 1.2 | 20 | 0 (0) | 0.04 (1.03) | 0.12 (3.17) | 0 (0) |
| 120 | 0 | YES | 1.2 | 30 | 0.02 (0.55) | 0.08 (2.13) | 0.18 (4.51) | 0 (0) |

| Number of days per year with temperatures >90 °F (32 °C) | Base Type | Widened Lane | Cd | Age (years) | Fault Depth with Dowels [in. (mm)] | | | Undoweled Fault Depth in. (mm) |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1500 psi (10.34 MPa) | 2500 psi (17.24 MPa) | 3500 psi (24.13 MPa) | |
| 0 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (1.14) | 0 (0) |
| 0 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.11) | 0.09 (2.25) | 0 (0) |
| 0 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (1.11) | 0.14 (3.48) | 0 (0) |
| 120 | 1 | YES | 1.2 | 10 | 0 (0) | 0 (0) | 0.04 (1.14) | 0 (0) |
| 120 | 1 | YES | 1.2 | 20 | 0 (0) | 0 (0.11) | 0.09 (2.25) | 0 (0) |
| 120 | 1 | YES | 1.2 | 30 | 0 (0) | 0.04 (1.11) | 0.14 (3.48) | 0 (0) |

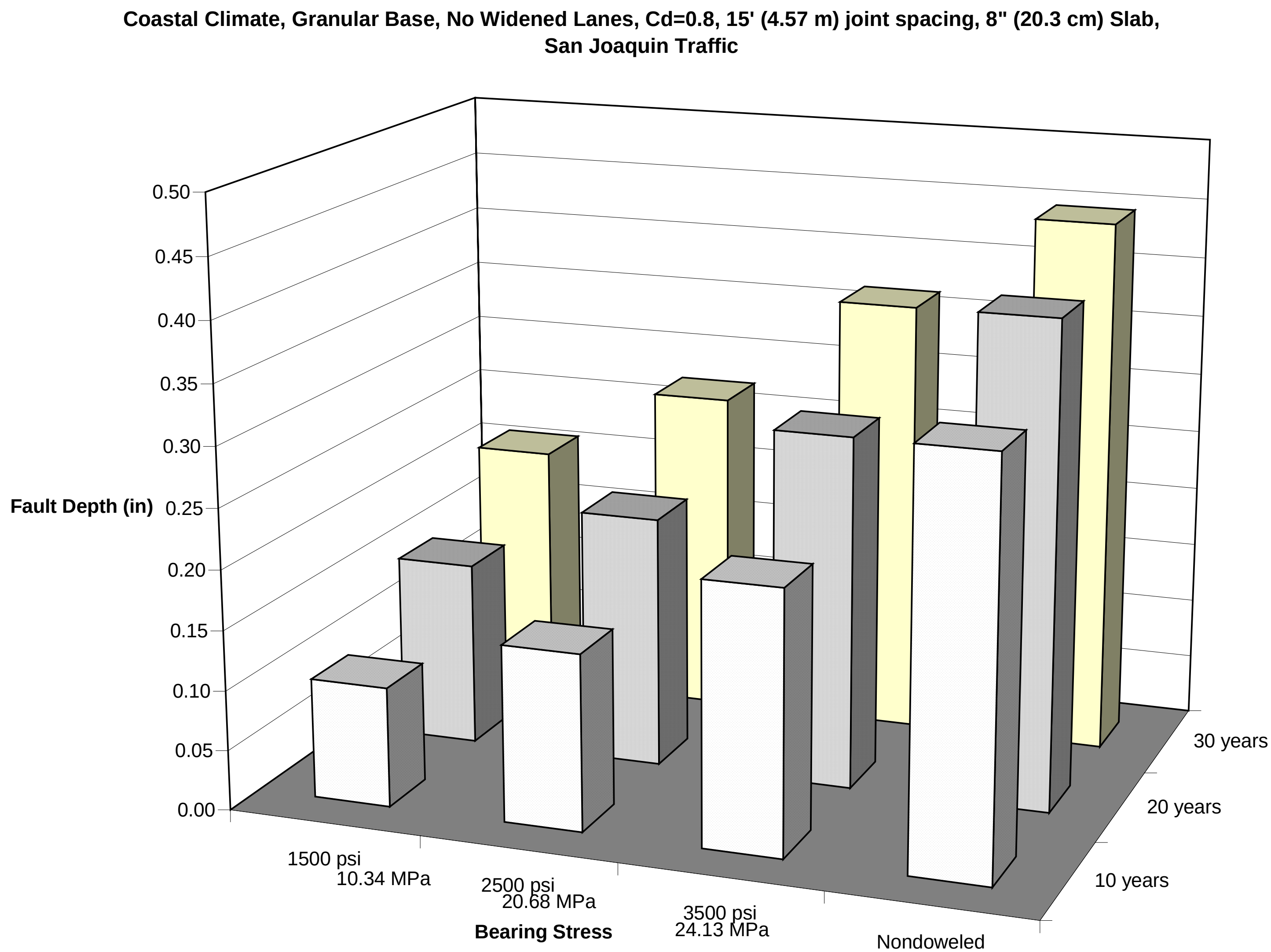



**Figure 41. Effects of dowels and dowel bearing stress on faulting.**

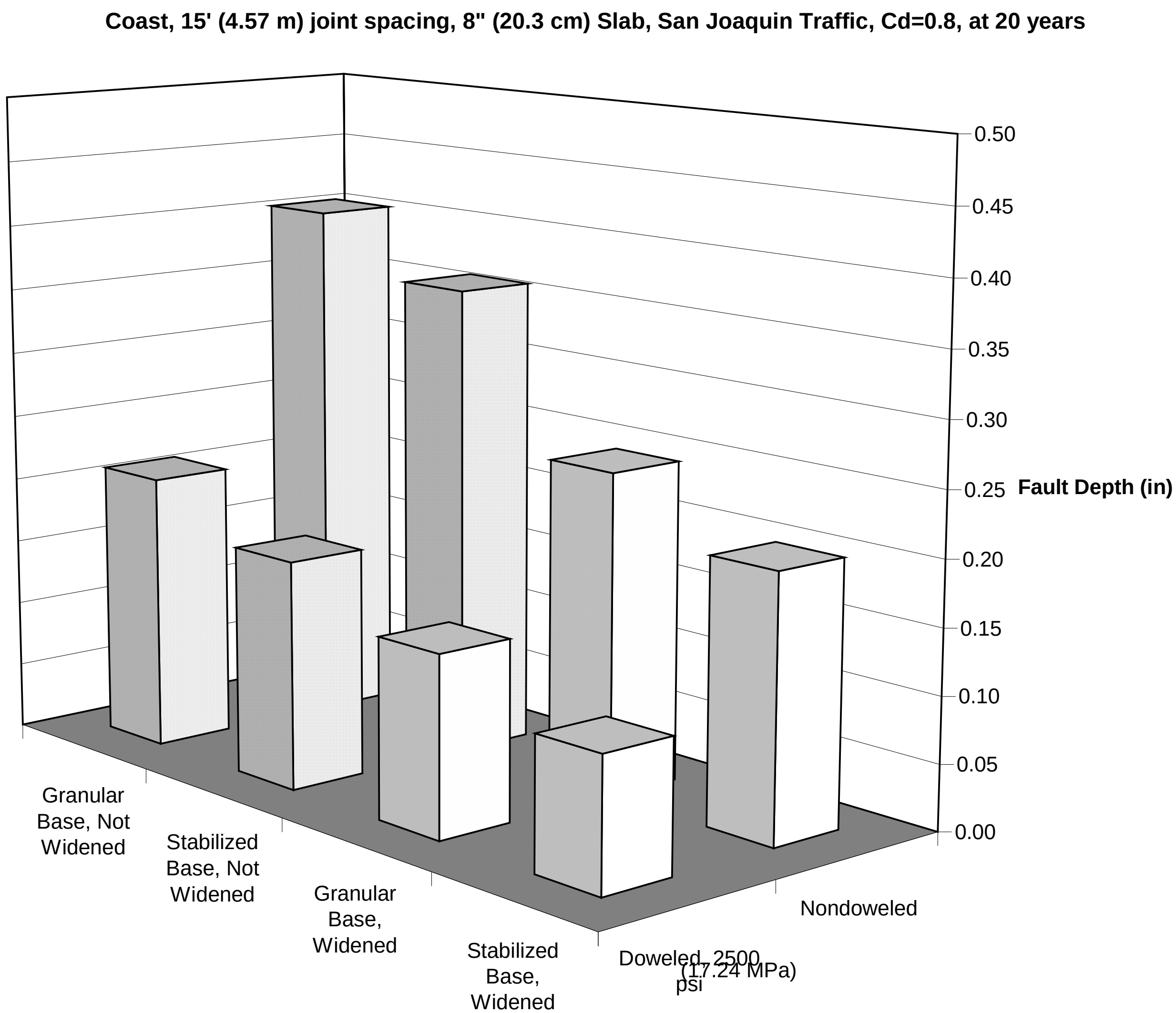



**Figure 42. Effects of base type and wide truck lane on faulting.**

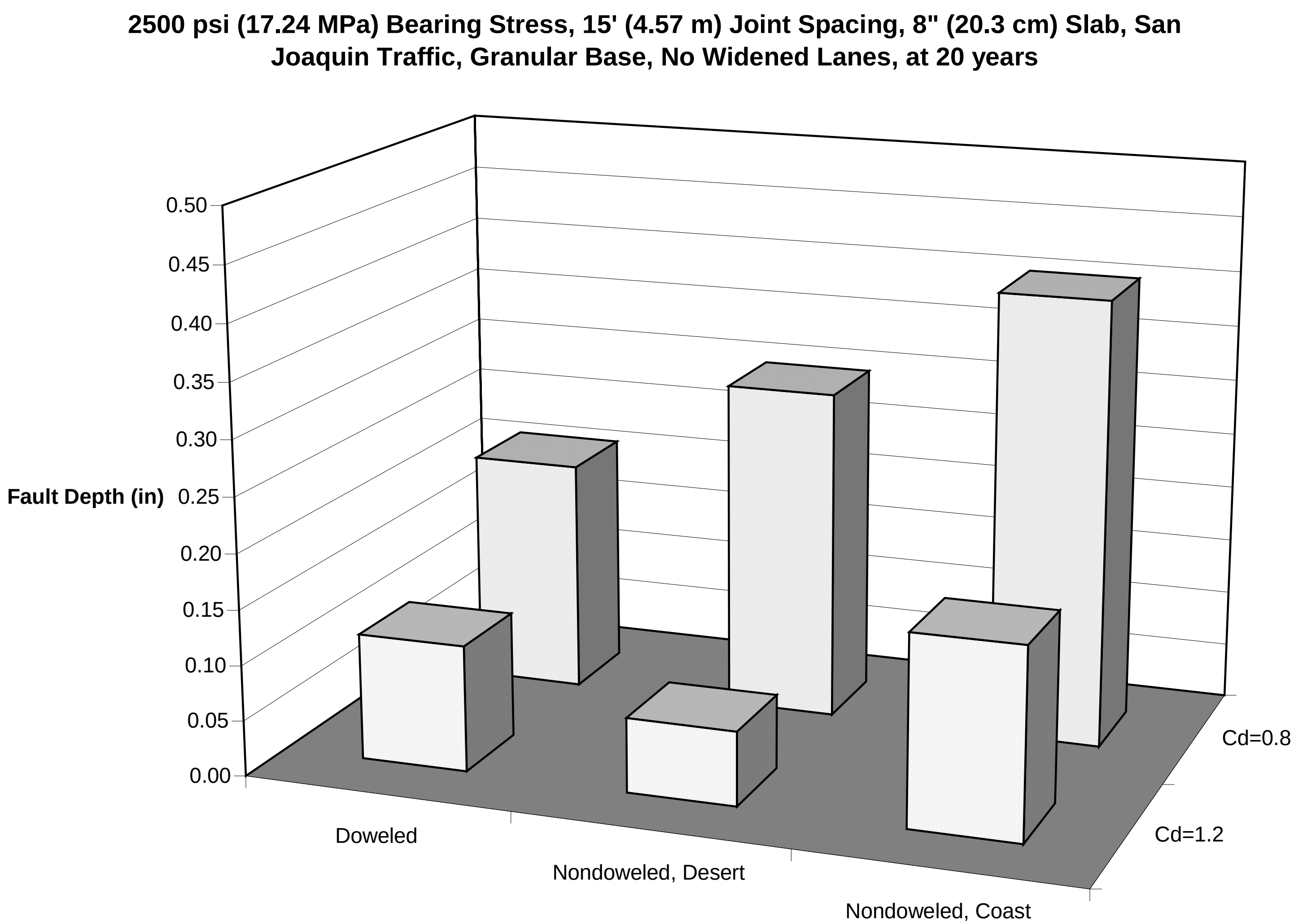



**Figure 43. Effects of drainage, dowels, and environment on faulting.**

## 3.8 Findings: Required Pavement Designs to Provide 30-year Life

The distresses present in current Caltrans rigid pavements and the performance of those pavements is a function of the structural design, materials, construction, truck traffic, and environmental conditions. In this chapter, a review has been made of the distresses present in Caltrans rigid pavements, and the mechanisms for those distresses have been briefly described. In addition, the designs, materials and construction used for those pavements over the years have been presented, as well as historical reviews of rigid pavement performance.

The findings of this chapter are summarized in the following sections.

### 3.8.1 The Various Design Methods Currently in Use Produce Different Results

Several design methods are currently used across the United States. They do not produce the same required slab thicknesses for the same design inputs. The ACPA/AASHTO and PCA methods consider both fatigue cracking and distresses associated with loss of support to the slab. The Illinois DOT method considers transverse fatigue cracking only. The PCA and Illinois DOT methods use a mechanistic-based approach for transverse fatigue cracking analysis, while the ACPA/AASHTO method uses an empirical approach. The ACPA/AASHTO method is extrapolated very far beyond the traffic levels encountered at the AASHO Road Test.

### 3.8.2 ACPA/AASHTO Design Method Slab Thickness Are Generally Greater than Those of Other Methods

In general, the required slab thicknesses for the ACPA/AASHTO method are much thicker than those of the Illinois DOT method. The required thicknesses from the Illinois DOT method are typically somewhat thicker than those from the PCA method, although at times they are in agreement.

### 3.8.3 Axle Loads will Probably Increase Over Next 30 Years

It is likely that axle loads will increase over the next 30 years, due to political pressure, and the need to increase freight throughput without increasing lane capacity for trucks.

### 3.8.4 Caltrans Flexural Strength Requirements Are Low Compared to Other State DOTs

Current concrete flexural strengths required by Caltrans are less than those required by many other State DOTs.

### 3.8.5 Dowels are Necessary to Improve Faulting Performance

The inclusion of dowels to increase load transfer at the transverse joints is necessary to obtain improved resistance to faulting, based on the results from the PCA and ACPA/AASHTO methods.

### 3.8.6 Large Diameter Dowels Increase Dowel Effectiveness

The benefit of including dowels to reduce faulting is substantially increased when large diameter dowels are used. The largest size dowel possible should be used, up to about 37 mm, provided that the concrete slab is thick enough to prevent cracking of the concrete cover around the dowels.

### 3.8.7 Use of Widened Truck Lanes or Tied Concrete Shoulders Improves Fatigue Cracking Performance

Use of widened truck lanes or tied concrete shoulders to provide good load transfer across longitudinal joints is necessary to improve fatigue cracking performance. These features will improve performance with respect to distresses associated with loss of support to the slab as well.

### 3.8.8 Use of Non-Erodable Bases Improves Distresses Associated with Loss of Subgrade Support

Use of non-erodable bases will improve performance for distresses associated with loss of subgrade support, such as faulting and corner cracking. The use of very stiff bases that cannot accommodate temperature curling may be detrimental to transverse fatigue cracking performance.

### 3.8.9 Concrete Strength and Slab Thickness Are Related in Terms of Cracking Resistance

Concrete strength of at least 650 psi (4.48 MPa) is needed to limit the thickness of the concrete slabs. Concrete strength of less than 650 psi (4.48 MPa) will require thicker slabs to prevent cracking.

### 3.8.10 Coefficient of Thermal Expansion Affects Tensile Stresses in Concrete

The coefficient of thermal expansion of the concrete plays an important role in determining tensile stresses in the slab due to temperature curling. Much thicker slabs are required if the new FSHCC coefficient of thermal expansion is greater than that of Portland cement concrete.

3.8.11 Axle Load Spectra Affect Required Slab Thickness

Axle load spectra play a role in determining required slab thickness because the heaviest loads in the spectrum generally determine pavement performance with respect to both fatigue cracking and faulting.

3.8.12 Design Methods Mostly Agree on Relative Benefits and Drawbacks of Design Variables

Although the three design methods generally did not require the same slab thicknesses for similar design inputs, they are nearly always in agreement as to the benefits and drawbacks of structural design features such as dowels, tied concrete shoulders, concrete flexural strength, thicker concrete slabs, and axle load spectra. The results from the PCA and Illinois DOT methods indicate that it may be possible to obtain 30-year design lives using 8- or 9-inch (203- or 229-mm) concrete slabs. Those methods indicate that in order to obtain 30-year design lives, the pavements must include all of the following features:

- concrete flexural strengths of 650 psi (4.48 MPa) or higher,
- lower concrete coefficient of thermal expansion ($<5\times10^{-6}$ in./in./°F),
- dowels, with as large diameters as possible while providing sufficient concrete cover,
- tied concrete shoulders with high load transfer, or widened truck lanes, preferably 0.6 m wider than standard (4.3 m as opposed to 3.7 m),
- non-erodable bases, that at the same time are not so stiff under loading times of several hours that they cannot deform when the concrete slab is curling under temperature changes.

Even with all of these features included in the proposed pavements, 30-year design lives with 8- or 9-inch (203- or 229-mm) slabs may not be consistently obtainable under the following conditions:

- joint spacings greater than 15 ft. (4.57 m),
- the Desert and Valley climatic regions, in which day to night temperature changes introduce large curling stresses.

## 4.0 RECOMMENDATIONS

The recommendations in the following sections are based on the findings presented in Sections 3.0 and 4.0 regarding the distresses and conditions that should be addressed in the LLPRS pavement designs, and the design features that should be included in the design to provide at least 30-year design lives.

### 4.1 Faulting

Faulting is the most prevalent distress occurring in Caltrans rigid pavements. Transverse cracking due to axle loading and temperature curling, corner cracking, and longitudinal cracking are also present in the network. Each distress must be addressed specifically in the pavement designs.

### 4.2 Axle Loads

Axle loads and the number of trucks in the design lanes will undoubtedly increase over the next 30 years. Designs that may have worked in the past may not work in the future, and designs that did not provide adequate performance in the past will deteriorate even more quickly under the increased loading. This traffic and loading growth must be accounted for in the pavement designs. The efficiency of evaluating truck traffic in terms of ESALs, as opposed to evaluating distress mechanisms in terms of axle load spectra, merits further investigation.

### 4.3 Climate and Slab Length

The performance of the LLPRS proposed pavement structures will depend in large part on the specific climate and the slab lengths of the adjoining lanes. Rigid pavements in the Desert and Valley climates, with their large day to night temperature changes, will deteriorate with respect to cracking faster than the milder coastal climates. Transverse joint spacings greater than 15 ft. (4.57 m) will also experience more rapid cracking than joint spacing less than 15 ft. (4.57 m), all other variables being equal. Pavement structural designs must be considered on a project by project basis, rather than applying a uniform structure across a variety of climates and joint spacings, as well as base, subgrade, and drainage conditions.

## 4.4 Stiff Bases

The use of very stiff bases may lead to earlier cracking because of temperature curling. This is particularly the case in the Valley and Desert climates with long slab lengths and large concrete coefficients of thermal expansion. At the same time, bases should be as non-erodable as possible in order to minimize loss of support to the slab, which contributes to faulting and corner cracking. The effectiveness of keeping the existing CTB bears further investigation, especially to evaluate its strength and condition. New asphalt concrete bases with relatively high asphalt contents may provide the desired properties of being non-erodable, yet with low stiffness under loading times of several hours. Alternative bases should be considered with respect to structural performance and constructability if existing CTB is deemed unsatisfactory.

## 4.5 Flexural Strength and Coefficient of Thermal Expansion

The most important concrete properties from a pavement structural performance perspective are flexural strength and coefficient of thermal expansion. Long term durability is also important, and is addressed in a separate report. (*38*) Large flexural strengths (650 to 800 psi [4.44 to 5.52 MPa]) and small coefficients of thermal expansion ($3\times10^{-6}$ to $5\times10^{-6}$ in./in./°F) are needed to minimize slab thicknesses. Development of materials meeting these requirements is essential if the desired design life of 30 or more years is to be obtained.

## 4.6 Dowels, Tied Concrete Shoulders, and Widened Truck Lanes

It is apparent from the design methods that the use of dowels is necessary to address faulting. The use of tied concrete shoulders or widened truck lanes is needed to address fatigue cracking and loss of support to the slab, which contributes to faulting and corner cracking. These features should be included in the LLPRS-Rigid strategies based on these preliminary investigations performed using existing design methods.

## 4.7 Slab Thickness

Although not exactly in agreement, the PCA and Illinois DOT methods indicate that 8- and 9-inch (203- and 229-mm) concrete slabs may provide adequate design lives, provided that all of the other factors included in these recommendations are addressed. At this time, it can be assumed that 8- to 9-in. (203- 229-mm) thicknesses will be adequate for some projects. At the same time, methods for constructing somewhat thicker slab thicknesses, probably ranging from 10 to 12 inches (254 to 305 mm), should be considered for projects with combinations of the heaviest truck traffic, Valley and Desert climates, and slab lengths greater than 15 ft. (4.57 m).

These recommendations are based on preliminary investigations conducted using existing design methods. Except for the study of the effects of bearing stress and dowel sizes on faulting performance, the design methods used in this report are primarily calibrated for conditions in the Midwestern states. Despite the Midwestern calibration, the results of this study provide good indications of the structure and materials requirements necessary to produce LLPRS pavements that will provide 30 or more years of good performance. Continued investigation of each of the variables included in this study is necessary for verification and calibration under expected conditions in California over the next 30 years.

