Sarsers
Company

Saidsadiq - Penjween Main Road Rehabilitaion

Mlay Nallma
Rigid Pavement Design

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Input Data (Design requirements)

١. **Loading:**

a. ١٠٠٠٠ ESAL $W_{١٨}$ ADT.
b. Growth factor ٤٪.
c. Design period ١٠ years.
Total Design $W_{١٨}$ = ٤٤,٠٠٠,٠٠٠ ESAL

٢. **Reliability (R): ٩٩٪.**

٣. **Serviceability :**

P : ٤,٥
Pt : ٢,٥
Δp : ٢

٤. **Portland cement (Concrete) Parameters :**

a. Elastic Modulus (Ec): ٤,٠٠٠,٠٠٠ psi.
b. Modulus of rapture: ٦٥٠ psi.
c. Concrete compressive strength: ٤٦٨٤ psi (٣٣٠kg/cm^{٢}).

٥. **Drainage factor (CD) : ١**

٦. **Load Transform Coefficient (J): ٣**

٧. **Modulus of sub grade reaction (K): ٤٠٠ pci**

٨. **Rigid pavement underneath:**

a. Sub grade CBR: ٤٪.
b. Sub base layer: ٣٠cm
c. Asphalt base course: ١٠cm

Design out Put

١. Slab concrete thickness: ٣٥cm

٢. Longitudinal reinforcement: Ø١٦mm @١٩cm c/c.

٣. Transverse Reinforcement: Ø١٦mm @ ٢٥cm c/c.

٤. Dowel Bars: Ø ٣٢mm @ ٤٠cm c/c and ١m long.

٥. Tie Bars: Ø ١٦mm @ ٩٠ c/c and ٨٠cm long.

According to the drawings

Recommended Design Values

Input Values

Input values for the following variables are needed as listed below for the AASHTO rigid pavement design procedure for a new construction or reconstruction project:

- Mean Concrete Modulus of Rupture, psi
- Concrete Elastic Modulus, psi
- Effective Modulus of Subbase/Subgrade Reaction, pci
- Serviceability Indices
- Load Transfer Coefficient
- Drainage Coefficient
- Overall Standard Deviation
- Reliability, %
- Design Traffic, ١٨-kip Equivalent Single Axle Load (ESAL).

Mean Concrete Modulus of Rupture, Mr

Mr of concrete is a measure of the flexural strength of the concrete as determined by breaking concrete beam test specimens. Mr Design values for the concrete are used in conjunction with the AASHTO rigid pavement thickness design procedure to determine the design thickness of the proposed concrete pavement. A Mr of ٦٥٠ psi is to be used with the current statewide specification for concrete pavement and standard detail drawings to calculate the concrete pavement thickness.

Concrete Elastic Modulus

The AASHTO design equation also requires a value for the concrete elastic modulus. This value varies depending on the coarse aggregate type. Although the value selected could be significantly different from the actual values, the elastic modulus does not have a significant effect on the final thickness generated by the equation.

The current recommended concrete elastic modulus values are:

- ٤,٠٠٠,٠٠٠ psi for concrete containing crushed limestone

- ٥,٠٠٠,٠٠٠ psi for concrete containing siliceous river gravel.

Effective Modulus of Subbase/Subgrade Reaction

k-value. The AASHTO guide allows pavement designers to take into account all layers to be placed under the concrete pavement. It also allows designers to consider the effect of loss of support of the underlying material due to erosion or deterioration.

The slab support is characterized by the modulus of subgrade/subbase reaction, otherwise known as the k-value. It can be measured in the field by applying a load equal to ١٠ psi on the subgrade/subbase combination using a ٣٠-inch diameter steel plate. The k-value is then calculated by dividing ١٠ psi by the measured deflection (in inches) of the layers under the plate.

A k-value of ٣٠٠ pci is to be used in the rigid pavement design procedure when one of the stabilized subbases layer combinations is specified. However, there is one exception to this requirement. Two inches of ACP will be allowed as a subbase under the following conditions:

- The project is an urban or county road project **and**
- The concrete pavement will be one inch thicker than is required by the AASHTO rigid pavement design procedure **and**
- The ٣٠-year ١٨-kip ESAL estimate is less than ٣,٠٠٠,٠٠٠.

Hence, a k-value of ١٤٠ pci is to be used in the rigid pavement design procedure when two inches of ACP is specified.

The pavement engineer can also assist in selecting a k-value for any subbase combination.

Currently, the modulus of subgrade/subbase reaction has a minimum effect on the concrete pavement thickness when using the AASHTO procedure. However, future revisions to concrete pavement thickness design may give more credit to subbase support than is given now, especially to non-erosive subbases.

Rigid Pavement Subbase Requirements. For new and reconstruction projects, we require one of the following stabilized subbase layer combinations for rigid pavement support:

- four inches of ACP or asphalt stabilized subbase **or**
- a one-inch asphalt concrete bond breaker over six inches of a cement stabilized subbase.