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## APPENDIX A: CONDITION SURVEY NOTES

The tables in this appendix use the following codes to indicate the severity of the degradation of the pavements being considered:

| | |
|---|---|
| Corner cracking | blank indicates no corner cracking evident<br>1 indicates existence of corner cracking |
| Transverse cracking | blank indicates no transverse cracking evident<br>1 indicates existence of transverse cracking |
| Longitudinal cracking | blank indicates no longitudinal cracking evident<br>1 indicates existence of longitudinal cracking |
| Faulting | blank indicates no faulting evident<br>1 indicates existence of slight noticeable faulting<br>2 indicates moderate faulting, somewhat uncomfortable ride quality<br>3 indicates severe faulting, very uncomfortable ride quality |

### Interstate 5

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 5 | south | 42.7 | | 1 | | 1 | Begin truck route. Smooth LC and some TC |
| 7 | Los Angeles | 5 | south | 40.9 | 1 | | 1 | | Good condition |
| 7 | Los Angeles | 5 | south | 39.7 | 1 | | | | Good condition |
| 7 | Los Angeles | 5 | south | 38.7 | 1 | | | | Good condition |
| 7 | Los Angeles | 5 | south | 38.3 | 1 | | | | Good condition |
| 7 | Los Angeles | 5 | south | 37.5 | 1 | | | | |
| 7 | Los Angeles | 5 | south | | 2 | | | | 405/5 |
| 7 | Los Angeles | 5 | south | 35.5 | 3 | | | | |
| 7 | Los Angeles | 5 | south | 34.9 | 1 | 1 | | | 7-8 R1, T1 |
| 7 | Los Angeles | 5 | south | 34.5 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 33.9 | 1 | | | | |
| 7 | Los Angeles | 5 | south | 33.5 | 2 | 1 | | | |
| 7 | Los Angeles | 5 | south | 32.9 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 32.7 | 1 | | | | |
| 7 | Los Angeles | 5 | south | 32.3 | 2 | | | | |
| 7 | Los Angeles | 5 | south | 31.9 | 2 | 1 | | | |
| 7 | Los Angeles | 5 | south | 31.7 | 1 | | | | |
| 7 | Los Angeles | 5 | south | 31.4 | | 1 | | | |
| 7 | Los Angeles | 5 | south | 30.8 | | | | | smooth |
| 7 | Los Angeles | 5 | south | 30.5 | | | | 1 | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 5 | south | 29.9 | | 1 | 1 | | |
| 7 | Los Angeles | 5 | south | 29.7 | | 1 | | | |
| 7 | Los Angeles | 5 | south | 29.3 | 2 | | 1 | 1 | |
| 7 | Los Angeles | 5 | south | 28.7 | | | | | ACOL good condition |
| 7 | Los Angeles | 5 | south | 23.7 | | | | | PCCP good |
| 7 | Los Angeles | 5 | south | 22.3 | 2 | 1 | 1 | | 9-13RI; large visible slab defl |
| 7 | Los Angeles | 5 | south | 22.1 | 2 | 1 | | | A1 |
| 7 | Los Angeles | 5 | south | 21.9 | 2 | | | | |
| 7 | Los Angeles | 5 | south | 21.3 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 20.3 | | | | | ACOL |
| 7 | Los Angeles | 5 | south | 19.7 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 19.5 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 18.7 | | | | | ACOL |
| 7 | Los Angeles | 5 | south | 18.6 | 2 | 1 | | | |
| 7 | Los Angeles | 5 | south | 17.9 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 17.7 | 1 | 1 | | | |
| 7 | Los Angeles | 5 | south | 17.5 | 2 | | | | |
| 7 | Los Angeles | 5 | south | 16.3 | | | | | D7 to D12 (60 to 405 interchange) |
| 7 | Los Angeles | 5 | south | 16.3 | | | | | AC good |
| 7 | Los Angeles | 5 | south | 11.6 | 1 | 1 | | | PCCP |
| 7 | Los Angeles | 5 | south | 11.3 | 1 | | | | |
| 7 | Los Angeles | 5 | south | 10.9 | 1 | 1 | | | perp. jts @15' ? |
| 7 | Los Angeles | 5 | south | 10.5 | 3 | 1 | 1 | | |
| 7 | Los Angeles | 5 | south | 10.3 | 2 | 1 | | | |
| 7 | Los Angeles | 5 | south | 9.3 | 2 | 1 | | | |
| 7 | Los Angeles | 5 | south | 8.7 | 2 | 1 | | | |
| 7 | Los Angeles | 5 | south | 7.9 | 2 | 1 | | | TC every slab |
| 7 | Los Angeles | 5 | south | 4.9 | 1 | 1 | | | ground joint in wp |
| 7 | Los Angeles | 5 | south | 4.7 | 1 | 1 | | | joint@joint |
| 7 | Los Angeles | 5 | south | 4.5 | 3 | 1 | 1 | | |
| 7 | Los Angeles | 5 | south | 3.9 | 3 | | 1 | | |
| 7 | Los Angeles | 5 | south | 3.7 | 3 | | | 1 | |
| 12 | Orange County | 5 | south | 44.6 | 2 | | | 1 | D12 |
| 12 | Orange County | 5 | south | 43.7 | 3 | 1 | | 1 | |
| 12 | Orange County | 5 | south | 43.6 | 3 | | | 1 | |
| 12 | Orange County | 5 | south | 43.4 | 2 | | | | ACOL |
| 12 | Orange County | 5 | south | 42.8 | 3 | | | 1 | |
| 12 | Orange County | 5 | south | 41.8 | 3 | | | | A6; 5 Orange County SB |
| 12 | Orange County | 5 | south | 40.8 | 3 | 1 | | 1 | |
| 12 | Orange County | 5 | south | 40.6 | | | | | ACOL faults |
| 12 | Orange County | 5 | south | 40.4 | 1 | | | | PCCP |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 12 | Orange County | 5 | south | 39.5 | 3 | 1 | 1 | 1 | spalled |
| 12 | Orange County | 5 | south | 38.7 | 3 | 1 | 1 | 1 | spalled |
| 12 | Orange County | 5 | south | 37.6 | 3 | | | | AC |
| 12 | Orange County | 5 | south | 36.4 | | | | | ACOL good |
| 12 | Orange County | 5 | south | 34.8 | 1 | | | | PCCP new |
| 12 | Orange County | 5 | south | 33.8 | 1 | | | | skew joints |
| 12 | Orange County | 5 | south | 32.6 | 1 | | | | |
| 12 | Orange County | 5 | south | 31.8 | | | | | AC good |
| 12 | Orange County | 5 | south | 20.5 | | | | | truck bypass |
| 12 | Orange County | 5 | south | 18.6 | 1 | | | | |
| 12 | Orange County | 5 | south | 17.6 | 2 | | | | |
| 11 | San Diego | 5 | north | 35 | 2 | | | | San Diego |
| 11 | San Diego | 5 | north | 51.6 | 3 | | | | |
| 11 | San Diego | 5 | north | 69 | 2 | | | | |
| 12 | Orange County | 5 | north | 0 | 3 | | | | Orange County |
| 12 | Orange County | 5 | north | 2.6 | | | | | ACOL |
| 12 | Orange County | 5 | north | 7.5 | 2 | | | | PCCP |
| 12 | Orange County | 5 | north | 13.3 | | | | 1 | |
| 12 | Orange County | 5 | north | 17.4 | 2 | | | | Orange County 12, NB |
| 12 | Orange County | 5 | north | 18.7 | | | | | joint in wp |
| 12 | Orange County | 5 | north | 22 | | | | | ACOL |
| 12 | Orange County | 5 | north | 32 | 1 | | | | PCCP |
| 12 | Orange County | 5 | north | 35 | | | | | ACOL |
| 12 | Orange County | 5 | north | 39 | 2 | | | | |
| 12 | Orange County | 5 | north | 41 | 2 | | | | |
| 12 | Orange County | 5 | north | 41.6 | | | | | ACOL |
| 12 | Orange County | 5 | north | 42.3 | 3 | | | | |
| 12 | Orange County | 5 | north | 43.4 | | 1 | | 1 | |
| 7 | Los Angeles | 5 | north | 0 | 2 | | | | Los Angeles |
| 7 | Los Angeles | 5 | north | 1.7 | 3 | | | | |
| 7 | Los Angeles | 5 | north | 4.4 | 1 | | | | |
| 7 | Los Angeles | 5 | north | 34.2 | 3 | | | | |
| 7 | Los Angeles | 5 | north | 37.2 | 3 | | | | |

## Interstate 10

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 10 | west | 18.3 | | 1 | | | |
| 7 | Los Angeles | 10 | west | 15.9 | | | | | bridge |
| 7 | Los Angeles | 10 | west | 15.7 | | | | | bridge |
| 7 | Los Angeles | 10 | west | 15.3 | | | | | bridge |
| 7 | Los Angeles | 10 | west | 14.9 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 14.8 | | 1 | 1 | | ravel |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 10 | west | 14.5 | | | | | bridge |
| 7 | Los Angeles | 10 | west | 14.4 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 13.7 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 13.5 | 1 | | | | skew |
| 7 | Los Angeles | 10 | west | 13.4 | 2 | | | | joints |
| 7 | Los Angeles | 10 | west | 13.3 | 2 | | | | 13,13,19,19 |
| 7 | Los Angeles | 10 | west | 12.9 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 11.9 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 11.5 | 1 | | | | |
| 7 | Los Angeles | 10 | west | 11.3 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 11.1 | 1 | | | | 14R1 |
| 7 | Los Angeles | 10 | west | 10.9 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 10.3 | 2 | | | | open long. joint |
| 7 | Los Angeles | 10 | west | 10 | 1 | | | | |
| 7 | Los Angeles | 10 | west | 9.5 | | | | | bridge |
| 7 | Los Angeles | 10 | west | 9.3 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 8.9 | | | | | ACOL slight cracking |
| 7 | Los Angeles | 10 | west | 8.7 | 2 | | | | PCCP |
| 7 | Los Angeles | 10 | west | 8.5 | | | | | PC patches |
| 7 | Los Angeles | 10 | west | 7.9 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 7.7 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 7.5 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 7.1 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 6.9 | 2 | | | | |
| 7 | Los Angeles | 10 | west | 6.7 | 2 | | | | moderate faults |
| 8 | San Bernardino | 10 | west | 31.5 | 1 | | | 1 | D8 |
| 8 | San Bernardino | 10 | west | 31.1 | 2 | | | 1 | |
| 8 | San Bernardino | 10 | west | 30.5 | 2 | 1 | | 1 | |
| 8 | San Bernardino | 10 | west | 29.9 | 2 | | | | |
| 8 | San Bernardino | 10 | west | 29.5 | 2 | | | | skew jts. |
| 8 | San Bernardino | 10 | west | 28.7 | 2 | | | | |
| 8 | San Bernardino | 10 | west | 28.5 | 2 | | | | |
| 8 | San Bernardino | 10 | west | 27.7 | 2 | | | | |
| 8 | San Bernardino | 10 | west | 27.3 | 2 | | | 1 | |
| 8 | San Bernardino | 10 | west | 26.3 | 2 | | | 1 | |
| 8 | San Bernardino | 10 | west | 25.7 | 3 | | 1 | 1 | |
| 7 | Los Angeles | 10 | east | 4.6 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 6.1 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 6.2 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 6.4 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 6.8 | | | | | 17R1, no vis. faults, no vis. defl. outer trucks @ jt. |
| 7 | Los Angeles | 10 | east | 7.2 | 1 | | | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 10 | east | 8.4 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 9.2 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 9.6 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 10.2 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 10.8 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 11.2 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 12.2 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 12.8 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 13.4 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 14.2 | 2 | | | | bridge |
| 7 | Los Angeles | 10 | east | 17.6 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 18.2 | | | | | bridge |
| 7 | Los Angeles | 10 | east | 18.8 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 19.2 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 20.2 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 20.8 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 21.6 | | | 1 | 1 | |
| 7 | Los Angeles | 10 | east | 22.2 | 1 | 1 | | | |
| 7 | Los Angeles | 10 | east | 22.8 | 2 | | | | spall |
| 7 | Los Angeles | 10 | east | 23.6 | 2 | | | 1 | |
| 7 | Los Angeles | 10 | east | 23.9 | 2 | | 1 | | |
| 7 | Los Angeles | 10 | east | 24.2 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 24.6 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 25.2 | | | | 1 | |
| 7 | Los Angeles | 10 | east | 25.6 | 2 | | | 1 | |
| 7 | Los Angeles | 10 | east | 25.8 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 26 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 26.5 | | | 1 | | |
| 7 | Los Angeles | 10 | east | 26.6 | | | | 1 | spalled |
| 7 | Los Angeles | 10 | east | 28 | | 1 | 1 | | spalled, jt @ c.l. LC |
| 7 | Los Angeles | 10 | east | 28.6 | 2 | | | 1 | |
| 7 | Los Angeles | 10 | east | 29 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 29.5 | | | | 1 | |
| 7 | Los Angeles | 10 | east | 29.8 | 2 | | | 1 | |
| 7 | Los Angeles | 10 | east | 30 | | | | | D7 CA;A2 |
| 7 | Los Angeles | 10 | east | 30 | 2 | | 1 | 1 | 15' perp. jts; no vis. jts @ outer truck |
| 7 | Los Angeles | 10 | east | 30.8 | 1 | | | | |
| 7 | Los Angeles | 10 | east | 31.1 | 3 | | 1 | | |
| 7 | Los Angeles | 10 | east | 31.6 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 32.2 | 3 | | 1 | | |
| 7 | Los Angeles | 10 | east | 32.8 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 33.4 | 3 | 1 | | | spalls, patches |
| 7 | Los Angeles | 10 | east | 33.8 | 3 | 1 | | | spalls, patches |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 10 | east | 34.4 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 35.2 | 3 | | | 1 | |
| 7 | Los Angeles | 10 | east | 35.6 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 35.8 | 3 | | | 1 | |
| 7 | Los Angeles | 10 | east | 36.2 | 3 | | | 1 | |
| 7 | Los Angeles | 10 | east | 36.3 | 3 | 1 | | | |
| 7 | Los Angeles | 10 | east | 36.6 | 3 | 1 | | | |
| 7 | Los Angeles | 10 | east | 37 | 2 | 1 | | | |
| 7 | Los Angeles | 10 | east | 37.4 | 3 | 1 | | | patches |
| 7 | Los Angeles | 10 | east | 37.8 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 38.6 | 3 | | 1 | | |
| 7 | Los Angeles | 10 | east | 39.2 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 39.4 | 2 | | 1 | 1 | |
| 7 | Los Angeles | 10 | east | 40.2 | 3 | | | | raveling |
| 7 | Los Angeles | 10 | east | 40.4 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 40.8 | 2 | | | | |
| 7 | Los Angeles | 10 | east | 41.4 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 41.6 | | | | | ACOL cracks |
| 7 | Los Angeles | 10 | east | 42.2 | 3 | | | | PCCP |
| 7 | Los Angeles | 10 | east | 42.8 | 3 | | | | |
| 7 | Los Angeles | 10 | east | 43.2 | 3 | 1 | 1 | 1 | patches, punchout |
| 7 | Los Angeles | 10 | east | 43.4 | 3 | 1 | 1 | 1 | patches, punchout, water |
| 7 | Los Angeles | 10 | east | 43.6 | 3 | 1 | 1 | 1 | patches, punchout, water |
| 7 | Los Angeles | 10 | east | 44.2 | 3 | 1 | 1 | 1 | mostly TC; patches, punchout, water |
| 7 | Los Angeles | 10 | east | 45 | 3 | 1 | | 1 | patches |
| 7 | Los Angeles | 10 | east | 45.4 | 3 | | 1 | | |
| 7 | Los Angeles | 10 | east | 45.6 | | | | | bad ACOLs in places |
| 7 | Los Angeles | 10 | east | 45.8 | | | | | ACOL OK |
| 7 | Los Angeles | 10 | east | 46.4 | 1 | | | | ACOL OK |
| 7 | Los Angeles | 10 | east | 47.2 | 1 | | | | ACOL OK |
| 7 | Los Angeles | 10 | east | 48 | 1 | | | | ACOL OK |
| 7 | Los Angeles | 10 | east | 48.4 | | | | | D8 |
| 8 | San Bernardino | 10 | east | 0 | 3 | | | | D8 |
| 8 | San Bernardino | 10 | east | 2 | 3 | 1 | 1 | | |
| 8 | San Bernardino | 10 | east | 2.1 | 3 | 1 | | | |
| 8 | San Bernardino | 10 | east | 3.1 | 3 | | 1 | | |
| 8 | San Bernardino | 10 | east | 4.1 | 3 | | 1 | | |
| 8 | San Bernardino | 10 | east | 5 | 3 | 1 | | | |
| 8 | San Bernardino | 10 | east | 5.6 | 3 | 1 | 1 | | |
| 8 | San Bernardino | 10 | east | 6.6 | 3 | | | 1 | |
| 8 | San Bernardino | 10 | east | 7.4 | 3 | | | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 8 | San Bernardino | 10 | east | 8 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 8.2 | 3 | | | 1 | |
| 8 | San Bernardino | 10 | east | 8.6 | 3 | | | 1 | |
| 8 | San Bernardino | 10 | east | 9.4 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 9.6 | 3 | 1 | | | 5R2, 13,13,18,18 skew TC in long. slab |
| 8 | San Bernardino | 10 | east | 10.2 | 3 | 1 | | | |
| 8 | San Bernardino | 10 | east | 10.4 | 1 | | | | |
| 8 | San Bernardino | 10 | east | 11.5 | 1 | 1 | | | |
| 8 | San Bernardino | 10 | east | 12.2 | 1 | 1 | | | |
| 8 | San Bernardino | 10 | east | 12.6 | 2 | | | | |
| 8 | San Bernardino | 10 | east | 13.2 | 2 | | | | |
| 8 | San Bernardino | 10 | east | 13.6 | 2 | 1 | | 1 | |
| 8 | San Bernardino | 10 | east | 14.2 | 2 | | | | |
| 8 | San Bernardino | 10 | east | 14.6 | 2 | | | | |
| 8 | San Bernardino | 10 | east | 15.3 | 1 | | | | A3; D8 San Bernardino |
| 8 | San Bernardino | 10 | east | 15.6 | 2 | | 1 | | |
| 8 | San Bernardino | 10 | east | 16.2 | 2 | | | 1 | |
| 8 | San Bernardino | 10 | east | 16.6 | 2 | 1 | | | |
| 8 | San Bernardino | 10 | east | 17.2 | 2 | 1 | | | |
| 8 | San Bernardino | 10 | east | 17.5 | 2 | 1 | | | TC every slab; 15' perp. jts; no vis defl @ jts |
| 8 | San Bernardino | 10 | east | 18.4 | 1 | | | | |
| 8 | San Bernardino | 10 | east | 19.2 | 1 | 1 | | | |
| 8 | San Bernardino | 10 | east | 19.7 | 2 | 1 | | | |
| 8 | San Bernardino | 10 | east | 20 | 2 | | | 1 | |
| 8 | San Bernardino | 10 | east | 20.6 | 3 | 1 | | | |
| 8 | San Bernardino | 10 | east | 21.2 | 3 | 1 | | | |
| 8 | San Bernardino | 10 | east | 21.6 | 1 | | | 1 | |
| 8 | San Bernardino | 10 | east | 21.8 | 1 | | | | |
| 8 | San Bernardino | 10 | east | 22.2 | 2 | | | | |
| 8 | San Bernardino | 10 | east | 23.2 | 1 | | | | |
| 8 | San Bernardino | 10 | east | 24.2 | 2 | | | | |
| 8 | San Bernardino | 10 | east | 24.6 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 25.2 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 25.6 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 26.2 | 3 | | | 1 | |
| 8 | San Bernardino | 10 | east | 26.6 | 3 | | | 1 | |
| 8 | San Bernardino | 10 | east | 27.2 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 27.6 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 28.2 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 28.6 | 3 | | | | |
| 8 | San Bernardino | 10 | east | 29.2 | 3 | | 1 | | |
| 8 | San Bernardino | 10 | east | 29.4 | 3 | 1 | | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 8 | San Bernardino | 10 | east | 29.6 | 2 | 1 | | | |
| 8 | San Bernardino | 10 | east | 29.8 | 2 | 1 | | 1 | |
| 8 | San Bernardino | 10 | east | 30 | 2 | | | 1 | |
| 8 | San Bernardino | 10 | east | 30.6 | 2 | 1 | | 1 | |
| 8 | San Bernardino | 10 | east | 31 | 3 | 1 | | | |
| 8 | San Bernardino | 10 | east | 31.2 | 3 | 1 | | 1 | |