The same exception to this requirement applies as in the k-value case. Two inches of ACP will be allowed as a subbase under the following conditions:

- The project is an urban or county road project **and**
- The concrete pavement will be one inch thicker than is required by the AASHTO rigid pavement design procedure **and**
- The ٣٠-year ١٨-kip ESAL estimate is less than ٣,٠٠٠,٠٠٠

We requires such stabilized sub bases since they do not erode over time under truck traffic loading. The general philosophy used is to prevent water intrusion and pumping of underlying materials by using sub bases that are dense graded, non-erosive, and stabilized. In addition, the longitudinal steel requirements for CRCP and transverse steel requirements for CRCP and CPCD were developed using the subbases listed above.

A bond breaker should always be used between concrete pavement and cement-stabilized subbases.

There have been several instances where excessive cracking and premature failures occurred when concrete pavement was placed directly on such subbases. These problems occur because concrete pavements tend to bond directly to cement-stabilized subbases. This increases the chances for cracks in the subbase to reflect through the overlying pavement. This also significantly increases tensile stresses in the concrete pavement due to temperature and moisture changes, which promotes cracking.

Usually, the subgrade is also stabilized or treated with lime or cement for facilitating construction.

Subbase Widths. The subbase should be designed two feet wider on each side than the concrete pavement width to accommodate the pavement equipment.

Serviceability Indices

For concrete pavement design, the difference between the initial and terminal serviceability is the most important factor. It is recommended that an initial serviceability value of ٤,٥ and a terminal serviceability value of ٢,٥ be used in the procedure, which results in a difference of ٢,٠.

Load Transfer Coefficient

The load transfer coefficient is used to indicate the effect of dowels, reinforcing steel, tied shoulders, and tied curb and gutter on reducing the stress due to traffic loading. The coefficients recommended in the AASHTO guide were based on findings from the AASHO Road Test.

Drainage Coefficient

The drainage coefficient characterizes the quality of drainage of the subbase layers under the concrete pavement. Good draining pavement structures do not give water the chance to saturate the subbase and subgrade; thus, pumping is not as likely to occur.

The AASHTO guide provides a table of drainage coefficients based on the anticipated exposure of the pavement structure to moisture and on the quality of drainage of the subbase layers. Higher drainage coefficients represent better drainage. The most credit is given to permeable subbases with edge drains.

We have not had much experience with positive drainage systems. As stated earlier, the general philosophy used is to prevent water intrusion and pumping by using subbases that are dense graded, non-erosive, and stabilized. Since the department has had vast experience with such subbases, it is believed that the subbases recommended earlier in this section provide performance equivalent to a fair level of drainage.

Currently, drainage coefficients for non-erosive stabilized subbases are based on the anticipated exposure of the pavement structure to water. Table ٣-٢ shows the recommended drainage coefficients. The coefficients are selected based on the annual rainfall in the project area.

Table ٣-٢. Recommended Drainage Coefficients

Annual Rainfall (inches)	**Drainage Coefficient**
٥٨ - ٥٠	٠.٩١ - ٠.٩٥

٤٨ - ٤٠	٠.٩٦ - ١.٠٠
٣٨ - ٣٠	١.٠١ - ١.٠٥
٢٨ - ٢٠	١.٠٦ - ١.١٠
١٨ - ٨	١.١١ - ١.١٦
NOTE: Higher drainage coefficients decrease the pavement thickness in the AASHTO procedure.	

Overall Standard Deviation

This value represents the variability of the input values used. It is recommended that a value of ٠,٣٩ be used for thickness design.

The AASHTO guide recommends values in the range of ٠,٣٠ to ٠,٤٠, with ٠,٣٥ being the overall standard deviation from the AASHO Road Test. Higher values represent more variability; thus, the pavement thickness increases with higher overall standard deviations. A value on the high end of the range is used since it is believed that the inputs recommended for Texas are less accurate than the inputs determined at the AASHO Road Test.

Reliability, %

The reliability value represents a "safety factor, " with higher reliabilities representing pavement structures with less chance of failure. We strongly recommends that higher reliabilities be used for pavements where the consequences of failure would be detrimental. As a result, higher reliabilities produce thicker concrete pavements in the AASHTO procedure.

It is assumed that higher reliability levels would produce facilities that require less maintenance over their design lives, thus causing fewer traffic delays. Therefore, higher reliabilities are provided in critical high traffic areas where traffic delays need to be minimized.

Design Traffic ١٨-kip ESAL

The AASHTO guide requires a prediction of the number of ١٨-kip ESALs that the pavement will experience over its design life.

The traffic projections for a highway project (in terms of ADT and one-way total ١٨-kip ESALs) are obtained from the traffic analysis report. This report is requested during the design phase of a project. Traffic for a ٢٠-year design period should be used.