### Interstate 215

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 8 | San Bernardino | 215 | | | | | | | Riverside 38.5 to 43.3, San Bernardino 6.9 to 8 |
| 8 | San Bernardino | 215 | north | 4 | | | | | 4 to 6.9 many patches, smooth, few cracks |
| 8 | San Bernardino | 215 | north | 5.6 | 2 | | | | |
| 8 | San Bernardino | 215 | north | 6 | 2 | | | | |
| 8 | San Bernardino | 215 | north | 6.2 | 2 | | | 1 | AC patches |
| 8 | San Bernardino | 215 | north | 6.8 | 2 | | | | AC patches |
| 8 | San Bernardino | 215 | north | 7.4 | 2 | | | | |
| 8 | San Bernardino | 215 | north | 8.6 | 2 | 1 | | 1 | |
| 8 | San Bernardino | 215 | south | 9.3 | 2 | 1 | | | A4; D8 San Bernardino |
| 8 | San Bernardino | 215 | south | 8.7 | 2 | 1 | | | |
| 8 | San Bernardino | 215 | south | 7.9 | 3 | 1 | 1 | | |
| 8 | San Bernardino | 215 | south | 7.7 | 2 | 1 | | | R2-12; 13-15' perp jts; every other slab w/ TC |
| 8 | San Bernardino | 215 | south | 7.5 | 3 | 1 | 1 | | |
| 8 | San Bernardino | 215 | south | 7.3 | 3 | 1 | 1 | 1 | |
| 8 | San Bernardino | 215 | south | 6.9 | 3 | 1 | 1 | 1 | |
| 8 | San Bernardino | 215 | south | 6.5 | 1 | 1 | | 1 | |
| 8 | San Bernardino | 215 | south | 4.3 | | | | | AC OK |
| 8 | Riverside | 215 | south | 43.5 | 3 | 1 | | | 215 Riverside SB 43.3-38.5 (60/215/91) |
| 8 | Riverside | 215 | south | 43.3 | 3 | 1 | | | AC, PC patches |
| 8 | Riverside | 215 | south | 42.7 | 3 | 1 | | | joint in wp |
| 8 | Riverside | 215 | south | 42.3 | 3 | 1 | | | |
| 8 | Riverside | 215 | south | 41.9 | 3 | | | | AC patches |
| 8 | Riverside | 215 | south | 41.5 | 3 | 1 | 1 | | |
| 8 | Riverside | 215 | south | 41.3 | 2 | | | | |
| 8 | Riverside | 215 | south | 41.2 | | | | | AC good |
| 8 | Riverside | 215 | south | 38.5 | | | | | AC good |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 8 | Riverside | 215 | north | 38.5 | | | | | Riverside 38.5 to 43.3 |
| 8 | Riverside | 215 | north | 38.6 | | | | | AC good, some long. refl. cracks |
| 8 | Riverside | 215 | north | 41.2 | 2 | 1 | | | PC |
| 8 | Riverside | 215 | north | 41.8 | 2 | 1 | | | |
| 8 | Riverside | 215 | north | 42.6 | 2 | 1 | | | |

## State Route 60

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 8 | Riverside | 60 | west | 0.8 | 2 | 1 | | | D8 Riverside 0.0 to 0.985 |
| 8 | Riverside | 60 | west | 0.2 | 2 | | | | |
| 8 | San Bernardino | 60 | west | 9.5 | 2 | 1 | | | D7 San Bernardino |
| 8 | San Bernardino | 60 | west | 8.7 | 3 | 1 | | | |
| 8 | San Bernardino | 60 | west | 6.1 | 3 | 1 | | | |
| 8 | San Bernardino | 60 | west | 4.3 | 1 | | | | |
| 8 | San Bernardino | 60 | west | 1.4 | 2 | 1 | | | |
| 8 | San Bernardino | 60 | west | 0.9 | 1 | | | | |
| 7 | Los Angeles | 60 | west | 29.4 | | | | | 7 Los Angeles 29.4 TO 1.0 |
| 7 | Los Angeles | 60 | west | 29.3 | 1 | | 1 | | |
| 7 | Los Angeles | 60 | west | 28.7 | 2 | | 1 | | |
| 7 | Los Angeles | 60 | west | 28.5 | 1 | | | 1 | |
| 7 | Los Angeles | 60 | west | 28.3 | 1 | | | 1 | |
| 7 | Los Angeles | 60 | west | 27.9 | 1 | | | 1 | |
| 7 | Los Angeles | 60 | west | 27.5 | 1 | | | 1 | |
| 7 | Los Angeles | 60 | west | 27.1 | | | | | bad ACOL |
| 7 | Los Angeles | 60 | west | 26.8 | 1 | | | | PCC |
| 7 | Los Angeles | 60 | west | 25.9 | 1 | | 1 | 1 | |
| 7 | Los Angeles | 60 | west | 25.5 | 2 | | | 1 | |
| 7 | Los Angeles | 60 | west | 24.7 | 2 | | | | |
| 7 | Los Angeles | 60 | west | 24.3 | 2 | | | | |
| 7 | Los Angeles | 60 | west | 23.9 | 2 | | 1 | 1 | |
| 7 | Los Angeles | 60 | west | 22.9 | 2 | | | | |
| 7 | Los Angeles | 60 | west | 22.5 | 2 | | | | |
| 7 | Los Angeles | 60 | west | 22.3 | 3 | | | | |
| 7 | Los Angeles | 60 | west | 21.7 | 3 | 1 | | | |
| 7 | Los Angeles | 60 | west | 21.5 | 3 | | | | |
| 7 | Los Angeles | 60 | west | 20.9 | 3 | | | | |
| 7 | Los Angeles | 60 | west | 20.5 | 2 | 1 | | | |
| 7 | Los Angeles | 60 | west | 19.9 | 3 | | | | |
| 7 | Los Angeles | 60 | west | 19.5 | 2 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 60 | west | 18.9 | 3 | | | 1 | |
| 7 | Los Angeles | 60 | west | 18.3 | 2 | | | 1 | |
| 7 | Los Angeles | 60 | west | 17.9 | 2 | | | 1 | |
| 7 | Los Angeles | 60 | west | 17.5 | 2 | | | 1 | |
| 7 | Los Angeles | 60 | west | 17.3 | 2 | 1 | 1 | 1 | 24R2, 13,13, 18, 18, skew; no vis defl. @outer load |
| 7 | Los Angeles | 60 | west | 16.9 | 1 | | | 1 | |
| 7 | Los Angeles | 60 | west | 16 | 2 | | | | |
| 7 | Los Angeles | 60 | west | 15.5 | 2 | | | 1 | |
| 8 | Los Angeles | 60 | west | 14.7 | 2 | | | | A5; D7 |
| 8 | Los Angeles | 60 | west | 14.3 | 3 | | | | joint in wp |
| 8 | Los Angeles | 60 | west | 13.5 | 2 | | | 1 | |
| 8 | Los Angeles | 60 | west | 12.9 | | | | | joint okay |
| 8 | Los Angeles | 60 | west | 12.5 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 11.9 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 11.3 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 10.5 | 2 | | | 1 | |
| 8 | Los Angeles | 60 | west | 9.9 | 3 | | | 1 | |
| 8 | Los Angeles | 60 | west | 9.3 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 8.5 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 7.7 | 3 | | | | |
| 8 | Los Angeles | 60 | west | 7.5 | 3 | | 1 | | |
| 8 | Los Angeles | 60 | west | 6.7 | 2 | 1 | | | |
| 8 | Los Angeles | 60 | west | 6.5 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 6.3 | 2 | | | 1 | |
| 8 | Los Angeles | 60 | west | 5.9 | 2 | | | 1 | |
| 8 | Los Angeles | 60 | west | 5.7 | 3 | | | 1 | |
| 8 | Los Angeles | 60 | west | 5.3 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 4.5 | 2 | | | | |
| 8 | Los Angeles | 60 | west | 3.7 | 3 | | | | |
| 8 | Los Angeles | 60 | west | 3.5 | 3 | | | | |
| 8 | Los Angeles | 60 | west | 2.9 | 3 | | | | |
| 8 | Los Angeles | 60 | west | 2.7 | 3 | | | | |
| 8 | Los Angeles | 60 | west | 1.9 | 3 | | | | |
| 8 | Los Angeles | 60 | west | 1.7 | 3 | 1 | 1 | | |
| 8 | Los Angeles | 60 | west | 0.9 | 3 | | | | |

## Interstate 405

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 12 | Orange | 405 | north | 0 | 1 | | | | D7 Los Angeles (0 to 710 interchange) |
| 12 | Orange | 405 | north | 1 | 1 | | | | |
| 12 | Orange | 405 | north | 1.3 | 1 | | | | |
| 12 | Orange | 405 | north | 1.7 | 1 | | | | |
| 12 | Orange | 405 | north | 2.5 | 1 | | | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 12 | Orange | 405 | north | 2.7 | 1 | | | 1 | 13,13,18,19 heavy skew; no defl @jt vis; R3-4 |
| 12 | Orange | 405 | north | 3.9 | 2 | | | 1 | |
| 12 | Orange | 405 | north | 4.7 | 2 | | | 1 | |
| 12 | Orange | 405 | north | 5.3 | 3 | | | | |
| 12 | Orange | 405 | north | 5.5 | 2 | | | | |
| 12 | Orange | 405 | north | 6.3 | 2 | | | 1 | |
| 12 | Orange | 405 | north | 6.7 | 2 | | | 1 | |
| 12 | Orange | 405 | north | 6.9 | 2 | | | 1 | grass in long. jt; jt in C.L. |
| 12 | Orange | 405 | north | 7.5 | | | | | joint OK |
| 12 | Orange | 405 | north | 7.9 | 2 | | | | |
| 12 | Orange | 405 | north | 8.5 | 2 | | | | |
| 12 | Orange | 405 | north | 8.9 | 1 | | | | |
| 12 | Orange | 405 | north | 9.5 | 1 | | | | |
| 12 | Orange | 405 | north | 10.3 | 1 | | | | |
| 12 | Orange | 405 | north | 11.7 | | | | | AC good condition |
| 12 | Orange | 405 | north | 17.1 | 1 | | | | PCCP |
| 12 | Orange | 405 | north | 18.7 | 2 | | | | |
| 12 | Orange | 405 | north | 20.3 | 3 | | | | |
| 12 | Orange | 405 | north | 20.9 | 2 | | | | |
| 12 | Orange | 405 | north | 21.7 | 3 | | | | |
| 12 | Orange | 405 | north | 24.3 | 2 | | | | |
| 7 | Los Angeles | 405 | north | 0 | | | | | D7 |
| 7 | Los Angeles | 405 | north | 0.6 | 1 | | | | |
| 7 | Los Angeles | 405 | north | 2.2 | 2 | | | | |
| 7 | Los Angeles | 405 | north | 2.4 | 3 | | | | |
| 7 | Los Angeles | 405 | north | 4.2 | 1 | | | | |
| 7 | Los Angeles | 405 | north | 4.6 | 3 | | | | |
| 7 | Los Angeles | 405 | north | 10 | 2 | | | | |
| 7 | Los Angeles | 405 | north | 12.6 | 2 | | | | |
| 7 | Los Angeles | 405 | north | 13.2 | | | | | AC |
| 7 | Los Angeles | 405 | north | 16.2 | 2 | | | 1 | |
| 7 | Los Angeles | 405 | north | 16.6 | | | | | AC |

## Interstate 710

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 710 | north | 6.8 | | | | | ACOL from 0 to 6.8 |
| 7 | Los Angeles | 710 | north | 7 | 2 | | | 1 | joint spall |
| 7 | Los Angeles | 710 | north | 7.2 | 3 | | 1 | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 710 | north | 7.4 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 7.8 | 3 | 1 | | | |
| 7 | Los Angeles | 710 | north | 7.9 | | | | | blowout cracks |
| 7 | Los Angeles | 710 | north | 8.2 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 8.4 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 8.6 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 9.2 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 9.4 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 9.6 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 10.2 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 10.4 | 1 | | | | |
| 7 | Los Angeles | 710 | north | 10.8 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 11.2 | 2 | | 1 | | |
| 7 | Los Angeles | 710 | north | 11.4 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 12.4 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 12.8 | 3 | 1 | | | blown cracks |
| 7 | Los Angeles | 710 | north | 13 | 3 | 1 | | | |
| 7 | Los Angeles | 710 | north | 13.2 | 3 | 1 | | | |
| 7 | Los Angeles | 710 | north | 13.6 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 13.8 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 14.2 | 3 | 1 | 1 | 1 | |
| 7 | Los Angeles | 710 | north | 14.4 | 3 | | | 1 | |
| 7 | Los Angeles | 710 | north | 14.6 | 3 | | 1 | 1 | |
| 7 | Los Angeles | 710 | north | 14.8 | 1 | | | | skew joints |
| 7 | Los Angeles | 710 | north | 15.4 | 1 | | | | |
| 7 | Los Angeles | 710 | north | 15.8 | 1 | | | | |
| 7 | Los Angeles | 710 | north | 16.4 | 1 | | | | |
| 7 | Los Angeles | 710 | north | 16.5 | 3 | 1 | 1 | 1 | bad perp. joints |
| 7 | Los Angeles | 710 | north | 17.6 | | | | | ACOL good |
| 7 | Los Angeles | 710 | north | 18.1 | 1 | 1 | | 1 | PCCP |
| 7 | Los Angeles | 710 | north | 18.4 | 2 | 1 | 1 | | cracked slabs drop |
| 7 | Los Angeles | 710 | north | 19 | 1 | 1 | | 1 | |
| 7 | Los Angeles | 710 | north | 19.4 | | | | | A9 |
| 7 | Los Angeles | 710 | north | 19.4 | 1 | 1 | 1 | | not spalled much |
| 7 | Los Angeles | 710 | north | 20.2 | 1 | | 1 | 1 | |
| 7 | Los Angeles | 710 | north | 20.4 | 2 | | 1 | 1 | |
| 7 | Los Angeles | 710 | north | 20.8 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 21.2 | 2 | 1 | | | every slab |
| 7 | Los Angeles | 710 | north | 21.8 | 2 | 1 | | | |
| 7 | Los Angeles | 710 | north | 22.2 | 2 | 1 | | | |
| 7 | Los Angeles | 710 | north | 22.6 | 2 | 1 | 1 | | |
| 7 | Los Angeles | 710 | north | 22.8 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 23.4 | 3 | 1 | 1 | | |
| 7 | Los Angeles | 710 | north | 23.6 | 2 | | | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 710 | north | 24.4 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 24.6 | 3 | | | 1 | |
| 7 | Los Angeles | 710 | north | 24.8 | 3 | | | 1 | |
| 7 | Los Angeles | 710 | north | 25.4 | 2 | | | 1 | |
| 7 | Los Angeles | 710 | north | 25.6 | | | | | ACOL |
| 7 | Los Angeles | 710 | north | 26 | 2 | | | | |
| 7 | Los Angeles | 710 | north | 27.2 | 3 | | | | |
| 7 | Los Angeles | 710 | north | 27.4 | | | | | end |
| 7 | Los Angeles | 710 | south | 27.3 | 2 | | | | |
| 7 | Los Angeles | 710 | south | 26.3 | 1 | | | | |
| 7 | Los Angeles | 710 | south | 25.9 | 2 | | | | |
| 7 | Los Angeles | 710 | south | 25.5 | 2 | | 1 | | |
| 7 | Los Angeles | 710 | south | 25.2 | 3 | | | 1 | |
| 7 | Los Angeles | 710 | south | 24.5 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 23.9 | 3 | | 1 | | |
| 7 | Los Angeles | 710 | south | 23.7 | 3 | | 1 | 1 | |
| 7 | Los Angeles | 710 | south | 23.5 | 2 | | | | |
| 7 | Los Angeles | 710 | south | 22.9 | | | | | bridge |
| 7 | Los Angeles | 710 | south | 22.7 | 3 | | 1 | | |
| 7 | Los Angeles | 710 | south | 22.3 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 21.9 | 2 | | 1 | | |
| 7 | Los Angeles | 710 | south | 21.7 | 3 | 1 | | | bad TC |
| 7 | Los Angeles | 710 | south | 21.5 | 1 | | | | |
| 7 | Los Angeles | 710 | south | 20.7 | 2 | | | | |
| 7 | Los Angeles | 710 | south | 20.5 | 2 | 1 | | | |
| 7 | Los Angeles | 710 | south | 19.9 | 3 | 1 | | 1 | |
| 7 | Los Angeles | 710 | south | 16.7 | 1 | | | | |
| 7 | Los Angeles | 710 | south | 15.7 | 1 | | | | spalls |
| 7 | Los Angeles | 710 | south | 15.5 | 1 | | | | |
| 7 | Los Angeles | 710 | south | 14.7 | 3 | 1 | 1 | | |
| 7 | Los Angeles | 710 | south | 14.5 | 2 | | 1 | | CC bad |
| 7 | Los Angeles | 710 | south | 13.5 | 2 | | | | A8 |
| 7 | Los Angeles | 710 | south | 13.1 | 2 | 1 | 1 | | |
| 7 | Los Angeles | 710 | south | 12.9 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 12.5 | 3 | 1 | | | |
| 7 | Los Angeles | 710 | south | 11.5 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 11.3 | 2 | | 1 | | |
| 7 | Los Angeles | 710 | south | 10.9 | 3 | 1 | 1 | | |
| 7 | Los Angeles | 710 | south | 10.7 | 2 | | | | |
| 7 | Los Angeles | 710 | south | 10.5 | 1 | | | | |
| 7 | Los Angeles | 710 | south | 10.3 | 2 | | | | |
| 7 | Los Angeles | 710 | south | 9.9 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 9.7 | 3 | | 1 | | |
| 7 | Los Angeles | 710 | south | 9.5 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 8.9 | 3 | 1 | 1 | | |

| District | County | Route | Direction | Postmile | Faulting | Trans-verse Cracking | Corner Cracking | Longi-tudinal Cracking | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Los Angeles | 710 | south | 8.3 | 3 | 1 | | | spalled; 12-15' jts., no vis defl. fault (~10mm vis) |
| 7 | Los Angeles | 710 | south | 7.9 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 7.7 | 3 | 1 | | | spalled |
| 7 | Los Angeles | 710 | south | 7.5 | 3 | 1 | | | every slab |
| 7 | Los Angeles | 710 | south | 7.3 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 6.9 | 3 | | | | |
| 7 | Los Angeles | 710 | south | 6.85 | | | | | RC holes, ACOL patched |

## APPENDIX B: PCA SENSITIVITY ANALYSIS

| Case | Subgrade K value | Axle Load | Trucks in Lane | Concrete Modulus of Rupture (psi) | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) | Distress Type |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 170 | PCA | 8750 | 500 | Yes | Yes | 1.2 | 11 | Fatigue |
| 2 | 170 | PCA | 17500 | 500 | Yes | Yes | 1.2 | 11.5 | Fatigue |
| 3 | 350 | PCA | 8750 | 500 | Yes | Yes | 1.2 | 10 | Fatigue |
| 4 | 350 | PCA | 17500 | 500 | Yes | Yes | 1.2 | 10.5 | Fatigue |
| 5 | 640 | PCA | 8750 | 500 | Yes | Yes | 1.2 | 9.5 | Fatigue |
| 6 | 640 | PCA | 17500 | 500 | Yes | Yes | 1.2 | 10 | Fatigue |
| 7 | 170 | San Diego | 8750 | 500 | Yes | Yes | 1.2 | 10 | Fatigue |
| 8 | 170 | San Diego | 17500 | 500 | Yes | Yes | 1.2 | 10.5 | Fatigue |
| 9 | 350 | San Diego | 8750 | 500 | Yes | Yes | 1.2 | 9 | Fatigue |
| 10 | 350 | San Diego | 17500 | 500 | Yes | Yes | 1.2 | 9.5 | Fatigue |
| 11 | 640 | San Diego | 8750 | 500 | Yes | Yes | 1.2 | 8.5 | Fatigue |
| 12 | 640 | San Diego | 17500 | 500 | Yes | Yes | 1.2 | 9 | Fatigue |
| 13 | 170 | San Joaquin | 8750 | 500 | Yes | Yes | 1.2 | 10 | Fatigue |
| 14 | 170 | San Joaquin | 17500 | 500 | Yes | Yes | 1.2 | 10.5 | Fatigue |
| 15 | 350 | San Joaquin | 8750 | 500 | Yes | Yes | 1.2 | 9 | Fatigue |
| 16 | 350 | San Joaquin | 17500 | 500 | Yes | Yes | 1.2 | 9.5 | Fatigue |
| 17 | 640 | San Joaquin | 8750 | 500 | Yes | Yes | 1.2 | 8.5 | Fatigue |
| 18 | 640 | San Joaquin | 17500 | 500 | Yes | Yes | 1.2 | 9 | Fatigue |
| 19 | 170 | PCA | 8750 | 650 | Yes | Yes | 1.2 | 9 | Fatigue |
| 20 | 170 | PCA | 17500 | 650 | Yes | Yes | 1.2 | 9.5 | Erosion |
| 21 | 350 | PCA | 8750 | 650 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 22 | 350 | PCA | 17500 | 650 | Yes | Yes | 1.2 | 9 | Erosion |
| 23 | 640 | PCA | 8750 | 650 | Yes | Yes | 1.2 | 8 | Erosion |
| 24 | 640 | PCA | 17500 | 650 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 25 | 170 | San Diego | 8750 | 650 | Yes | Yes | 1.2 | 8.5 | Fatigue |
| 26 | 170 | San Diego | 17500 | 650 | Yes | Yes | 1.2 | 8.5 | Fatigue |
| 27 | 350 | San Diego | 8750 | 650 | Yes | Yes | 1.2 | 7.5 | Fatigue |
| 28 | 350 | San Diego | 17500 | 650 | Yes | Yes | 1.2 | 8 | Fatigue |
| 29 | 640 | San Diego | 8750 | 650 | Yes | Yes | 1.2 | 7 | Erosion |
| 30 | 640 | San Diego | 17500 | 650 | Yes | Yes | 1.2 | 7.5 | Erosion |
| 31 | 170 | San Joaquin | 8750 | 650 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 32 | 170 | San Joaquin | 17500 | 650 | Yes | Yes | 1.2 | 9 | Erosion |
| 33 | 350 | San Joaquin | 8750 | 650 | Yes | Yes | 1.2 | 8 | Erosion |
| 34 | 350 | San Joaquin | 17500 | 650 | Yes | Yes | 1.2 | 8 | Erosion |
| 35 | 640 | San Joaquin | 8750 | 650 | Yes | Yes | 1.2 | 7.5 | Erosion |
| 36 | 640 | San Joaquin | 17500 | 650 | Yes | Yes | 1.2 | 8 | Erosion |
| 37 | 170 | PCA | 8750 | 800 | Yes | Yes | 1.2 | 9 | Erosion |

| **Case** | **Subgrade K value** | **Axle Load** | **Trucks in Lane** | **Concrete Modulus of Rupture (psi)** | **Dowels** | **Tied Shoulder** | **Load Safety Factor** | **Slab Thicknes s (in.)** | **Distress Type** |
|---|---|---|---|---|---|---|---|---|---|
| 38 | 170 | PCA | 17500 | 800 | Yes | Yes | 1.2 | 9.5 | Erosion |
| 39 | 350 | PCA | 8750 | 800 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 40 | 350 | PCA | 17500 | 800 | Yes | Yes | 1.2 | 9 | Erosion |
| 41 | 640 | PCA | 8750 | 800 | Yes | Yes | 1.2 | 8 | Erosion |
| 42 | 640 | PCA | 17500 | 800 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 43 | 170 | San Diego | 8750 | 800 | Yes | Yes | 1.2 | 8 | Erosion |
| 44 | 170 | San Diego | 17500 | 800 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 45 | 350 | San Diego | 8750 | 800 | Yes | Yes | 1.2 | 7.5 | Erosion |
| 46 | 350 | San Diego | 17500 | 800 | Yes | Yes | 1.2 | 7.5 | Erosion |
| 47 | 640 | San Diego | 8750 | 800 | Yes | Yes | 1.2 | 7 | Erosion |
| 48 | 640 | San Diego | 17500 | 800 | Yes | Yes | 1.2 | 7.5 | Erosion |
| 49 | 170 | San Joaquin | 8750 | 800 | Yes | Yes | 1.2 | 8.5 | Erosion |
| 50 | 170 | San Joaquin | 17500 | 800 | Yes | Yes | 1.2 | 9 | Erosion |
| 51 | 350 | San Joaquin | 8750 | 800 | Yes | Yes | 1.2 | 8 | Erosion |
| 52 | 350 | San Joaquin | 17500 | 800 | Yes | Yes | 1.2 | 8 | Erosion |
| 53 | 640 | San Joaquin | 8750 | 800 | Yes | Yes | 1.2 | 7.5 | Erosion |
| 54 | 640 | San Joaquin | 17500 | 800 | Yes | Yes | 1.2 | 8 | Erosion |
| 55 | 170 | PCA | 8750 | 500 | Yes | No | 1.2 | 12.5 | Fatigue |
| 56 | 170 | PCA | 17500 | 500 | Yes | No | 1.2 | 13 | Fatigue |
| 57 | 350 | PCA | 8750 | 500 | Yes | No | 1.2 | 11.5 | Fatigue |
| 58 | 350 | PCA | 17500 | 500 | Yes | No | 1.2 | 12 | Fatigue |
| 59 | 640 | PCA | 8750 | 500 | Yes | No | 1.2 | 10.5 | Fatigue |
| 60 | 640 | PCA | 17500 | 500 | Yes | No | 1.2 | 11 | Fatigue |
| 61 | 170 | San Diego | 8750 | 500 | Yes | No | 1.2 | 11.5 | Fatigue |
| 62 | 170 | San Diego | 17500 | 500 | Yes | No | 1.2 | 12 | Fatigue |
| 63 | 350 | San Diego | 8750 | 500 | Yes | No | 1.2 | 10.5 | Fatigue |
| 64 | 350 | San Diego | 17500 | 500 | Yes | No | 1.2 | 10.5 | Fatigue |
| 65 | 640 | San Diego | 8750 | 500 | Yes | No | 1.2 | 9.5 | Fatigue |
| 66 | 640 | San Diego | 17500 | 500 | Yes | No | 1.2 | 10 | Fatigue |
| 67 | 170 | San Joaquin | 8750 | 500 | Yes | No | 1.2 | 11.5 | Fatigue |
| 68 | 170 | San Joaquin | 17500 | 500 | Yes | No | 1.2 | 12 | Erosion |
| 69 | 350 | San Joaquin | 8750 | 500 | Yes | No | 1.2 | 10.5 | Erosion |
| 70 | 350 | San Joaquin | 17500 | 500 | Yes | No | 1.2 | 11 | Erosion |
| 71 | 640 | San Joaquin | 8750 | 500 | Yes | No | 1.2 | 10 | Erosion |
| 72 | 640 | San Joaquin | 17500 | 500 | Yes | No | 1.2 | 10.5 | Erosion |
| 73 | 170 | PCA | 8750 | 650 | Yes | No | 1.2 | 10.5 | Erosion |
| 74 | 170 | PCA | 17500 | 650 | Yes | No | 1.2 | 11.5 | Erosion |
| 75 | 350 | PCA | 8750 | 650 | Yes | No | 1.2 | 10 | Erosion |
| 76 | 350 | PCA | 17500 | 650 | Yes | No | 1.2 | 10.5 | Erosion |

| **Case** | **Subgrade K value** | **Axle Load** | **Trucks in Lane** | **Concrete Modulus of Rupture (psi)** | **Dowels** | **Tied Shoulder** | **Load Safety Factor** | **Slab Thicknes s (in.)** | **Distress Type** |
|---|---|---|---|---|---|---|---|---|---|
| 77 | 640 | PCA | 8750 | 650 | Yes | No | 1.2 | 10 | Erosion |
| 78 | 640 | PCA | 17500 | 650 | Yes | No | 1.2 | 10.5 | Erosion |
| 79 | 170 | San Diego | 8750 | 650 | Yes | No | 1.2 | 10 | Erosion |
| 80 | 170 | San Diego | 17500 | 650 | Yes | No | 1.2 | 10.5 | Erosion |
| 81 | 350 | San Diego | 8750 | 650 | Yes | No | 1.2 | 9.5 | Erosion |
| 82 | 350 | San Diego | 17500 | 650 | Yes | No | 1.2 | 10 | Erosion |
| 83 | 640 | San Diego | 8750 | 650 | Yes | No | 1.2 | 9 | Erosion |
| 84 | 640 | San Diego | 17500 | 650 | Yes | No | 1.2 | 9.5 | Erosion |
| 85 | 170 | San Joaquin | 8750 | 650 | Yes | No | 1.2 | 11 | Erosion |
| 86 | 170 | San Joaquin | 17500 | 650 | Yes | No | 1.2 | 11.5 | Erosion |
| 87 | 350 | San Joaquin | 8750 | 650 | Yes | No | 1.2 | 10.5 | Erosion |
| 88 | 350 | San Joaquin | 17500 | 650 | Yes | No | 1.2 | 11 | Erosion |
| 89 | 640 | San Joaquin | 8750 | 650 | Yes | No | 1.2 | 10 | Erosion |
| 90 | 640 | San Joaquin | 17500 | 650 | Yes | No | 1.2 | 10.5 | Erosion |
| 91 | 170 | PCA | 8750 | 800 | Yes | No | 1.2 | 10.5 | Erosion |
| 92 | 170 | PCA | 17500 | 800 | Yes | No | 1.2 | 11.5 | Erosion |
| 93 | 350 | PCA | 8750 | 800 | Yes | No | 1.2 | 10 | Erosion |
| 94 | 350 | PCA | 17500 | 800 | Yes | No | 1.2 | 10.5 | Erosion |
| 95 | 640 | PCA | 8750 | 800 | Yes | No | 1.2 | 10 | Erosion |
| 96 | 640 | PCA | 17500 | 800 | Yes | No | 1.2 | 10.5 | Erosion |
| 97 | 170 | San Diego | 8750 | 800 | Yes | No | 1.2 | 10 | Erosion |
| 98 | 170 | San Diego | 17500 | 800 | Yes | No | 1.2 | 10.5 | Erosion |
| 99 | 350 | San Diego | 8750 | 800 | Yes | No | 1.2 | 9.5 | Erosion |
| 100 | 350 | San Diego | 17500 | 800 | Yes | No | 1.2 | 10 | Erosion |
| 101 | 640 | San Diego | 8750 | 800 | Yes | No | 1.2 | 9 | Erosion |
| 102 | 640 | San Diego | 17500 | 800 | Yes | No | 1.2 | 9.5 | Erosion |
| 103 | 170 | San Joaquin | 8750 | 800 | Yes | No | 1.2 | 11 | Erosion |
| 104 | 170 | San Joaquin | 17500 | 800 | Yes | No | 1.2 | 11.5 | Erosion |
| 105 | 350 | San Joaquin | 8750 | 800 | Yes | No | 1.2 | 10.5 | Erosion |
| 106 | 350 | San Joaquin | 17500 | 800 | Yes | No | 1.2 | 11 | Erosion |
| 107 | 640 | San Joaquin | 8750 | 800 | Yes | No | 1.2 | 10 | Erosion |
| 108 | 640 | San Joaquin | 17500 | 800 | Yes | No | 1.2 | 10.5 | Erosion |
| 109 | 170 | PCA | 8750 | 500 | No | Yes | 1.2 | 11.5 | Erosion |
| 110 | 170 | PCA | 17500 | 500 | No | Yes | 1.2 | 12.5 | Erosion |
| 111 | 350 | PCA | 8750 | 500 | No | Yes | 1.2 | 10.5 | Erosion |
| 112 | 350 | PCA | 17500 | 500 | No | Yes | 1.2 | 11 | Erosion |
| 113 | 640 | PCA | 8750 | 500 | No | Yes | 1.2 | 9.5 | Erosion |
| 114 | 640 | PCA | 17500 | 500 | No | Yes | 1.2 | 10.5 | Erosion |
| 115 | 170 | San Diego | 8750 | 500 | No | Yes | 1.2 | 10.5 | Erosion |

| **Case** | **Subgrade K value** | **Axle Load** | **Trucks in Lane** | **Concrete Modulus of Rupture (psi)** | **Dowels** | **Tied Shoulder** | **Load Safety Factor** | **Slab Thicknes s (in.)** | **Distress Type** |
|---|---|---|---|---|---|---|---|---|---|
| 116 | 170 | San Diego | 17500 | 500 | No | Yes | 1.2 | 11 | Erosion |
| 117 | 350 | San Diego | 8750 | 500 | No | Yes | 1.2 | 9 | Erosion |
| 118 | 350 | San Diego | 17500 | 500 | No | Yes | 1.2 | 9.5 | Erosion |
| 119 | 640 | San Diego | 8750 | 500 | No | Yes | 1.2 | 8.5 | Erosion |
| 120 | 640 | San Diego | 17500 | 500 | No | Yes | 1.2 | 9 | Erosion |
| 121 | 170 | San Joaquin | 8750 | 500 | No | Yes | 1.2 | 11 | Erosion |
| 122 | 170 | San Joaquin | 17500 | 500 | No | Yes | 1.2 | 11.5 | Erosion |
| 123 | 350 | San Joaquin | 8750 | 500 | No | Yes | 1.2 | 10 | Erosion |
| 124 | 350 | San Joaquin | 17500 | 500 | No | Yes | 1.2 | 10 | Erosion |
| 125 | 640 | San Joaquin | 8750 | 500 | No | Yes | 1.2 | 9.5 | Erosion |
| 126 | 640 | San Joaquin | 17500 | 500 | No | Yes | 1.2 | 9.5 | Erosion |
| 127 | 170 | PCA | 8750 | 650 | No | Yes | 1.2 | 11.5 | Erosion |
| 128 | 170 | PCA | 17500 | 650 | No | Yes | 1.2 | 12.5 | Erosion |
| 129 | 350 | PCA | 8750 | 650 | No | Yes | 1.2 | 10.5 | Erosion |
| 130 | 350 | PCA | 17500 | 650 | No | Yes | 1.2 | 11 | Erosion |
| 131 | 640 | PCA | 8750 | 650 | No | Yes | 1.2 | 9.5 | Erosion |
| 132 | 640 | PCA | 17500 | 650 | No | Yes | 1.2 | 10.5 | Erosion |
| 133 | 170 | San Diego | 8750 | 650 | No | Yes | 1.2 | 10.5 | Erosion |
| 134 | 170 | San Diego | 17500 | 650 | No | Yes | 1.2 | 11 | Erosion |
| 135 | 350 | San Diego | 8750 | 650 | No | Yes | 1.2 | 9 | Erosion |
| 136 | 350 | San Diego | 17500 | 650 | No | Yes | 1.2 | 9.5 | Erosion |
| 137 | 640 | San Diego | 8750 | 650 | No | Yes | 1.2 | 8.5 | Erosion |
| 138 | 640 | San Diego | 17500 | 650 | No | Yes | 1.2 | 9 | Erosion |
| 139 | 170 | San Joaquin | 8750 | 650 | No | Yes | 1.2 | 11 | Erosion |
| 140 | 170 | San Joaquin | 17500 | 650 | No | Yes | 1.2 | 11.5 | Erosion |
| 141 | 350 | San Joaquin | 8750 | 650 | No | Yes | 1.2 | 10 | Erosion |
| 142 | 350 | San Joaquin | 17500 | 650 | No | Yes | 1.2 | 10 | Erosion |
| 143 | 640 | San Joaquin | 8750 | 650 | No | Yes | 1.2 | 9.5 | Erosion |
| 144 | 640 | San Joaquin | 17500 | 650 | No | Yes | 1.2 | 9.5 | Erosion |
| 145 | 170 | PCA | 8750 | 800 | No | Yes | 1.2 | 11.5 | Erosion |
| 146 | 170 | PCA | 17500 | 800 | No | Yes | 1.2 | 12.5 | Erosion |
| 147 | 350 | PCA | 8750 | 800 | No | Yes | 1.2 | 10.5 | Erosion |
| 148 | 350 | PCA | 17500 | 800 | No | Yes | 1.2 | 11 | Erosion |
| 149 | 640 | PCA | 8750 | 800 | No | Yes | 1.2 | 9.5 | Erosion |
| 150 | 640 | PCA | 17500 | 800 | No | Yes | 1.2 | 10.5 | Erosion |
| 151 | 170 | San Diego | 8750 | 800 | No | Yes | 1.2 | 10.5 | Erosion |
| 152 | 170 | San Diego | 17500 | 800 | No | Yes | 1.2 | 11 | Erosion |
| 153 | 350 | San Diego | 8750 | 800 | No | Yes | 1.2 | 9 | Erosion |
| 154 | 350 | San Diego | 17500 | 800 | No | Yes | 1.2 | 9.5 | Erosion |

| Case | Subgrade K value | Axle Load | Trucks in Lane | Concrete Modulus of Rupture (psi) | Dowels | Tied Shoulder | Load Safety Factor | Slab Thicknes s (in.) | Distress Type |
|---|---|---|---|---|---|---|---|---|---|
| 155 | 640 | San Diego | 8750 | 800 | No | Yes | 1.2 | 8.5 | Erosion |
| 156 | 640 | San Diego | 17500 | 800 | No | Yes | 1.2 | 9 | Erosion |
| 157 | 170 | San Joaquin | 8750 | 800 | No | Yes | 1.2 | 11 | Erosion |
| 158 | 170 | San Joaquin | 17500 | 800 | No | Yes | 1.2 | 11.5 | Erosion |
| 159 | 350 | San Joaquin | 8750 | 800 | No | Yes | 1.2 | 10 | Erosion |
| 160 | 350 | San Joaquin | 17500 | 800 | No | Yes | 1.2 | 10 | Erosion |
| 161 | 640 | San Joaquin | 8750 | 800 | No | Yes | 1.2 | 9.5 | Erosion |
| 162 | 640 | San Joaquin | 17500 | 800 | No | Yes | 1.2 | 9.5 | Erosion |
| 163 | 170 | PCA | 8750 | 500 | No | No | 1.2 | >>14 | Erosion |
| 164 | 170 | PCA | 17500 | 500 | No | No | 1.2 | >>14 | Erosion |
| 165 | 350 | PCA | 8750 | 500 | No | No | 1.2 | 12.5 | Erosion |
| 166 | 350 | PCA | 17500 | 500 | No | No | 1.2 | 13.5 | Erosion |
| 167 | 640 | PCA | 8750 | 500 | No | No | 1.2 | 12 | Erosion |
| 168 | 640 | PCA | 17500 | 500 | No | No | 1.2 | 12.5 | Erosion |
| 169 | 170 | San Diego | 8750 | 500 | No | No | 1.2 | 13.5 | Erosion |
| 170 | 170 | San Diego | 17500 | 500 | No | No | 1.2 | >>14 | Erosion |
| 171 | 350 | San Diego | 8750 | 500 | No | No | 1.2 | 12 | Erosion |
| 172 | 350 | San Diego | 17500 | 500 | No | No | 1.2 | 12.5 | Erosion |
| 173 | 640 | San Diego | 8750 | 500 | No | No | 1.2 | 11 | Erosion |
| 174 | 640 | San Diego | 17500 | 500 | No | No | 1.2 | 11.5 | Erosion |
| 175 | 170 | San Joaquin | 8750 | 500 | No | No | 1.2 | >>14 | Erosion |
| 176 | 170 | San Joaquin | 17500 | 500 | No | No | 1.2 | >>14 | Erosion |
| 177 | 350 | San Joaquin | 8750 | 500 | No | No | 1.2 | 13 | Erosion |
| 178 | 350 | San Joaquin | 17500 | 500 | No | No | 1.2 | 14 | Erosion |
| 179 | 640 | San Joaquin | 8750 | 500 | No | No | 1.2 | 12 | Erosion |
| 180 | 640 | San Joaquin | 17500 | 500 | No | No | 1.2 | 12.5 | Erosion |
| 181 | 170 | PCA | 8750 | 650 | No | No | 1.2 | >>14 | Erosion |
| 182 | 170 | PCA | 17500 | 650 | No | No | 1.2 | >>14 | Erosion |
| 183 | 350 | PCA | 8750 | 650 | No | No | 1.2 | 12.5 | Erosion |
| 184 | 350 | PCA | 17500 | 650 | No | No | 1.2 | 13.5 | Erosion |
| 185 | 640 | PCA | 8750 | 650 | No | No | 1.2 | 12 | Erosion |
| 186 | 640 | PCA | 17500 | 650 | No | No | 1.2 | 12.5 | Erosion |
| 187 | 170 | San Diego | 8750 | 650 | No | No | 1.2 | 13.5 | Erosion |
| 188 | 170 | San Diego | 17500 | 650 | No | No | 1.2 | >>14 | Erosion |
| 189 | 350 | San Diego | 8750 | 650 | No | No | 1.2 | 12 | Erosion |
| 190 | 350 | San Diego | 17500 | 650 | No | No | 1.2 | 12.5 | Erosion |
| 191 | 640 | San Diego | 8750 | 650 | No | No | 1.2 | 11 | Erosion |
| 192 | 640 | San Diego | 17500 | 650 | No | No | 1.2 | 11.5 | Erosion |
| 193 | 170 | San Joaquin | 8750 | 650 | No | No | 1.2 | >>14 | Erosion |

| **Case** | **Subgrade K value** | **Axle Load** | **Trucks in Lane** | **Concrete Modulus of Rupture (psi)** | **Dowels** | **Tied Shoulder** | **Load Safety Factor** | **Slab Thicknes s (in.)** | **Distress Type** |
|---|---|---|---|---|---|---|---|---|---|
| 194 | 170 | San Joaquin | 17500 | 650 | No | No | 1.2 | >>14 | Erosion |
| 195 | 350 | San Joaquin | 8750 | 650 | No | No | 1.2 | 13 | Erosion |
| 196 | 350 | San Joaquin | 17500 | 650 | No | No | 1.2 | 14 | Erosion |
| 197 | 640 | San Joaquin | 8750 | 650 | No | No | 1.2 | 12 | Erosion |
| 198 | 640 | San Joaquin | 17500 | 650 | No | No | 1.2 | 12.5 | Erosion |
| 199 | 170 | PCA | 8750 | 800 | No | No | 1.2 | >>14 | Erosion |
| 200 | 170 | PCA | 17500 | 800 | No | No | 1.2 | >>14 | Erosion |
| 201 | 350 | PCA | 8750 | 800 | No | No | 1.2 | 12.5 | Erosion |
| 202 | 350 | PCA | 17500 | 800 | No | No | 1.2 | 13.5 | Erosion |
| 203 | 640 | PCA | 8750 | 800 | No | No | 1.2 | 12 | Erosion |
| 204 | 640 | PCA | 17500 | 800 | No | No | 1.2 | 12.5 | Erosion |
| 205 | 170 | San Diego | 8750 | 800 | No | No | 1.2 | 13.5 | Erosion |
| 206 | 170 | San Diego | 17500 | 800 | No | No | 1.2 | >>14 | Erosion |
| 207 | 350 | San Diego | 8750 | 800 | No | No | 1.2 | 12 | Erosion |
| 208 | 350 | San Diego | 17500 | 800 | No | No | 1.2 | 12.5 | Erosion |
| 209 | 640 | San Diego | 8750 | 800 | No | No | 1.2 | 11 | Erosion |
| 210 | 640 | San Diego | 17500 | 800 | No | No | 1.2 | 11.5 | Erosion |
| 211 | 170 | San Joaquin | 8750 | 800 | No | No | 1.2 | >>14 | Erosion |
| 212 | 170 | San Joaquin | 17500 | 800 | No | No | 1.2 | >>14 | Erosion |
| 213 | 350 | San Joaquin | 8750 | 800 | No | No | 1.2 | 13 | Erosion |
| 214 | 350 | San Joaquin | 17500 | 800 | No | No | 1.2 | 14 | Erosion |
| 215 | 640 | San Joaquin | 8750 | 800 | No | No | 1.2 | 12 | Erosion |
| 216 | 640 | San Joaquin | 17500 | 800 | No | No | 1.2 | 12.5 | Erosion |

# APPENDIX C: ACPA/AASHTO SENSITIVITY ANALYSIS

## AASHTO SENSITIVITY ANALYSIS

Coefficient of Drainage = 0.8

Reliability = 95%

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture (psi) | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.7 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.19 |
| 2 | 2.7 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.01 |
| 3 | 2.7 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.54 |
| 4 | 2.7 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.37 |
| 5 | 2.7 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.37 |
| 6 | 2.7 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.2 |
| 7 | 2.7 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.17 |
| 8 | 2.7 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.79 |
| 9 | 2.7 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.61 |
| 10 | 2.7 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.19 |
| 11 | 2.7 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.45 |
| 12 | 2.7 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.04 |
| 13 | 2.7 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.77 |
| 14 | 2.7 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.21 |
| 15 | 2.7 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.21 |
| 16 | 2.7 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.66 |
| 17 | 2.7 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.07 |
| 18 | 2.7 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.51 |
| 19 | 2.7 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.18 |
| 20 | 2.7 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19 |
| 21 | 2.7 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.54 |
| 22 | 2.7 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.36 |
| 23 | 2.7 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.37 |
| 24 | 2.7 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.19 |
| 25 | 2.7 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.17 |
| 26 | 2.7 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.78 |
| 27 | 2.7 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.58 |
| 28 | 2.7 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.19 |
| 29 | 2.7 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.42 |
| 30 | 2.7 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.03 |
| 31 | 2.7 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.74 |
| 32 | 2.7 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.21 |
| 33 | 2.7 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.18 |
| 34 | 2.7 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.65 |
| 35 | 2.7 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.03 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture (psi) | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 2.7 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.5 |
| 37 | 2.7 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.16 |
| 38 | 2.7 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 39 | 2.7 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.52 |
| 40 | 2.7 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 41 | 2.7 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.53 |
| 42 | 2.7 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 43 | 2.7 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.92 |
| 44 | 2.7 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.71 |
| 45 | 2.7 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.33 |
| 46 | 2.7 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.12 |
| 47 | 2.7 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.17 |
| 48 | 2.7 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.96 |
| 49 | 2.7 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.33 |
| 50 | 2.7 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.95 |
| 51 | 2.7 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.78 |
| 52 | 2.7 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.4 |
| 53 | 2.7 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.63 |
| 54 | 2.7 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.26 |
| 55 | 3.2 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.7 |
| 56 | 3.2 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 57 | 3.2 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.06 |
| 58 | 3.2 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 59 | 3.2 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.89 |
| 60 | 3.2 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.86 |
| 61 | 3.2 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.51 |
| 62 | 3.2 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.26 |
| 63 | 3.2 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.95 |
| 64 | 3.2 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.67 |
| 65 | 3.2 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.8 |
| 66 | 3.2 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.52 |
| 67 | 3.2 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.99 |
| 68 | 3.2 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.55 |
| 69 | 3.2 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.44 |
| 70 | 3.2 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16 |
| 71 | 3.2 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.29 |
| 72 | 3.2 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.85 |
| 73 | 3.2 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.7 |
| 74 | 3.2 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 75 | 3.2 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.05 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture (psi) | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 76 | 3.2 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 77 | 3.2 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.89 |
| 78 | 3.2 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.86 |
| 79 | 3.2 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.51 |
| 80 | 3.2 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.26 |
| 81 | 3.2 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.92 |
| 82 | 3.2 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.67 |
| 83 | 3.2 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.76 |
| 84 | 3.2 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.51 |
| 85 | 3.2 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.96 |
| 86 | 3.2 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.54 |
| 87 | 3.2 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.41 |
| 88 | 3.2 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.99 |
| 89 | 3.2 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.26 |
| 90 | 3.2 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.85 |
| 91 | 3.2 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 92 | 3.2 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 93 | 3.2 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 94 | 3.2 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 95 | 3.2 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 96 | 3.2 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 97 | 3.2 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.41 |
| 98 | 3.2 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 99 | 3.2 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.81 |
| 100 | 3.2 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.75 |
| 101 | 3.2 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.66 |
| 102 | 3.2 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.59 |
| 103 | 3.2 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.68 |
| 104 | 3.2 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.44 |
| 105 | 3.2 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.13 |
| 106 | 3.2 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.88 |
| 107 | 3.2 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.98 |
| 108 | 3.2 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.74 |
| 109 | 3.6 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.83 |
| 110 | 3.6 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 111 | 3.6 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.18 |
| 112 | 3.6 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 113 | 3.6 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.02 |
| 114 | 3.6 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 115 | 3.6 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.51 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture (psi) | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 116 | 3.6 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.36 |
| 117 | 3.6 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.95 |
| 118 | 3.6 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.76 |
| 119 | 3.6 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.8 |
| 120 | 3.6 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.61 |
| 121 | 3.6 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.9 |
| 122 | 3.6 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.54 |
| 123 | 3.6 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.35 |
| 124 | 3.6 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.99 |
| 125 | 3.6 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.2 |
| 126 | 3.6 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.84 |
| 127 | 3.6 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.82 |
| 128 | 3.6 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 129 | 3.6 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.18 |
| 130 | 3.6 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 131 | 3.6 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.01 |
| 132 | 3.6 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 133 | 3.6 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.51 |
| 134 | 3.6 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.35 |
| 135 | 3.6 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.91 |
| 136 | 3.6 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.76 |
| 137 | 3.6 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.76 |
| 138 | 3.6 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.6 |
| 139 | 3.6 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.86 |
| 140 | 3.6 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.54 |
| 141 | 3.6 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.31 |
| 142 | 3.6 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.99 |
| 143 | 3.6 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.16 |
| 144 | 3.6 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.84 |
| 145 | 3.6 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 146 | 3.6 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 147 | 3.6 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 148 | 3.6 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 149 | 3.6 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 150 | 3.6 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 151 | 3.6 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.51 |
| 152 | 3.6 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 153 | 3.6 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.92 |
| 154 | 3.6 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 155 | 3.6 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.76 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture (psi) | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 156 | 3.6 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 157 | 3.6 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.68 |
| 158 | 3.6 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 19.53 |
| 159 | 3.6 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.13 |
| 160 | 3.6 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.98 |
| 161 | 3.6 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.98 |
| 162 | 3.6 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.84 |
| 163 | 4.3 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 164 | 4.3 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 165 | 4.3 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 166 | 4.3 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 167 | 4.3 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 168 | 4.3 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 169 | 4.3 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.12 |
| 170 | 4.3 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 171 | 4.3 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.56 |
| 172 | 4.3 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 173 | 4.3 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.41 |
| 174 | 4.3 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 175 | 4.3 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.36 |
| 176 | 4.3 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 19.15 |
| 177 | 4.3 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.81 |
| 178 | 4.3 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.59 |
| 179 | 4.3 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.66 |
| 180 | 4.3 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.45 |
| 181 | 4.3 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 182 | 4.3 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 183 | 4.3 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 184 | 4.3 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 185 | 4.3 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 186 | 4.3 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 187 | 4.3 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.11 |
| 188 | 4.3 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 189 | 4.3 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.52 |
| 190 | 4.3 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 191 | 4.3 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.37 |
| 192 | 4.3 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 193 | 4.3 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.32 |
| 194 | 4.3 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 19.14 |
| 195 | 4.3 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.77 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture (psi) | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 196 | 4.3 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.59 |
| 197 | 4.3 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.63 |
| 198 | 4.3 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.45 |
| 199 | 4.3 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 200 | 4.3 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 201 | 4.3 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 202 | 4.3 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 203 | 4.3 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 204 | 4.3 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20 |
| 205 | 4.3 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 206 | 4.3 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 207 | 4.3 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 208 | 4.3 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 209 | 4.3 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 210 | 4.3 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 20 |
| 211 | 4.3 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 19.3 |
| 212 | 4.3 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 20 |
| 213 | 4.3 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.75 |
| 214 | 4.3 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 20 |
| 215 | 4.3 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 18.6 |
| 216 | 4.3 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 20 |

## AASHTO SENSITIVITY ANALYSIS

Coefficient of Drainage = 1.2
Reliability = 95%

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.7 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.02 |
| 2 | 2.7 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.53 |
| 3 | 2.7 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 13.36 |
| 4 | 2.7 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.88 |
| 5 | 2.7 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 13.19 |
| 6 | 2.7 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.71 |
| 7 | 2.7 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.36 |
| 8 | 2.7 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.70 |
| 9 | 2.7 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 11.76 |
| 10 | 2.7 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.10 |
| 11 | 2.7 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 11.59 |
| 12 | 2.7 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.95 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 2.7 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.19 |
| 14 | 2.7 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.40 |
| 15 | 2.7 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 10.62 |
| 16 | 2.7 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.85 |
| 17 | 2.7 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 10.47 |
| 18 | 2.7 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.70 |
| 19 | 2.7 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.01 |
| 20 | 2.7 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.52 |
| 21 | 2.7 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 13.36 |
| 22 | 2.7 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.87 |
| 23 | 2.7 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 13.18 |
| 24 | 2.7 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.70 |
| 25 | 2.7 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.36 |
| 26 | 2.7 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.69 |
| 27 | 2.7 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 11.75 |
| 28 | 2.7 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.10 |
| 29 | 2.7 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 11.59 |
| 30 | 2.7 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.94 |
| 31 | 2.7 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.18 |
| 32 | 2.7 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.40 |
| 33 | 2.7 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 10.62 |
| 34 | 2.7 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.84 |
| 35 | 2.7 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 10.46 |
| 36 | 2.7 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.69 |
| 37 | 2.7 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.65 |
| 38 | 2.7 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.32 |
| 39 | 2.7 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.00 |
| 40 | 2.7 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.68 |
| 41 | 2.7 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.83 |
| 42 | 2.7 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.51 |
| 43 | 2.7 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.81 |
| 44 | 2.7 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.29 |
| 45 | 2.7 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.22 |
| 46 | 2.7 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.70 |
| 47 | 2.7 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.06 |
| 36 | 2.7 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.54 |
| 37 | 2.7 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.51 |
| 38 | 2.7 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.85 |
| 39 | 2.7 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.95 |
| 40 | 2.7 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.30 |
| 41 | 2.7 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.80 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 42 | 2.7 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.15 |
| 43 | 3.2 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.27 |
| 44 | 3.2 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.91 |
| 45 | 3.2 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.63 |
| 46 | 3.2 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.26 |
| 47 | 3.2 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.45 |
| 48 | 3.2 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.09 |
| 49 | 3.2 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.47 |
| 50 | 3.2 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.92 |
| 51 | 3.2 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.88 |
| 52 | 3.2 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.33 |
| 53 | 3.2 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.72 |
| 54 | 3.2 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.17 |
| 55 | 3.2 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.20 |
| 56 | 3.2 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.52 |
| 57 | 3.2 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.64 |
| 58 | 3.2 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.96 |
| 59 | 3.2 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.49 |
| 60 | 3.2 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.82 |
| 61 | 3.2 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.27 |
| 62 | 3.2 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.90 |
| 63 | 3.2 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.62 |
| 64 | 3.2 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.26 |
| 65 | 3.2 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 14.45 |
| 66 | 3.2 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.09 |
| 67 | 3.2 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.47 |
| 68 | 3.2 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.92 |
| 69 | 3.2 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.87 |
| 70 | 3.2 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.33 |
| 71 | 3.2 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 12.71 |
| 72 | 3.2 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.17 |
| 73 | 3.2 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.20 |
| 74 | 3.2 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.51 |
| 75 | 3.2 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.64 |
| 76 | 3.2 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.96 |
| 77 | 3.2 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 11.49 |
| 78 | 3.2 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.81 |
| 79 | 3.2 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.04 |
| 80 | 3.2 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.85 |
| 81 | 3.2 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.40 |
| 82 | 3.2 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.21 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 83 | 3.2 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.23 |
| 84 | 3.2 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.04 |
| 85 | 3.2 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.04 |
| 86 | 3.2 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.64 |
| 87 | 3.2 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.45 |
| 88 | 3.2 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.05 |
| 89 | 3.2 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.29 |
| 90 | 3.2 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.90 |
| 91 | 3.2 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.63 |
| 92 | 3.2 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.08 |
| 93 | 3.2 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.07 |
| 94 | 3.2 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.53 |
| 95 | 3.2 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.92 |
| 96 | 3.2 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.38 |
| 97 | 3.6 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.20 |
| 98 | 3.6 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.93 |
| 99 | 3.6 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.56 |
| 100 | 3.6 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.28 |
| 101 | 3.6 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.38 |
| 102 | 3.6 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.11 |
| 103 | 3.6 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.30 |
| 104 | 3.6 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.83 |
| 105 | 3.6 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.71 |
| 106 | 3.6 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.24 |
| 107 | 3.6 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.55 |
| 108 | 3.6 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.08 |
| 109 | 3.6 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.95 |
| 110 | 3.6 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.34 |
| 111 | 3.6 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.40 |
| 112 | 3.6 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.79 |
| 113 | 3.6 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.24 |
| 114 | 3.6 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.64 |
| 115 | 3.6 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.20 |
| 116 | 3.6 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.92 |
| 117 | 3.6 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.56 |
| 118 | 3.6 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.28 |
| 119 | 3.6 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 15.38 |
| 120 | 3.6 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.11 |
| 121 | 3.6 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.30 |
| 122 | 3.6 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.82 |
| 123 | 3.6 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.70 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 124 | 3.6 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.23 |
| 125 | 3.6 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 13.54 |
| 126 | 3.6 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.08 |
| 127 | 3.6 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.95 |
| 128 | 3.6 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.34 |
| 129 | 3.6 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.39 |
| 130 | 3.6 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.78 |
| 131 | 3.6 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 12.24 |
| 132 | 3.6 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.64 |
| 133 | 3.6 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.07 |
| 134 | 3.6 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.98 |
| 135 | 3.6 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.43 |
| 136 | 3.6 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.34 |
| 137 | 3.6 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.26 |
| 138 | 3.6 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.17 |
| 139 | 3.6 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.95 |
| 140 | 3.6 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.65 |
| 141 | 3.6 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.36 |
| 142 | 3.6 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.06 |
| 143 | 3.6 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.21 |
| 144 | 3.6 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.90 |
| 145 | 3.6 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.45 |
| 146 | 3.6 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.99 |
| 147 | 3.6 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.90 |
| 148 | 3.6 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.44 |
| 149 | 3.6 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.76 |
| 150 | 3.6 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.30 |
| 151 | 4.3 | 100 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.71 |
| 152 | 4.3 | 100 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.59 |
| 153 | 4.3 | 353 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.06 |
| 154 | 4.3 | 353 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.94 |
| 155 | 4.3 | 457 | PCA | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.89 |
| 156 | 4.3 | 457 | PCA | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.77 |
| 157 | 4.3 | 100 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.63 |
| 158 | 4.3 | 100 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.29 |
| 159 | 4.3 | 353 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.04 |
| 160 | 4.3 | 353 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.70 |
| 161 | 4.3 | 457 | PCA | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.88 |
| 162 | 4.3 | 457 | PCA | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.55 |
| 163 | 4.3 | 100 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.16 |
| 164 | 4.3 | 100 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.67 |

| Case | Joint Load Transfer | Subgrade K Value | Axle Load Location | ADTT (trucks/lane one direction) | Concrete Modulus of Rupture | Concrete Elastic Modulus Epcc | Dowels | Tied Shoulder | Load Safety Factor | Slab Thickness (in.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 165 | 4.3 | 353 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.61 |
| 166 | 4.3 | 353 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.12 |
| 167 | 4.3 | 457 | PCA | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.46 |
| 168 | 4.3 | 457 | PCA | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.97 |
| 169 | 4.3 | 100 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.70 |
| 170 | 4.3 | 100 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.58 |
| 171 | 4.3 | 353 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 17.06 |
| 172 | 4.3 | 353 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.93 |
| 173 | 4.3 | 457 | San Diego | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 16.89 |
| 174 | 4.3 | 457 | San Diego | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.76 |
| 175 | 4.3 | 100 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.63 |
| 176 | 4.3 | 100 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.29 |
| 177 | 4.3 | 353 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 15.04 |
| 178 | 4.3 | 353 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.70 |
| 179 | 4.3 | 457 | San Diego | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 14.88 |
| 180 | 4.3 | 457 | San Diego | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.54 |
| 181 | 4.3 | 100 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.16 |
| 182 | 4.3 | 100 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.67 |
| 183 | 4.3 | 353 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.60 |
| 184 | 4.3 | 353 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.11 |
| 185 | 4.3 | 457 | San Diego | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 13.46 |
| 186 | 4.3 | 457 | San Diego | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 14.97 |
| 187 | 4.3 | 100 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.78 |
| 188 | 4.3 | 100 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20.00 |
| 189 | 4.3 | 353 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 19.09 |
| 190 | 4.3 | 353 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20.00 |
| 191 | 4.3 | 457 | San Joaquin | 8750 | 500 | 3.375×106 | Yes | Yes | 1.2 | 18.92 |
| 192 | 4.3 | 457 | San Joaquin | 17500 | 500 | 3.375×106 | Yes | Yes | 1.2 | 20.00 |
| 193 | 4.3 | 100 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 17.43 |
| 194 | 4.3 | 100 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 19.27 |
| 195 | 4.3 | 353 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.84 |
| 196 | 4.3 | 353 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.68 |
| 197 | 4.3 | 457 | San Joaquin | 8750 | 650 | 4.388×106 | Yes | Yes | 1.2 | 16.68 |
| 198 | 4.3 | 457 | San Joaquin | 17500 | 650 | 4.388×106 | Yes | Yes | 1.2 | 18.52 |
| 199 | 4.3 | 100 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.79 |
| 200 | 4.3 | 100 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 17.46 |
| 201 | 4.3 | 353 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.24 |
| 202 | 4.3 | 353 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.91 |
| 203 | 4.3 | 457 | San Joaquin | 8750 | 800 | 5.400×106 | Yes | Yes | 1.2 | 15.10 |
| 204 | 4.3 | 457 | San Joaquin | 17500 | 800 | 5.400×106 | Yes | Yes | 1.2 | 16.77 |

## APPENDIX D: ILLINOIS DEPARTMENT OF TRANSPORTATION, ILLICON RESULTS

In the “Shoulder” column of the tables in this appendix, the following abbreviations apply:

| | |
|---|---|
| AC | asphalt concrete shoulder |
| High LTE | High Load Transfer Efficiency |
| Low LTE | Low Load Transfer Efficiency |
| .3m | widened lane, .3m additional width |
| .6m | widened lane, .6m additional width |

### ILLICON Results - Main Experiment

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Los Angeles | 15 | AC | PCA | 100 | 500 | 12 |
| Los Angeles | 15 | AC | PCA | 100 | 650 | 10.5 |
| Los Angeles | 15 | AC | PCA | 100 | 800 | 9 |
| Los Angeles | 15 | AC | PCA | 250 | 500 | 13 |
| Los Angeles | 15 | AC | PCA | 250 | 650 | 11 |
| Los Angeles | 15 | AC | PCA | 250 | 800 | 9.5 |
| Los Angeles | 15 | AC | PCA | 500 | 500 | 13.5 |
| Los Angeles | 15 | AC | PCA | 500 | 650 | 11 |
| Los Angeles | 15 | AC | PCA | 500 | 800 | 9 |
| Los Angeles | 15 | AC | San Diego | 100 | 500 | 11.5 |
| Los Angeles | 15 | AC | San Diego | 100 | 650 | 10 |
| Los Angeles | 15 | AC | San Diego | 100 | 800 | 9 |
| Los Angeles | 15 | AC | San Diego | 250 | 500 | 12.5 |
| Los Angeles | 15 | AC | San Diego | 250 | 650 | 10.5 |
| Los Angeles | 15 | AC | San Diego | 250 | 800 | 9 |
| Los Angeles | 15 | AC | San Diego | 500 | 500 | 13 |
| Los Angeles | 15 | AC | San Diego | 500 | 650 | 10.5 |
| Los Angeles | 15 | AC | San Diego | 500 | 800 | 8.5 |
| Los Angeles | 15 | AC | San Joaquin | 100 | 500 | 11.5 |
| Los Angeles | 15 | AC | San Joaquin | 100 | 650 | 10 |
| Los Angeles | 15 | AC | San Joaquin | 100 | 800 | 9 |
| Los Angeles | 15 | AC | San Joaquin | 250 | 500 | 12.5 |
| Los Angeles | 15 | AC | San Joaquin | 250 | 650 | 10.5 |
| Los Angeles | 15 | AC | San Joaquin | 250 | 800 | 9 |
| Los Angeles | 15 | AC | San Joaquin | 500 | 500 | 13 |
| Los Angeles | 15 | AC | San Joaquin | 500 | 650 | 11 |
| Los Angeles | 15 | AC | San Joaquin | 500 | 800 | 9 |
| Los Angeles | 15 | Low LTE | PCA | 100 | 500 | 12 |
| Los Angeles | 15 | Low LTE | PCA | 100 | 650 | 10.5 |
| Los Angeles | 15 | Low LTE | PCA | 100 | 800 | 9 |
| Los Angeles | 15 | Low LTE | PCA | 250 | 500 | 12.5 |
| Los Angeles | 15 | Low LTE | PCA | 250 | 650 | 10.5 |
| Los Angeles | 15 | Low LTE | PCA | 250 | 800 | 9.5 |
| Los Angeles | 15 | Low LTE | PCA | 500 | 500 | 13 |

| **Climatic region** | **Slab Length (ft.)** | **Shoulder** | **Traffic** | **k-value** | **Concrete Modulus of Rupture (psi)** | **Thickness (in.)** |
|---|---|---|---|---|---|---|
| Los Angeles | 15 | Low LTE | PCA | 500 | 650 | 11 |
| Los Angeles | 15 | Low LTE | PCA | 500 | 800 | 9 |
| Los Angeles | 15 | Low LTE | San Diego | 100 | 500 | 11.5 |
| Los Angeles | 15 | Low LTE | San Diego | 100 | 650 | 10 |
| Los Angeles | 15 | Low LTE | San Diego | 100 | 800 | 8.5 |
| Los Angeles | 15 | Low LTE | San Diego | 250 | 500 | 12 |
| Los Angeles | 15 | Low LTE | San Diego | 250 | 650 | 10.5 |
| Los Angeles | 15 | Low LTE | San Diego | 250 | 800 | 9 |
| Los Angeles | 15 | Low LTE | San Diego | 500 | 500 | 13 |
| Los Angeles | 15 | Low LTE | San Diego | 500 | 650 | 10.5 |
| Los Angeles | 15 | Low LTE | San Diego | 500 | 800 | 8.5 |
| Los Angeles | 15 | Low LTE | San Joaquin | 100 | 500 | 11.5 |
| Los Angeles | 15 | Low LTE | San Joaquin | 100 | 650 | 10 |
| Los Angeles | 15 | Low LTE | San Joaquin | 100 | 800 | 9 |
| Los Angeles | 15 | Low LTE | San Joaquin | 250 | 500 | 12.5 |
| Los Angeles | 15 | Low LTE | San Joaquin | 250 | 650 | 10.5 |
| Los Angeles | 15 | Low LTE | San Joaquin | 250 | 800 | 9 |
| Los Angeles | 15 | Low LTE | San Joaquin | 500 | 500 | 13 |
| Los Angeles | 15 | Low LTE | San Joaquin | 500 | 650 | 11 |
| Los Angeles | 15 | Low LTE | San Joaquin | 500 | 800 | 9 |
| Los Angeles | 15 | High LTE | PCA | 100 | 500 | 10 |
| Los Angeles | 15 | High LTE | PCA | 100 | 650 | 8.5 |
| Los Angeles | 15 | High LTE | PCA | 100 | 800 | 7.5 |
| Los Angeles | 15 | High LTE | PCA | 250 | 500 | 11 |
| Los Angeles | 15 | High LTE | PCA | 250 | 650 | 9 |
| Los Angeles | 15 | High LTE | PCA | 250 | 800 | 7.5 |
| Los Angeles | 15 | High LTE | PCA | 500 | 500 | 11.5 |
| Los Angeles | 15 | High LTE | PCA | 500 | 650 | 9 |
| Los Angeles | 15 | High LTE | PCA | 500 | 800 | 7 |
| Los Angeles | 15 | High LTE | San Diego | 100 | 500 | 9.5 |
| Los Angeles | 15 | High LTE | San Diego | 100 | 650 | 8 |
| Los Angeles | 15 | High LTE | San Diego | 100 | 800 | 7 |
| Los Angeles | 15 | High LTE | San Diego | 250 | 500 | 10.5 |
| Los Angeles | 15 | High LTE | San Diego | 250 | 650 | 8.5 |
| Los Angeles | 15 | High LTE | San Diego | 250 | 800 | 7 |
| Los Angeles | 15 | High LTE | San Diego | 500 | 500 | 11.5 |
| Los Angeles | 15 | High LTE | San Diego | 500 | 650 | 8.5 |
| Los Angeles | 15 | High LTE | San Diego | 500 | 800 | 6.5 |
| Los Angeles | 15 | High LTE | San Joaquin | 100 | 500 | 10 |
| Los Angeles | 15 | High LTE | San Joaquin | 100 | 650 | 8.5 |
| Los Angeles | 15 | High LTE | San Joaquin | 100 | 800 | 7 |
| Los Angeles | 15 | High LTE | San Joaquin | 250 | 500 | 11 |
| Los Angeles | 15 | High LTE | San Joaquin | 250 | 650 | 9 |
| Los Angeles | 15 | High LTE | San Joaquin | 250 | 800 | 7 |
| Los Angeles | 15 | High LTE | San Joaquin | 500 | 500 | 11.5 |
| Los Angeles | 15 | High LTE | San Joaquin | 500 | 650 | 9 |
| Los Angeles | 15 | High LTE | San Joaquin | 500 | 800 | 7 |

| **Climatic region** | **Slab Length (ft.)** | **Shoulder** | **Traffic** | **k-value** | **Concrete Modulus of Rupture (psi)** | **Thickness (in.)** |
|---|---|---|---|---|---|---|
| Los Angeles | 15 | 0.3m | PCA | 100 | 500 | 11.5 |
| Los Angeles | 15 | 0.3m | PCA | 100 | 650 | 10 |
| Los Angeles | 15 | 0.3m | PCA | 100 | 800 | 9 |
| Los Angeles | 15 | 0.3m | PCA | 250 | 500 | 12 |
| Los Angeles | 15 | 0.3m | PCA | 250 | 650 | 10.5 |
| Los Angeles | 15 | 0.3m | PCA | 250 | 800 | 9 |
| Los Angeles | 15 | 0.3m | PCA | 500 | 500 | 12.5 |
| Los Angeles | 15 | 0.3m | PCA | 500 | 650 | 10.5 |
| Los Angeles | 15 | 0.3m | PCA | 500 | 800 | 8.5 |
| Los Angeles | 15 | 0.3m | San Diego | 100 | 500 | 11 |
| Los Angeles | 15 | 0.3m | San Diego | 100 | 650 | 9.5 |
| Los Angeles | 15 | 0.3m | San Diego | 100 | 800 | 8.5 |
| Los Angeles | 15 | 0.3m | San Diego | 250 | 500 | 11.5 |
| Los Angeles | 15 | 0.3m | San Diego | 250 | 650 | 10 |
| Los Angeles | 15 | 0.3m | San Diego | 250 | 800 | 8.5 |
| Los Angeles | 15 | 0.3m | San Diego | 500 | 500 | 12 |
| Los Angeles | 15 | 0.3m | San Diego | 500 | 650 | 10 |
| Los Angeles | 15 | 0.3m | San Diego | 500 | 800 | 8 |
| Los Angeles | 15 | 0.3m | San Joaquin | 100 | 500 | 11 |
| Los Angeles | 15 | 0.3m | San Joaquin | 100 | 650 | 9.5 |
| Los Angeles | 15 | 0.3m | San Joaquin | 100 | 800 | 8.5 |
| Los Angeles | 15 | 0.3m | San Joaquin | 250 | 500 | 12 |
| Los Angeles | 15 | 0.3m | San Joaquin | 250 | 650 | 10 |
| Los Angeles | 15 | 0.3m | San Joaquin | 250 | 800 | 8.5 |
| Los Angeles | 15 | 0.3m | San Joaquin | 500 | 500 | 12.5 |
| Los Angeles | 15 | 0.3m | San Joaquin | 500 | 650 | 10 |
| Los Angeles | 15 | 0.3m | San Joaquin | 500 | 800 | 8.5 |
| Los Angeles | 15 | 0.6m | PCA | 100 | 500 | 10 |
| Los Angeles | 15 | 0.6m | PCA | 100 | 650 | 8.5 |
| Los Angeles | 15 | 0.6m | PCA | 100 | 800 | 7 |
| Los Angeles | 15 | 0.6m | PCA | 250 | 500 | 10.5 |
| Los Angeles | 15 | 0.6m | PCA | 250 | 650 | 8.5 |
| Los Angeles | 15 | 0.6m | PCA | 250 | 800 | 6.5 |
| Los Angeles | 15 | 0.6m | PCA | 500 | 500 | 11 |
| Los Angeles | 15 | 0.6m | PCA | 500 | 650 | 8 |
| Los Angeles | 15 | 0.6m | PCA | 500 | 800 | 6 |
| Los Angeles | 15 | 0.6m | San Diego | 100 | 500 | 9.5 |
| Los Angeles | 15 | 0.6m | San Diego | 100 | 650 | 8 |
| Los Angeles | 15 | 0.6m | San Diego | 100 | 800 | 6.5 |
| Los Angeles | 15 | 0.6m | San Diego | 250 | 500 | 10 |
| Los Angeles | 15 | 0.6m | San Diego | 250 | 650 | 8 |
| Los Angeles | 15 | 0.6m | San Diego | 250 | 800 | 6 |
| Los Angeles | 15 | 0.6m | San Diego | 500 | 500 | 10.5 |
| Los Angeles | 15 | 0.6m | San Diego | 500 | 650 | 7.5 |
| Los Angeles | 15 | 0.6m | San Diego | 500 | 800 | 5.5 |
| Los Angeles | 15 | 0.6m | San Joaquin | 100 | 500 | 9.5 |
| Los Angeles | 15 | 0.6m | San Joaquin | 100 | 650 | 8 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Los Angeles | 15 | 0.6m | San Joaquin | 100 | 800 | 7 |
| Los Angeles | 15 | 0.6m | San Joaquin | 250 | 500 | 10 |
| Los Angeles | 15 | 0.6m | San Joaquin | 250 | 650 | 8 |
| Los Angeles | 15 | 0.6m | San Joaquin | 250 | 800 | 6.5 |
| Los Angeles | 15 | 0.6m | San Joaquin | 500 | 500 | 11 |
| Los Angeles | 15 | 0.6m | San Joaquin | 500 | 650 | 8 |
| Los Angeles | 15 | 0.6m | San Joaquin | 500 | 800 | 6 |
| Los Angeles | 19 | AC | PCA | 100 | 500 | 14 |
| Los Angeles | 19 | AC | PCA | 100 | 650 | 11.5 |
| Los Angeles | 19 | AC | PCA | 100 | 800 | 10 |
| Los Angeles | 19 | AC | PCA | 250 | 500 | 15 |
| Los Angeles | 19 | AC | PCA | 250 | 650 | 12.5 |
| Los Angeles | 19 | AC | PCA | 250 | 800 | 10.5 |
| Los Angeles | 19 | AC | PCA | 500 | 500 | 16 |
| Los Angeles | 19 | AC | PCA | 500 | 650 | 12.5 |
| Los Angeles | 19 | AC | PCA | 500 | 800 | 10 |
| Los Angeles | 19 | AC | San Diego | 100 | 500 | 13 |
| Los Angeles | 19 | AC | San Diego | 100 | 650 | 11 |
| Los Angeles | 19 | AC | San Diego | 100 | 800 | 9.5 |
| Los Angeles | 19 | AC | San Diego | 250 | 500 | 14.5 |
| Los Angeles | 19 | AC | San Diego | 250 | 650 | 12 |
| Los Angeles | 19 | AC | San Diego | 250 | 800 | 10 |
| Los Angeles | 19 | AC | San Diego | 500 | 500 | 15.5 |
| Los Angeles | 19 | AC | San Diego | 500 | 650 | 12 |
| Los Angeles | 19 | AC | San Diego | 500 | 800 | 9.5 |
| Los Angeles | 19 | AC | San Joaquin | 100 | 500 | 13.5 |
| Los Angeles | 19 | AC | San Joaquin | 100 | 650 | 11.5 |
| Los Angeles | 19 | AC | San Joaquin | 100 | 800 | 10 |
| Los Angeles | 19 | AC | San Joaquin | 250 | 500 | 15 |
| Los Angeles | 19 | AC | San Joaquin | 250 | 650 | 12 |
| Los Angeles | 19 | AC | San Joaquin | 250 | 800 | 10 |
| Los Angeles | 19 | AC | San Joaquin | 500 | 500 | 16 |
| Los Angeles | 19 | AC | San Joaquin | 500 | 650 | 12.5 |
| Los Angeles | 19 | AC | San Joaquin | 500 | 800 | 10 |
| Los Angeles | 19 | Low LTE | PCA | 100 | 500 | 13.5 |
| Los Angeles | 19 | Low LTE | PCA | 100 | 650 | 11.5 |
| Los Angeles | 19 | Low LTE | PCA | 100 | 800 | 10 |
| Los Angeles | 19 | Low LTE | PCA | 250 | 500 | 15 |
| Los Angeles | 19 | Low LTE | PCA | 250 | 650 | 12 |
| Los Angeles | 19 | Low LTE | PCA | 250 | 800 | 10 |
| Los Angeles | 19 | Low LTE | PCA | 500 | 500 | 16 |
| Los Angeles | 19 | Low LTE | PCA | 500 | 650 | 12.5 |
| Los Angeles | 19 | Low LTE | PCA | 500 | 800 | 10 |
| Los Angeles | 19 | Low LTE | San Diego | 100 | 500 | 13 |
| Los Angeles | 19 | Low LTE | San Diego | 100 | 650 | 11 |
| Los Angeles | 19 | Low LTE | San Diego | 100 | 800 | 9.5 |
| Los Angeles | 19 | Low LTE | San Diego | 250 | 500 | 14.5 |

| **Climatic region** | **Slab Length (ft.)** | **Shoulder** | **Traffic** | **k-value** | **Concrete Modulus of Rupture (psi)** | **Thickness (in.)** |
|---|---|---|---|---|---|---|
| Los Angeles | 19 | Low LTE | San Diego | 250 | 650 | 11.5 |
| Los Angeles | 19 | Low LTE | San Diego | 250 | 800 | 9.5 |
| Los Angeles | 19 | Low LTE | San Diego | 500 | 500 | 15.5 |
| Los Angeles | 19 | Low LTE | San Diego | 500 | 650 | 12 |
| Los Angeles | 19 | Low LTE | San Diego | 500 | 800 | 9.5 |
| Los Angeles | 19 | Low LTE | San Joaquin | 100 | 500 | 13.5 |
| Los Angeles | 19 | Low LTE | San Joaquin | 100 | 650 | 11.5 |
| Los Angeles | 19 | Low LTE | San Joaquin | 100 | 800 | 10 |
| Los Angeles | 19 | Low LTE | San Joaquin | 250 | 500 | 15 |
| Los Angeles | 19 | Low LTE | San Joaquin | 250 | 650 | 12 |
| Los Angeles | 19 | Low LTE | San Joaquin | 250 | 800 | 10 |
| Los Angeles | 19 | Low LTE | San Joaquin | 500 | 500 | 16 |
| Los Angeles | 19 | Low LTE | San Joaquin | 500 | 650 | 12.5 |
| Los Angeles | 19 | Low LTE | San Joaquin | 500 | 800 | 10 |
| Los Angeles | 19 | High LTE | PCA | 100 | 500 | 12 |
| Los Angeles | 19 | High LTE | PCA | 100 | 650 | 10 |
| Los Angeles | 19 | High LTE | PCA | 100 | 800 | 8 |
| Los Angeles | 19 | High LTE | PCA | 250 | 500 | 13 |
| Los Angeles | 19 | High LTE | PCA | 250 | 650 | 10.5 |
| Los Angeles | 19 | High LTE | PCA | 250 | 800 | 8 |
| Los Angeles | 19 | High LTE | PCA | 500 | 500 | 14.5 |
| Los Angeles | 19 | High LTE | PCA | 500 | 650 | 10.5 |
| Los Angeles | 19 | High LTE | PCA | 500 | 800 | 7.5 |
| Los Angeles | 19 | High LTE | San Diego | 100 | 500 | 11.5 |
| Los Angeles | 19 | High LTE | San Diego | 100 | 650 | 9.5 |
| Los Angeles | 19 | High LTE | San Diego | 100 | 800 | 7.5 |
| Los Angeles | 19 | High LTE | San Diego | 250 | 500 | 13 |
| Los Angeles | 19 | High LTE | San Diego | 250 | 650 | 10 |
| Los Angeles | 19 | High LTE | San Diego | 250 | 800 | 7.5 |
| Los Angeles | 19 | High LTE | San Diego | 500 | 500 | 14 |
| Los Angeles | 19 | High LTE | San Diego | 500 | 650 | 10 |
| Los Angeles | 19 | High LTE | San Diego | 500 | 800 | 7 |
| Los Angeles | 19 | High LTE | San Joaquin | 100 | 500 | 11.5 |
| Los Angeles | 19 | High LTE | San Joaquin | 100 | 650 | 9.5 |
| Los Angeles | 19 | High LTE | San Joaquin | 100 | 800 | 8 |
| Los Angeles | 19 | High LTE | San Joaquin | 250 | 500 | 13.5 |
| Los Angeles | 19 | High LTE | San Joaquin | 250 | 650 | 10.5 |
| Los Angeles | 19 | High LTE | San Joaquin | 250 | 800 | 8 |
| Los Angeles | 19 | High LTE | San Joaquin | 500 | 500 | 14.5 |
| Los Angeles | 19 | High LTE | San Joaquin | 500 | 650 | 11 |
| Los Angeles | 19 | High LTE | San Joaquin | 500 | 800 | 7.5 |
| Los Angeles | 19 | 0.3m | PCA | 100 | 500 | 13 |
| Los Angeles | 19 | 0.3m | PCA | 100 | 650 | 11 |
| Los Angeles | 19 | 0.3m | PCA | 100 | 800 | 9.5 |
| Los Angeles | 19 | 0.3m | PCA | 250 | 500 | 14 |
| Los Angeles | 19 | 0.3m | PCA | 250 | 650 | 11.5 |
| Los Angeles | 19 | 0.3m | PCA | 250 | 800 | 9.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Los Angeles | 19 | 0.3m | PCA | 500 | 500 | 15 |
| Los Angeles | 19 | 0.3m | PCA | 500 | 650 | 11.5 |
| Los Angeles | 19 | 0.3m | PCA | 500 | 800 | 9 |
| Los Angeles | 19 | 0.3m | San Diego | 100 | 500 | 12.5 |
| Los Angeles | 19 | 0.3m | San Diego | 100 | 650 | 10.5 |
| Los Angeles | 19 | 0.3m | San Diego | 100 | 800 | 9 |
| Los Angeles | 19 | 0.3m | San Diego | 250 | 500 | 13.5 |
| Los Angeles | 19 | 0.3m | San Diego | 250 | 650 | 11 |
| Los Angeles | 19 | 0.3m | San Diego | 250 | 800 | 9 |
| Los Angeles | 19 | 0.3m | San Diego | 500 | 500 | 14.5 |
| Los Angeles | 19 | 0.3m | San Diego | 500 | 650 | 11 |
| Los Angeles | 19 | 0.3m | San Diego | 500 | 800 | 8.5 |
| Los Angeles | 19 | 0.3m | San Joaquin | 100 | 500 | 13 |
| Los Angeles | 19 | 0.3m | San Joaquin | 100 | 650 | 11 |
| Los Angeles | 19 | 0.3m | San Joaquin | 100 | 800 | 9.5 |
| Los Angeles | 19 | 0.3m | San Joaquin | 250 | 500 | 14 |
| Los Angeles | 19 | 0.3m | San Joaquin | 250 | 650 | 11.5 |
| Los Angeles | 19 | 0.3m | San Joaquin | 250 | 800 | 9.5 |
| Los Angeles | 19 | 0.3m | San Joaquin | 500 | 500 | 15 |
| Los Angeles | 19 | 0.3m | San Joaquin | 500 | 650 | 11.5 |
| Los Angeles | 19 | 0.3m | San Joaquin | 500 | 800 | 9 |
| Los Angeles | 19 | 0.6m | PCA | 100 | 500 | 11.5 |
| Los Angeles | 19 | 0.6m | PCA | 100 | 650 | 9.5 |
| Los Angeles | 19 | 0.6m | PCA | 100 | 800 | 7.5 |
| Los Angeles | 19 | 0.6m | PCA | 250 | 500 | 12.5 |
| Los Angeles | 19 | 0.6m | PCA | 250 | 650 | 9.5 |
| Los Angeles | 19 | 0.6m | PCA | 250 | 800 | 7 |
| Los Angeles | 19 | 0.6m | PCA | 500 | 500 | 13.5 |
| Los Angeles | 19 | 0.6m | PCA | 500 | 650 | 9 |
| Los Angeles | 19 | 0.6m | PCA | 500 | 800 | 6 |
| Los Angeles | 19 | 0.6m | San Diego | 100 | 500 | 11 |
| Los Angeles | 19 | 0.6m | San Diego | 100 | 650 | 9 |
| Los Angeles | 19 | 0.6m | San Diego | 100 | 800 | 7.5 |
| Los Angeles | 19 | 0.6m | San Diego | 250 | 500 | 12.5 |
| Los Angeles | 19 | 0.6m | San Diego | 250 | 650 | 9 |
| Los Angeles | 19 | 0.6m | San Diego | 250 | 800 | 6.5 |
| Los Angeles | 19 | 0.6m | San Diego | 500 | 500 | 13.5 |
| Los Angeles | 19 | 0.6m | San Diego | 500 | 650 | 8.5 |
| Los Angeles | 19 | 0.6m | San Diego | 500 | 800 | 5.5 |
| Los Angeles | 19 | 0.6m | San Joaquin | 100 | 500 | 11.5 |
| Los Angeles | 19 | 0.6m | San Joaquin | 100 | 650 | 9 |
| Los Angeles | 19 | 0.6m | San Joaquin | 100 | 800 | 7.5 |
| Los Angeles | 19 | 0.6m | San Joaquin | 250 | 500 | 12.5 |
| Los Angeles | 19 | 0.6m | San Joaquin | 250 | 650 | 9.5 |
| Los Angeles | 19 | 0.6m | San Joaquin | 250 | 800 | 7 |
| Los Angeles | 19 | 0.6m | San Joaquin | 500 | 500 | 14 |
| Los Angeles | 19 | 0.6m | San Joaquin | 500 | 650 | 9 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Los Angeles | 19 | 0.6m | San Joaquin | 500 | 800 | 5.5 |
| Fresno | 15 | AC | PCA | 100 | 500 | 13 |
| Fresno | 15 | AC | PCA | 100 | 650 | 11 |
| Fresno | 15 | AC | PCA | 100 | 800 | 10 |
| Fresno | 15 | AC | PCA | 250 | 500 | 13.5 |
| Fresno | 15 | AC | PCA | 250 | 650 | 12 |
| Fresno | 15 | AC | PCA | 250 | 800 | 10.5 |
| Fresno | 15 | AC | PCA | 500 | 500 | 14 |
| Fresno | 15 | AC | PCA | 500 | 650 | 12 |
| Fresno | 15 | AC | PCA | 500 | 800 | 10 |
| Fresno | 15 | AC | San Diego | 100 | 500 | 12.5 |
| Fresno | 15 | AC | San Diego | 100 | 650 | 10.5 |
| Fresno | 15 | AC | San Diego | 100 | 800 | 9.5 |
| Fresno | 15 | AC | San Diego | 250 | 500 | 13.5 |
| Fresno | 15 | AC | San Diego | 250 | 650 | 11.5 |
| Fresno | 15 | AC | San Diego | 250 | 800 | 10 |
| Fresno | 15 | AC | San Diego | 500 | 500 | 13.5 |
| Fresno | 15 | AC | San Diego | 500 | 650 | 11.5 |
| Fresno | 15 | AC | San Diego | 500 | 800 | 10 |
| Fresno | 15 | AC | San Joaquin | 100 | 500 | 12.5 |
| Fresno | 15 | AC | San Joaquin | 100 | 650 | 11 |
| Fresno | 15 | AC | San Joaquin | 100 | 800 | 9.5 |
| Fresno | 15 | AC | San Joaquin | 250 | 500 | 13.5 |
| Fresno | 15 | AC | San Joaquin | 250 | 650 | 11.5 |
| Fresno | 15 | AC | San Joaquin | 250 | 800 | 10.5 |
| Fresno | 15 | AC | San Joaquin | 500 | 500 | 14 |
| Fresno | 15 | AC | San Joaquin | 500 | 650 | 12 |
| Fresno | 15 | AC | San Joaquin | 500 | 800 | 10 |
| Fresno | 15 | Low LTE | PCA | 100 | 500 | 12.5 |
| Fresno | 15 | Low LTE | PCA | 100 | 650 | 11 |
| Fresno | 15 | Low LTE | PCA | 100 | 800 | 10 |
| Fresno | 15 | Low LTE | PCA | 250 | 500 | 13.5 |
| Fresno | 15 | Low LTE | PCA | 250 | 650 | 12 |
| Fresno | 15 | Low LTE | PCA | 250 | 800 | 10.5 |
| Fresno | 15 | Low LTE | PCA | 500 | 500 | 14 |
| Fresno | 15 | Low LTE | PCA | 500 | 650 | 11.5 |
| Fresno | 15 | Low LTE | PCA | 500 | 800 | 10 |
| Fresno | 15 | Low LTE | San Diego | 100 | 500 | 12.5 |
| Fresno | 15 | Low LTE | San Diego | 100 | 650 | 10.5 |
| Fresno | 15 | Low LTE | San Diego | 100 | 800 | 9.5 |
| Fresno | 15 | Low LTE | San Diego | 250 | 500 | 13 |
| Fresno | 15 | Low LTE | San Diego | 250 | 650 | 11.5 |
| Fresno | 15 | Low LTE | San Diego | 250 | 800 | 10 |
| Fresno | 15 | Low LTE | San Diego | 500 | 500 | 13.5 |
| Fresno | 15 | Low LTE | San Diego | 500 | 650 | 11.5 |
| Fresno | 15 | Low LTE | San Diego | 500 | 800 | 10 |
| Fresno | 15 | Low LTE | San Joaquin | 100 | 500 | 12.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Fresno | 15 | Low LTE | San Joaquin | 100 | 650 | 11 |
| Fresno | 15 | Low LTE | San Joaquin | 100 | 800 | 9.5 |
| Fresno | 15 | Low LTE | San Joaquin | 250 | 500 | 13.5 |
| Fresno | 15 | Low LTE | San Joaquin | 250 | 650 | 11.5 |
| Fresno | 15 | Low LTE | San Joaquin | 250 | 800 | 10 |
| Fresno | 15 | Low LTE | San Joaquin | 500 | 500 | 14 |
| Fresno | 15 | Low LTE | San Joaquin | 500 | 650 | 12 |
| Fresno | 15 | Low LTE | San Joaquin | 500 | 800 | 10 |
| Fresno | 15 | High LTE | PCA | 100 | 500 | 11 |
| Fresno | 15 | High LTE | PCA | 100 | 650 | 9.5 |
| Fresno | 15 | High LTE | PCA | 100 | 800 | 8.5 |
| Fresno | 15 | High LTE | PCA | 250 | 500 | 12.5 |
| Fresno | 15 | High LTE | PCA | 250 | 650 | 10.5 |
| Fresno | 15 | High LTE | PCA | 250 | 800 | 9.5 |
| Fresno | 15 | High LTE | PCA | 500 | 500 | 12.5 |
| Fresno | 15 | High LTE | PCA | 500 | 650 | 10.5 |
| Fresno | 15 | High LTE | PCA | 500 | 800 | 9 |
| Fresno | 15 | High LTE | San Diego | 100 | 500 | 11 |
| Fresno | 15 | High LTE | San Diego | 100 | 650 | 9.5 |
| Fresno | 15 | High LTE | San Diego | 100 | 800 | 8 |
| Fresno | 15 | High LTE | San Diego | 250 | 500 | 12 |
| Fresno | 15 | High LTE | San Diego | 250 | 650 | 10 |
| Fresno | 15 | High LTE | San Diego | 250 | 800 | 8.5 |
| Fresno | 15 | High LTE | San Diego | 500 | 500 | 12.5 |
| Fresno | 15 | High LTE | San Diego | 500 | 650 | 10.5 |
| Fresno | 15 | High LTE | San Diego | 500 | 800 | 8.5 |
| Fresno | 15 | High LTE | San Joaquin | 100 | 500 | 11 |
| Fresno | 15 | High LTE | San Joaquin | 100 | 650 | 9.5 |
| Fresno | 15 | High LTE | San Joaquin | 100 | 800 | 8.5 |
| Fresno | 15 | High LTE | San Joaquin | 250 | 500 | 12.5 |
| Fresno | 15 | High LTE | San Joaquin | 250 | 650 | 10.5 |
| Fresno | 15 | High LTE | San Joaquin | 250 | 800 | 9 |
| Fresno | 15 | High LTE | San Joaquin | 500 | 500 | 12.5 |
| Fresno | 15 | High LTE | San Joaquin | 500 | 650 | 10.5 |
| Fresno | 15 | High LTE | San Joaquin | 500 | 800 | 9 |
| Fresno | 15 | 0.3m | PCA | 100 | 500 | 12.5 |
| Fresno | 15 | 0.3m | PCA | 100 | 650 | 10.5 |
| Fresno | 15 | 0.3m | PCA | 100 | 800 | 9.5 |
| Fresno | 15 | 0.3m | PCA | 250 | 500 | 13 |
| Fresno | 15 | 0.3m | PCA | 250 | 650 | 11.5 |
| Fresno | 15 | 0.3m | PCA | 250 | 800 | 10 |
| Fresno | 15 | 0.3m | PCA | 500 | 500 | 13.5 |
| Fresno | 15 | 0.3m | PCA | 500 | 650 | 11.5 |
| Fresno | 15 | 0.3m | PCA | 500 | 800 | 9.5 |
| Fresno | 15 | 0.3m | San Diego | 100 | 500 | 12 |
| Fresno | 15 | 0.3m | San Diego | 100 | 650 | 10.5 |
| Fresno | 15 | 0.3m | San Diego | 100 | 800 | 9 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Fresno | 15 | 0.3m | San Diego | 250 | 500 | 13 |
| Fresno | 15 | 0.3m | San Diego | 250 | 650 | 11 |
| Fresno | 15 | 0.3m | San Diego | 250 | 800 | 9.5 |
| Fresno | 15 | 0.3m | San Diego | 500 | 500 | 13 |
| Fresno | 15 | 0.3m | San Diego | 500 | 650 | 11 |
| Fresno | 15 | 0.3m | San Diego | 500 | 800 | 9.5 |
| Fresno | 15 | 0.3m | San Joaquin | 100 | 500 | 12 |
| Fresno | 15 | 0.3m | San Joaquin | 100 | 650 | 10.5 |
| Fresno | 15 | 0.3m | San Joaquin | 100 | 800 | 9 |
| Fresno | 15 | 0.3m | San Joaquin | 250 | 500 | 13 |
| Fresno | 15 | 0.3m | San Joaquin | 250 | 650 | 11 |
| Fresno | 15 | 0.3m | San Joaquin | 250 | 800 | 9.5 |
| Fresno | 15 | 0.3m | San Joaquin | 500 | 500 | 13.5 |
| Fresno | 15 | 0.3m | San Joaquin | 500 | 650 | 11.5 |
| Fresno | 15 | 0.3m | San Joaquin | 500 | 800 | 9.5 |
| Fresno | 15 | 0.6m | PCA | 100 | 500 | 11 |
| Fresno | 15 | 0.6m | PCA | 100 | 650 | 9.5 |
| Fresno | 15 | 0.6m | PCA | 100 | 800 | 8 |
| Fresno | 15 | 0.6m | PCA | 250 | 500 | 12 |
| Fresno | 15 | 0.6m | PCA | 250 | 650 | 10 |
| Fresno | 15 | 0.6m | PCA | 250 | 800 | 8.5 |
| Fresno | 15 | 0.6m | PCA | 500 | 500 | 12 |
| Fresno | 15 | 0.6m | PCA | 500 | 650 | 10 |
| Fresno | 15 | 0.6m | PCA | 500 | 800 | 8 |
| Fresno | 15 | 0.6m | San Diego | 100 | 500 | 10.5 |
| Fresno | 15 | 0.6m | San Diego | 100 | 650 | 9 |
| Fresno | 15 | 0.6m | San Diego | 100 | 800 | 8 |
| Fresno | 15 | 0.6m | San Diego | 250 | 500 | 11.5 |
| Fresno | 15 | 0.6m | San Diego | 250 | 650 | 9.5 |
| Fresno | 15 | 0.6m | San Diego | 250 | 800 | 8 |
| Fresno | 15 | 0.6m | San Diego | 500 | 500 | 12 |
| Fresno | 15 | 0.6m | San Diego | 500 | 650 | 10 |
| Fresno | 15 | 0.6m | San Diego | 500 | 800 | 8 |
| Fresno | 15 | 0.6m | San Joaquin | 100 | 500 | 11 |
| Fresno | 15 | 0.6m | San Joaquin | 100 | 650 | 9 |
| Fresno | 15 | 0.6m | San Joaquin | 100 | 800 | 8 |
| Fresno | 15 | 0.6m | San Joaquin | 250 | 500 | 12 |
| Fresno | 15 | 0.6m | San Joaquin | 250 | 650 | 10 |
| Fresno | 15 | 0.6m | San Joaquin | 250 | 800 | 8.5 |
| Fresno | 15 | 0.6m | San Joaquin | 500 | 500 | 12 |
| Fresno | 15 | 0.6m | San Joaquin | 500 | 650 | 10 |
| Fresno | 15 | 0.6m | San Joaquin | 500 | 800 | 8.5 |
| Fresno | 19 | AC | PCA | 100 | 500 | 15 |
| Fresno | 19 | AC | PCA | 100 | 650 | 13 |
| Fresno | 19 | AC | PCA | 100 | 800 | 11.5 |
| Fresno | 19 | AC | PCA | 250 | 500 | 17 |
| Fresno | 19 | AC | PCA | 250 | 650 | 14.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Fresno | 19 | AC | PCA | 250 | 800 | 12.5 |
| Fresno | 19 | AC | PCA | 500 | 500 | 17.5 |
| Fresno | 19 | AC | PCA | 500 | 650 | 14.5 |
| Fresno | 19 | AC | PCA | 500 | 800 | 12.5 |
| Fresno | 19 | AC | San Diego | 100 | 500 | 15 |
| Fresno | 19 | AC | San Diego | 100 | 650 | 12.5 |
| Fresno | 19 | AC | San Diego | 100 | 800 | 11 |
| Fresno | 19 | AC | San Diego | 250 | 500 | 16.5 |
| Fresno | 19 | AC | San Diego | 250 | 650 | 14 |
| Fresno | 19 | AC | San Diego | 250 | 800 | 12 |
| Fresno | 19 | AC | San Diego | 500 | 500 | 17 |
| Fresno | 19 | AC | San Diego | 500 | 650 | 14.5 |
| Fresno | 19 | AC | San Diego | 500 | 800 | 12.5 |
| Fresno | 19 | AC | San Joaquin | 100 | 500 | 15 |
| Fresno | 19 | AC | San Joaquin | 100 | 650 | 13 |
| Fresno | 19 | AC | San Joaquin | 100 | 800 | 11.5 |
| Fresno | 19 | AC | San Joaquin | 250 | 500 | 17 |
| Fresno | 19 | AC | San Joaquin | 250 | 650 | 14.5 |
| Fresno | 19 | AC | San Joaquin | 250 | 800 | 12.5 |
| Fresno | 19 | AC | San Joaquin | 500 | 500 | 17.5 |
| Fresno | 19 | AC | San Joaquin | 500 | 650 | 14.5 |
| Fresno | 19 | AC | San Joaquin | 500 | 800 | 12.5 |
| Fresno | 19 | Low LTE | PCA | 100 | 500 | 15 |
| Fresno | 19 | Low LTE | PCA | 100 | 650 | 13 |
| Fresno | 19 | Low LTE | PCA | 100 | 800 | 11.5 |
| Fresno | 19 | Low LTE | PCA | 250 | 500 | 17 |
| Fresno | 19 | Low LTE | PCA | 250 | 650 | 14.5 |
| Fresno | 19 | Low LTE | PCA | 250 | 800 | 12.5 |
| Fresno | 19 | Low LTE | PCA | 500 | 500 | 17 |
| Fresno | 19 | Low LTE | PCA | 500 | 650 | 14.5 |
| Fresno | 19 | Low LTE | PCA | 500 | 800 | 12.5 |
| Fresno | 19 | Low LTE | San Diego | 100 | 500 | 14.5 |
| Fresno | 19 | Low LTE | San Diego | 100 | 650 | 12.5 |
| Fresno | 19 | Low LTE | San Diego | 100 | 800 | 11 |
| Fresno | 19 | Low LTE | San Diego | 250 | 500 | 16.5 |
| Fresno | 19 | Low LTE | San Diego | 250 | 650 | 14 |
| Fresno | 19 | Low LTE | San Diego | 250 | 800 | 12 |
| Fresno | 19 | Low LTE | San Diego | 500 | 500 | 17 |
| Fresno | 19 | Low LTE | San Diego | 500 | 650 | 14.5 |
| Fresno | 19 | Low LTE | San Diego | 500 | 800 | 12 |
| Fresno | 19 | Low LTE | San Joaquin | 100 | 500 | 15 |
| Fresno | 19 | Low LTE | San Joaquin | 100 | 650 | 13 |
| Fresno | 19 | Low LTE | San Joaquin | 100 | 800 | 11.5 |
| Fresno | 19 | Low LTE | San Joaquin | 250 | 500 | 17 |
| Fresno | 19 | Low LTE | San Joaquin | 250 | 650 | 14.5 |
| Fresno | 19 | Low LTE | San Joaquin | 250 | 800 | 12.5 |
| Fresno | 19 | Low LTE | San Joaquin | 500 | 500 | 17.5 |

| **Climatic region** | **Slab Length (ft.)** | **Shoulder** | **Traffic** | **k-value** | **Concrete Modulus of Rupture (psi)** | **Thickness (in.)** |
|---|---|---|---|---|---|---|
| Fresno | 19 | Low LTE | San Joaquin | 500 | 650 | 14.5 |
| Fresno | 19 | Low LTE | San Joaquin | 500 | 800 | 12.5 |
| Fresno | 19 | High LTE | PCA | 100 | 500 | 13.5 |
| Fresno | 19 | High LTE | PCA | 100 | 650 | 11.5 |
| Fresno | 19 | High LTE | PCA | 100 | 800 | 10 |
| Fresno | 19 | High LTE | PCA | 250 | 500 | 15.5 |
| Fresno | 19 | High LTE | PCA | 250 | 650 | 13 |
| Fresno | 19 | High LTE | PCA | 250 | 800 | 11 |
| Fresno | 19 | High LTE | PCA | 500 | 500 | 16.5 |
| Fresno | 19 | High LTE | PCA | 500 | 650 | 13.5 |
| Fresno | 19 | High LTE | PCA | 500 | 800 | 11 |
| Fresno | 19 | High LTE | San Diego | 100 | 500 | 13.5 |
| Fresno | 19 | High LTE | San Diego | 100 | 650 | 11.5 |
| Fresno | 19 | High LTE | San Diego | 100 | 800 | 10 |
| Fresno | 19 | High LTE | San Diego | 250 | 500 | 15.5 |
| Fresno | 19 | High LTE | San Diego | 250 | 650 | 13 |
| Fresno | 19 | High LTE | San Diego | 250 | 800 | 11 |
| Fresno | 19 | High LTE | San Diego | 500 | 500 | 16 |
| Fresno | 19 | High LTE | San Diego | 500 | 650 | 13.5 |
| Fresno | 19 | High LTE | San Diego | 500 | 800 | 11 |
| Fresno | 19 | High LTE | San Joaquin | 100 | 500 | 14 |
| Fresno | 19 | High LTE | San Joaquin | 100 | 650 | 12 |
| Fresno | 19 | High LTE | San Joaquin | 100 | 800 | 10 |
| Fresno | 19 | High LTE | San Joaquin | 250 | 500 | 16 |
| Fresno | 19 | High LTE | San Joaquin | 250 | 650 | 13.5 |
| Fresno | 19 | High LTE | San Joaquin | 250 | 800 | 11.5 |
| Fresno | 19 | High LTE | San Joaquin | 500 | 500 | 16.5 |
| Fresno | 19 | High LTE | San Joaquin | 500 | 650 | 14 |
| Fresno | 19 | High LTE | San Joaquin | 500 | 800 | 11.5 |
| Fresno | 19 | 0.3m | PCA | 100 | 500 | 14.5 |
| Fresno | 19 | 0.3m | PCA | 100 | 650 | 12.5 |
| Fresno | 19 | 0.3m | PCA | 100 | 800 | 11 |
| Fresno | 19 | 0.3m | PCA | 250 | 500 | 16 |
| Fresno | 19 | 0.3m | PCA | 250 | 650 | 13.5 |
| Fresno | 19 | 0.3m | PCA | 250 | 800 | 11.5 |
| Fresno | 19 | 0.3m | PCA | 500 | 500 | 16.5 |
| Fresno | 19 | 0.3m | PCA | 500 | 650 | 14 |
| Fresno | 19 | 0.3m | PCA | 500 | 800 | 11.5 |
| Fresno | 19 | 0.3m | San Diego | 100 | 500 | 14 |
| Fresno | 19 | 0.3m | San Diego | 100 | 650 | 12 |
| Fresno | 19 | 0.3m | San Diego | 100 | 800 | 10.5 |
| Fresno | 19 | 0.3m | San Diego | 250 | 500 | 16 |
| Fresno | 19 | 0.3m | San Diego | 250 | 650 | 13.5 |
| Fresno | 19 | 0.3m | San Diego | 250 | 800 | 11.5 |
| Fresno | 19 | 0.3m | San Diego | 500 | 500 | 16.5 |
| Fresno | 19 | 0.3m | San Diego | 500 | 650 | 13.5 |
| Fresno | 19 | 0.3m | San Diego | 500 | 800 | 11.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Fresno | 19 | 0.3m | San Joaquin | 100 | 500 | 14.5 |
| Fresno | 19 | 0.3m | San Joaquin | 100 | 650 | 12.5 |
| Fresno | 19 | 0.3m | San Joaquin | 100 | 800 | 11 |
| Fresno | 19 | 0.3m | San Joaquin | 250 | 500 | 16.5 |
| Fresno | 19 | 0.3m | San Joaquin | 250 | 650 | 13.5 |
| Fresno | 19 | 0.3m | San Joaquin | 250 | 800 | 11.5 |
| Fresno | 19 | 0.3m | San Joaquin | 500 | 500 | 17 |
| Fresno | 19 | 0.3m | San Joaquin | 500 | 650 | 14 |
| Fresno | 19 | 0.3m | San Joaquin | 500 | 800 | 12 |
| Fresno | 19 | 0.6m | PCA | 100 | 500 | 13.5 |
| Fresno | 19 | 0.6m | PCA | 100 | 650 | 11.5 |
| Fresno | 19 | 0.6m | PCA | 100 | 800 | 9.5 |
| Fresno | 19 | 0.6m | PCA | 250 | 500 | 15.5 |
| Fresno | 19 | 0.6m | PCA | 250 | 650 | 12.5 |
| Fresno | 19 | 0.6m | PCA | 250 | 800 | 10.5 |
| Fresno | 19 | 0.6m | PCA | 500 | 500 | 16 |
| Fresno | 19 | 0.6m | PCA | 500 | 650 | 13 |
| Fresno | 19 | 0.6m | PCA | 500 | 800 | 10.5 |
| Fresno | 19 | 0.6m | San Diego | 100 | 500 | 13.5 |
| Fresno | 19 | 0.6m | San Diego | 100 | 650 | 11 |
| Fresno | 19 | 0.6m | San Diego | 100 | 800 | 9.5 |
| Fresno | 19 | 0.6m | San Diego | 250 | 500 | 15.5 |
| Fresno | 19 | 0.6m | San Diego | 250 | 650 | 12.5 |
| Fresno | 19 | 0.6m | San Diego | 250 | 800 | 10 |
| Fresno | 19 | 0.6m | San Diego | 500 | 500 | 16 |
| Fresno | 19 | 0.6m | San Diego | 500 | 650 | 13 |
| Fresno | 19 | 0.6m | San Diego | 500 | 800 | 10.5 |
| Fresno | 19 | 0.6m | San Joaquin | 100 | 500 | 13.5 |
| Fresno | 19 | 0.6m | San Joaquin | 100 | 650 | 11.5 |
| Fresno | 19 | 0.6m | San Joaquin | 100 | 800 | 9.5 |
| Fresno | 19 | 0.6m | San Joaquin | 250 | 500 | 15.5 |
| Fresno | 19 | 0.6m | San Joaquin | 250 | 650 | 13 |
| Fresno | 19 | 0.6m | San Joaquin | 250 | 800 | 10.5 |
| Fresno | 19 | 0.6m | San Joaquin | 500 | 500 | 16 |
| Fresno | 19 | 0.6m | San Joaquin | 500 | 650 | 13.5 |
| Fresno | 19 | 0.6m | San Joaquin | 500 | 800 | 11 |
| Daggett | 15 | AC | PCA | 100 | 500 | 13 |
| Daggett | 15 | AC | PCA | 100 | 650 | 11 |
| Daggett | 15 | AC | PCA | 100 | 800 | 10 |
| Daggett | 15 | AC | PCA | 250 | 500 | 14 |
| Daggett | 15 | AC | PCA | 250 | 650 | 12 |
| Daggett | 15 | AC | PCA | 250 | 800 | 10.5 |
| Daggett | 15 | AC | PCA | 500 | 500 | 14 |
| Daggett | 15 | AC | PCA | 500 | 650 | 12 |
| Daggett | 15 | AC | PCA | 500 | 800 | 10.5 |
| Daggett | 15 | AC | San Diego | 100 | 500 | 12.5 |
| Daggett | 15 | AC | San Diego | 100 | 650 | 10.5 |

| **Climatic region** | **Slab Length (ft.)** | **Shoulder** | **Traffic** | **k-value** | **Concrete Modulus of Rupture (psi)** | **Thickness (in.)** |
|---|---|---|---|---|---|---|
| Daggett | 15 | AC | San Diego | 100 | 800 | 9.5 |
| Daggett | 15 | AC | San Diego | 250 | 500 | 13.5 |
| Daggett | 15 | AC | San Diego | 250 | 650 | 11.5 |
| Daggett | 15 | AC | San Diego | 250 | 800 | 10 |
| Daggett | 15 | AC | San Diego | 500 | 500 | 13.5 |
| Daggett | 15 | AC | San Diego | 500 | 650 | 11.5 |
| Daggett | 15 | AC | San Diego | 500 | 800 | 10 |
| Daggett | 15 | AC | San Joaquin | 100 | 500 | 12.5 |
| Daggett | 15 | AC | San Joaquin | 100 | 650 | 11 |
| Daggett | 15 | AC | San Joaquin | 100 | 800 | 9.5 |
| Daggett | 15 | AC | San Joaquin | 250 | 500 | 13.5 |
| Daggett | 15 | AC | San Joaquin | 250 | 650 | 11.5 |
| Daggett | 15 | AC | San Joaquin | 250 | 800 | 10.5 |
| Daggett | 15 | AC | San Joaquin | 500 | 500 | 14 |
| Daggett | 15 | AC | San Joaquin | 500 | 650 | 12 |
| Daggett | 15 | AC | San Joaquin | 500 | 800 | 10.5 |
| Daggett | 15 | Low LTE | PCA | 100 | 500 | 12.5 |
| Daggett | 15 | Low LTE | PCA | 100 | 650 | 11 |
| Daggett | 15 | Low LTE | PCA | 100 | 800 | 10 |
| Daggett | 15 | Low LTE | PCA | 250 | 500 | 13.5 |
| Daggett | 15 | Low LTE | PCA | 250 | 650 | 12 |
| Daggett | 15 | Low LTE | PCA | 250 | 800 | 10.5 |
| Daggett | 15 | Low LTE | PCA | 500 | 500 | 14 |
| Daggett | 15 | Low LTE | PCA | 500 | 650 | 12 |
| Daggett | 15 | Low LTE | PCA | 500 | 800 | 10 |
| Daggett | 15 | Low LTE | San Diego | 100 | 500 | 12.5 |
| Daggett | 15 | Low LTE | San Diego | 100 | 650 | 10.5 |
| Daggett | 15 | Low LTE | San Diego | 100 | 800 | 9.5 |
| Daggett | 15 | Low LTE | San Diego | 250 | 500 | 13 |
| Daggett | 15 | Low LTE | San Diego | 250 | 650 | 11.5 |
| Daggett | 15 | Low LTE | San Diego | 250 | 800 | 10 |
| Daggett | 15 | Low LTE | San Diego | 500 | 500 | 13.5 |
| Daggett | 15 | Low LTE | San Diego | 500 | 650 | 11.5 |
| Daggett | 15 | Low LTE | San Diego | 500 | 800 | 10 |
| Daggett | 15 | Low LTE | San Joaquin | 100 | 500 | 12.5 |
| Daggett | 15 | Low LTE | San Joaquin | 100 | 650 | 11 |
| Daggett | 15 | Low LTE | San Joaquin | 100 | 800 | 9.5 |
| Daggett | 15 | Low LTE | San Joaquin | 250 | 500 | 13.5 |
| Daggett | 15 | Low LTE | San Joaquin | 250 | 650 | 11.5 |
| Daggett | 15 | Low LTE | San Joaquin | 250 | 800 | 10 |
| Daggett | 15 | Low LTE | San Joaquin | 500 | 500 | 14 |
| Daggett | 15 | Low LTE | San Joaquin | 500 | 650 | 12 |
| Daggett | 15 | Low LTE | San Joaquin | 500 | 800 | 10 |
| Daggett | 15 | High LTE | PCA | 100 | 500 | 11 |
| Daggett | 15 | High LTE | PCA | 100 | 650 | 9.5 |
| Daggett | 15 | High LTE | PCA | 100 | 800 | 8.5 |
| Daggett | 15 | High LTE | PCA | 250 | 500 | 12.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Daggett | 15 | High LTE | PCA | 250 | 650 | 10.5 |
| Daggett | 15 | High LTE | PCA | 250 | 800 | 9 |
| Daggett | 15 | High LTE | PCA | 500 | 500 | 12.5 |
| Daggett | 15 | High LTE | PCA | 500 | 650 | 10.5 |
| Daggett | 15 | High LTE | PCA | 500 | 800 | 9 |
| Daggett | 15 | High LTE | San Diego | 100 | 500 | 11 |
| Daggett | 15 | High LTE | San Diego | 100 | 650 | 9.5 |
| Daggett | 15 | High LTE | San Diego | 100 | 800 | 8 |
| Daggett | 15 | High LTE | San Diego | 250 | 500 | 12 |
| Daggett | 15 | High LTE | San Diego | 250 | 650 | 10 |
| Daggett | 15 | High LTE | San Diego | 250 | 800 | 8.5 |
| Daggett | 15 | High LTE | San Diego | 500 | 500 | 12.5 |
| Daggett | 15 | High LTE | San Diego | 500 | 650 | 10.5 |
| Daggett | 15 | High LTE | San Diego | 500 | 800 | 8.5 |
| Daggett | 15 | High LTE | San Joaquin | 100 | 500 | 11 |
| Daggett | 15 | High LTE | San Joaquin | 100 | 650 | 9.5 |
| Daggett | 15 | High LTE | San Joaquin | 100 | 800 | 8.5 |
| Daggett | 15 | High LTE | San Joaquin | 250 | 500 | 12.5 |
| Daggett | 15 | High LTE | San Joaquin | 250 | 650 | 10.5 |
| Daggett | 15 | High LTE | San Joaquin | 250 | 800 | 9 |
| Daggett | 15 | High LTE | San Joaquin | 500 | 500 | 13 |
| Daggett | 15 | High LTE | San Joaquin | 500 | 650 | 11 |
| Daggett | 15 | High LTE | San Joaquin | 500 | 800 | 9 |
| Daggett | 15 | 0.3m | PCA | 100 | 500 | 12.5 |
| Daggett | 15 | 0.3m | PCA | 100 | 650 | 10.5 |
| Daggett | 15 | 0.3m | PCA | 100 | 800 | 9.5 |
| Daggett | 15 | 0.3m | PCA | 250 | 500 | 13 |
| Daggett | 15 | 0.3m | PCA | 250 | 650 | 11.5 |
| Daggett | 15 | 0.3m | PCA | 250 | 800 | 10 |
| Daggett | 15 | 0.3m | PCA | 500 | 500 | 13.5 |
| Daggett | 15 | 0.3m | PCA | 500 | 650 | 11.5 |
| Daggett | 15 | 0.3m | PCA | 500 | 800 | 9.5 |
| Daggett | 15 | 0.3m | San Diego | 100 | 500 | 12 |
| Daggett | 15 | 0.3m | San Diego | 100 | 650 | 10.5 |
| Daggett | 15 | 0.3m | San Diego | 100 | 800 | 9 |
| Daggett | 15 | 0.3m | San Diego | 250 | 500 | 13 |
| Daggett | 15 | 0.3m | San Diego | 250 | 650 | 11 |
| Daggett | 15 | 0.3m | San Diego | 250 | 800 | 9.5 |
| Daggett | 15 | 0.3m | San Diego | 500 | 500 | 13 |
| Daggett | 15 | 0.3m | San Diego | 500 | 650 | 11 |
| Daggett | 15 | 0.3m | San Diego | 500 | 800 | 9.5 |
| Daggett | 15 | 0.3m | San Joaquin | 100 | 500 | 12 |
| Daggett | 15 | 0.3m | San Joaquin | 100 | 650 | 10.5 |
| Daggett | 15 | 0.3m | San Joaquin | 100 | 800 | 9 |
| Daggett | 15 | 0.3m | San Joaquin | 250 | 500 | 13 |
| Daggett | 15 | 0.3m | San Joaquin | 250 | 650 | 11 |
| Daggett | 15 | 0.3m | San Joaquin | 250 | 800 | 9.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Daggett | 15 | 0.3m | San Joaquin | 500 | 500 | 13.5 |
| Daggett | 15 | 0.3m | San Joaquin | 500 | 650 | 11.5 |
| Daggett | 15 | 0.3m | San Joaquin | 500 | 800 | 9.5 |
| Daggett | 15 | 0.6m | PCA | 100 | 500 | 11 |
| Daggett | 15 | 0.6m | PCA | 100 | 650 | 9.5 |
| Daggett | 15 | 0.6m | PCA | 100 | 800 | 8 |
| Daggett | 15 | 0.6m | PCA | 250 | 500 | 12 |
| Daggett | 15 | 0.6m | PCA | 250 | 650 | 10 |
| Daggett | 15 | 0.6m | PCA | 250 | 800 | 8.5 |
| Daggett | 15 | 0.6m | PCA | 500 | 500 | 12 |
| Daggett | 15 | 0.6m | PCA | 500 | 650 | 10 |
| Daggett | 15 | 0.6m | PCA | 500 | 800 | 8 |
| Daggett | 15 | 0.6m | San Diego | 100 | 500 | 10.5 |
| Daggett | 15 | 0.6m | San Diego | 100 | 650 | 9 |
| Daggett | 15 | 0.6m | San Diego | 100 | 800 | 7.5 |
| Daggett | 15 | 0.6m | San Diego | 250 | 500 | 11.5 |
| Daggett | 15 | 0.6m | San Diego | 250 | 650 | 9.5 |
| Daggett | 15 | 0.6m | San Diego | 250 | 800 | 8 |
| Daggett | 15 | 0.6m | San Diego | 500 | 500 | 12 |
| Daggett | 15 | 0.6m | San Diego | 500 | 650 | 10 |
| Daggett | 15 | 0.6m | San Diego | 500 | 800 | 8 |
| Daggett | 15 | 0.6m | San Joaquin | 100 | 500 | 11 |
| Daggett | 15 | 0.6m | San Joaquin | 100 | 650 | 9 |
| Daggett | 15 | 0.6m | San Joaquin | 100 | 800 | 8 |
| Daggett | 15 | 0.6m | San Joaquin | 250 | 500 | 12 |
| Daggett | 15 | 0.6m | San Joaquin | 250 | 650 | 10 |
| Daggett | 15 | 0.6m | San Joaquin | 250 | 800 | 8.5 |
| Daggett | 15 | 0.6m | San Joaquin | 500 | 500 | 12 |
| Daggett | 15 | 0.6m | San Joaquin | 500 | 650 | 10 |
| Daggett | 15 | 0.6m | San Joaquin | 500 | 800 | 8.5 |
| Daggett | 19 | AC | PCA | 100 | 500 | 15 |
| Daggett | 19 | AC | PCA | 100 | 650 | 13 |
| Daggett | 19 | AC | PCA | 100 | 800 | 11.5 |
| Daggett | 19 | AC | PCA | 250 | 500 | 17 |
| Daggett | 19 | AC | PCA | 250 | 650 | 14.5 |
| Daggett | 19 | AC | PCA | 250 | 800 | 12.5 |
| Daggett | 19 | AC | PCA | 500 | 500 | 17.5 |
| Daggett | 19 | AC | PCA | 500 | 650 | 14.5 |
| Daggett | 19 | AC | PCA | 500 | 800 | 12.5 |
| Daggett | 19 | AC | San Diego | 100 | 500 | 14.5 |
| Daggett | 19 | AC | San Diego | 100 | 650 | 12.5 |
| Daggett | 19 | AC | San Diego | 100 | 800 | 11 |
| Daggett | 19 | AC | San Diego | 250 | 500 | 16.5 |
| Daggett | 19 | AC | San Diego | 250 | 650 | 14 |
| Daggett | 19 | AC | San Diego | 250 | 800 | 12 |
| Daggett | 19 | AC | San Diego | 500 | 500 | 17 |
| Daggett | 19 | AC | San Diego | 500 | 650 | 14.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Daggett | 19 | AC | San Diego | 500 | 800 | 12 |
| Daggett | 19 | AC | San Joaquin | 100 | 500 | 15 |
| Daggett | 19 | AC | San Joaquin | 100 | 650 | 13 |
| Daggett | 19 | AC | San Joaquin | 100 | 800 | 11.5 |
| Daggett | 19 | AC | San Joaquin | 250 | 500 | 17 |
| Daggett | 19 | AC | San Joaquin | 250 | 650 | 14.5 |
| Daggett | 19 | AC | San Joaquin | 250 | 800 | 12.5 |
| Daggett | 19 | AC | San Joaquin | 500 | 500 | 17.5 |
| Daggett | 19 | AC | San Joaquin | 500 | 650 | 15 |
| Daggett | 19 | AC | San Joaquin | 500 | 800 | 12.5 |
| Daggett | 19 | Low LTE | PCA | 100 | 500 | 15 |
| Daggett | 19 | Low LTE | PCA | 100 | 650 | 13 |
| Daggett | 19 | Low LTE | PCA | 100 | 800 | 11.5 |
| Daggett | 19 | Low LTE | PCA | 250 | 500 | 17 |
| Daggett | 19 | Low LTE | PCA | 250 | 650 | 14.5 |
| Daggett | 19 | Low LTE | PCA | 250 | 800 | 12 |
| Daggett | 19 | Low LTE | PCA | 500 | 500 | 17.5 |
| Daggett | 19 | Low LTE | PCA | 500 | 650 | 14.5 |
| Daggett | 19 | Low LTE | PCA | 500 | 800 | 12.5 |
| Daggett | 19 | Low LTE | San Diego | 100 | 500 | 14.5 |
| Daggett | 19 | Low LTE | San Diego | 100 | 650 | 12.5 |
| Daggett | 19 | Low LTE | San Diego | 100 | 800 | 11 |
| Daggett | 19 | Low LTE | San Diego | 250 | 500 | 16.5 |
| Daggett | 19 | Low LTE | San Diego | 250 | 650 | 14 |
| Daggett | 19 | Low LTE | San Diego | 250 | 800 | 12 |
| Daggett | 19 | Low LTE | San Diego | 500 | 500 | 17 |
| Daggett | 19 | Low LTE | San Diego | 500 | 650 | 14.5 |
| Daggett | 19 | Low LTE | San Diego | 500 | 800 | 12 |
| Daggett | 19 | Low LTE | San Joaquin | 100 | 500 | 15 |
| Daggett | 19 | Low LTE | San Joaquin | 100 | 650 | 13 |
| Daggett | 19 | Low LTE | San Joaquin | 100 | 800 | 11.5 |
| Daggett | 19 | Low LTE | San Joaquin | 250 | 500 | 17 |
| Daggett | 19 | Low LTE | San Joaquin | 250 | 650 | 14.5 |
| Daggett | 19 | Low LTE | San Joaquin | 250 | 800 | 12.5 |
| Daggett | 19 | Low LTE | San Joaquin | 500 | 500 | 17.5 |
| Daggett | 19 | Low LTE | San Joaquin | 500 | 650 | 14.5 |
| Daggett | 19 | Low LTE | San Joaquin | 500 | 800 | 12.5 |
| Daggett | 19 | High LTE | PCA | 100 | 500 | 13.5 |
| Daggett | 19 | High LTE | PCA | 100 | 650 | 11.5 |
| Daggett | 19 | High LTE | PCA | 100 | 800 | 10 |
| Daggett | 19 | High LTE | PCA | 250 | 500 | 15.5 |
| Daggett | 19 | High LTE | PCA | 250 | 650 | 13 |
| Daggett | 19 | High LTE | PCA | 250 | 800 | 11 |
| Daggett | 19 | High LTE | PCA | 500 | 500 | 16.5 |
| Daggett | 19 | High LTE | PCA | 500 | 650 | 13.5 |
| Daggett | 19 | High LTE | PCA | 500 | 800 | 11 |
| Daggett | 19 | High LTE | San Diego | 100 | 500 | 13.5 |

| Climatic region | Slab Length (ft.) | Shoulder | Traffic | k-value | Concrete Modulus of Rupture (psi) | Thickness (in.) |
|---|---|---|---|---|---|---|
| Daggett | 19 | High LTE | San Diego | 100 | 650 | 11.5 |
| Daggett | 19 | High LTE | San Diego | 100 | 800 | 10 |
| Daggett | 19 | High LTE | San Diego | 250 | 500 | 15.5 |
| Daggett | 19 | High LTE | San Diego | 250 | 650 | 13 |
| Daggett | 19 | High LTE | San Diego | 250 | 800 | 11 |
| Daggett | 19 | High LTE | San Diego | 500 | 500 | 16 |
| Daggett | 19 | High LTE | San Diego | 500 | 650 | 13.5 |
| Daggett | 19 | High LTE | San Diego | 500 | 800 | 11 |
| Daggett | 19 | High LTE | San Joaquin | 100 | 500 | 14 |
| Daggett | 19 | High LTE | San Joaquin | 100 | 650 | 12 |
| Daggett | 19 | High LTE | San Joaquin | 100 | 800 | 10 |
| Daggett | 19 | High LTE | San Joaquin | 250 | 500 | 16 |
| Daggett | 19 | High LTE | San Joaquin | 250 | 650 | 13.5 |
| Daggett | 19 | High LTE | San Joaquin | 250 | 800 | 11 |
| Daggett | 19 | High LTE | San Joaquin | 500 | 500 | 16.5 |
| Daggett | 19 | High LTE | San Joaquin | 500 | 650 | 14 |
| Daggett | 19 | High LTE | San Joaquin | 500 | 800 | 11.5 |
| Daggett | 19 | 0.3m | PCA | 100 | 500 | 14.5 |
| Daggett | 19 | 0.3m | PCA | 100 | 650 | 12.5 |
| Daggett | 19 | 0.3m | PCA | 100 | 800 | 11 |
| Daggett | 19 | 0.3m | PCA | 250 | 500 | 16 |
| Daggett | 19 | 0.3m | PCA | 250 | 650 | 13.5 |
| Daggett | 19 | 0.3m | PCA | 250 | 800 | 11.5 |
| Daggett | 19 | 0.3m | PCA | 500 | 500 | 16.5 |
| Daggett | 19 | 0.3m | PCA | 500 | 650 | 14 |
| Daggett | 19 | 0.3m | PCA | 500 | 800 | 11.5 |
| Daggett | 19 | 0.3m | San Diego | 100 | 500 | 14 |
| Daggett | 19 | 0.3m | San Diego | 100 | 650 | 12 |
| Daggett | 19 | 0.3m | San Diego | 100 | 800 | 10.5 |
| Daggett | 19 | 0.3m | San Diego | 250 | 500 | 16 |
| Daggett | 19 | 0.3m | San Diego | 250 | 650 | 13.5 |
| Daggett | 19 | 0.3m | San Diego | 250 | 800 | 11.5 |
| Daggett | 19 | 0.3m | San Diego | 500 | 500 | 16.5 |
| Daggett | 19 | 0.3m | San Diego | 500 | 650 | 13.5 |
| Daggett | 19 | 0.3m | San Diego | 500 | 800 | 11.5 |
| Daggett | 19 | 0.3m | San Joaquin | 100 | 500 | 14.5 |
| Daggett | 19 | 0.3m | San Joaquin | 100 | 650 | 12.5 |
| Daggett | 19 | 0.3m | San Joaquin | 100 | 800 | 11 |
| Daggett | 19 | 0.3m | San Joaquin | 250 | 500 | 16.5 |
| Daggett | 19 | 0.3m | San Joaquin | 250 | 650 | 13.5 |
| Daggett | 19 | 0.3m | San Joaquin | 250 | 800 | 11.5 |
| Daggett | 19 | 0.3m | San Joaquin | 500 | 500 | 17 |
| Daggett | 19 | 0.3m | San Joaquin | 500 | 650 | 14 |
| Daggett | 19 | 0.3m | San Joaquin | 500 | 800 | 12 |
| Daggett | 19 | 0.6m | PCA | 100 | 500 | 13.5 |
| Daggett | 19 | 0.6m | PCA | 100 | 650 | 11.5 |
| Daggett | 19 | 0.6m | PCA | 100 | 800 | 9.5 |

| **Climatic region** | **Slab Length (ft.)** | **Shoulder** | **Traffic** | **k-value** | **Concrete Modulus of Rupture (psi)** | **Thickness (in.)** |
|---|---|---|---|---|---|---|
| Daggett | 19 | 0.6m | PCA | 250 | 500 | 15.5 |
| Daggett | 19 | 0.6m | PCA | 250 | 650 | 12.5 |
| Daggett | 19 | 0.6m | PCA | 250 | 800 | 10.5 |
| Daggett | 19 | 0.6m | PCA | 500 | 500 | 16 |
| Daggett | 19 | 0.6m | PCA | 500 | 650 | 13 |
| Daggett | 19 | 0.6m | PCA | 500 | 800 | 10.5 |
| Daggett | 19 | 0.6m | San Diego | 100 | 500 | 13.5 |
| Daggett | 19 | 0.6m | San Diego | 100 | 650 | 11 |
| Daggett | 19 | 0.6m | San Diego | 100 | 800 | 9.5 |
| Daggett | 19 | 0.6m | San Diego | 250 | 500 | 15.5 |
| Daggett | 19 | 0.6m | San Diego | 250 | 650 | 12.5 |
| Daggett | 19 | 0.6m | San Diego | 250 | 800 | 10 |
| Daggett | 19 | 0.6m | San Diego | 500 | 500 | 16 |
| Daggett | 19 | 0.6m | San Diego | 500 | 650 | 13 |
| Daggett | 19 | 0.6m | San Diego | 500 | 800 | 10.5 |
| Daggett | 19 | 0.6m | San Joaquin | 100 | 500 | 13.5 |
| Daggett | 19 | 0.6m | San Joaquin | 100 | 650 | 11.5 |
| Daggett | 19 | 0.6m | San Joaquin | 100 | 800 | 9.5 |
| Daggett | 19 | 0.6m | San Joaquin | 250 | 500 | 15.5 |
| Daggett | 19 | 0.6m | San Joaquin | 250 | 650 | 13 |
| Daggett | 19 | 0.6m | San Joaquin | 250 | 800 | 10.5 |
| Daggett | 19 | 0.6m | San Joaquin | 500 | 500 | 16 |
| Daggett | 19 | 0.6m | San Joaquin | 500 | 650 | 13.5 |
| Daggett | 19 | 0.6m | San Joaquin | 500 | 800 | 11 |