In addition, the predicted ١٨-kip ESALs is multiplied by a lane distribution factor (LDF). This factor represents the percentage of the total one-way ١٨-kip ESALs that could be expected in the design lane. The design lane, in this case, is the lane that will carry the most traffic. Usually, it is assumed that the outer lane of a highway with two lanes in each direction carries the most traffic. For a three-lane facility, the middle lane is assumed to carry the most traffic. Traffic distribution in urban areas is somewhat more complex due to merging and exiting operations, but the same assumptions could apply.

Table ٣-٤ shows the current recommended LDF values.

Table ٣-٤. Recommended LDF

Number of Lanes in Both Directions	LDF
≤ ٤	١.٠
٦	٠.٧
≥ ٨	٠.٦

The LDF decreases with an increase in the number of lanes of a facility. So, a highway with two lanes in each direction would have a higher LDF than a highway with three or more lanes in each direction. This is because traffic tends to spread out over the available lanes.

The traffic analysis report also lists a directional distribution of traffic, which indicates the percent distribution of the design hourly volume in each direction of a highway facility. This value is used for capacity analysis and applies to all vehicles in the design hourly volume. However, we assume that the directional distribution of heavy vehicles on any project is evenly split in both directions. Therefore, the directional distribution factor listed in the report should not be used to modify the design ١٨-kip ESALs.

Base Course

The base course is immediately beneath the surface course. It provides (١) additional load distribution, (٢) contributes to drainage and frost resistance, (٣) uniform support to the pavement and (٤) a stable platform for construction equipment (ACPA, ٢٠٠١). Bases also help prevent subgrade soil movement due to slab pumping. Base courses are usually constructed out of:

١. Aggregate base. A simple base course of crushed aggregate has been a common option since the early ١٩٠٠s and is still appropriate in many situations today.

٢. Stabilized aggregate or soil (see Figure ٢,٢٣). Stabilizing agents are used to bind otherwise loose particles to one another, providing strength and cohesion. Cement treated bases (CTBs) can be built to as much as ٢٠ - ٢٥ percent of the surface course strength (FHWA, ١٩٩٩). However, cement treated bases (CTBs) used in the ١٩٥٠s and early ١٩٦٠s had a tendency to lose excessive amounts of material leading to panel cracking and settling.

٣. Dense-graded HMA. In situations where high base stiffness is desired base courses can be constructed using a dense-graded HMA layer.

٤. *Permeable HMA*. In certain situations where high base stiffness and excellent drainage is desired, base courses can be constructed using an open graded HMA. Recent research may indicate some significant problems with ATPB use.

٥. Lean concrete (see Figure ٢,٢٤). Contains less portland cement paste than a typical PCC and is stronger than a stabilized aggregate. Lean concrete bases (LCBs) can be built to as much as ٢٥ - ٥٠ percent of the surface course strength (FHWA, ١٩٩٩). A lean concrete base functions much like a regular PCC surface course and therefore, it requires construction joints and will crack over time. These joints and cracks can potentially cause reflection cracking in the surface course if they are not carefully matched.

Figure ٢,٢٤: Lean Concrete Base Material

Subbase Course

The subbase course is the portion of the pavement structure between the base course and the subgrade. It functions primarily as structural support but it can also:

١. Minimize the intrusion of fines from the subgrade into the pavement structure.

٢. Improve drainage.

٣. Minimize frost action damage.

٤. Provide a working platform for construction.

The subbase generally consists of lower quality materials than the base course but better than the subgrade soils. Appropriate materials are aggregate and high quality structural fill. A subbase course is not always needed or used.

Joints

Joints are purposefully placed discontinuities in a rigid pavement surface course. The most common types of pavement joints, defined by their function, are (AASHTO, ١٩٩٣): contraction, expansion, isolation and construction.

Contraction Joints

A contraction joint is a sawed, formed, or tooled groove in a concrete slab that creates a weakened vertical plane. It regulates the location of the cracking caused by dimensional changes in the slab. Unregulated cracks can grow and result in an unacceptably rough surface as well as water infiltration into the base, subbase and subgrade, which can enable other types of pavement distress. Contraction joints are the most common type of joint in concrete pavements, thus the generic term "joint" generally refers to a contraction joint.

Contraction joints are chiefly defined by their spacing and their method of load transfer. They are generally between ١/٤ - ١/٣ the depth of the slab and typically spaced every ٣.١ - ١٥ m (١٢ - ٥٠ ft.) with thinner slabs having shorter spacing . Some states use a semi-random joint spacing pattern to minimize their resonant effect on vehicles. These patterns typically use a repeating sequence of joint spacing (for example: ٢.٧ m (٩ ft.) then ٣.٠ m (١٠ ft.) then ٤.٣ m (١٤ ft.) then ٤.٠ m (١٣ ft.)). Transverse contraction joints can be cut at right angles to the direction of traffic flow or at an angle (called a "skewed joint"). Skewed joints are cut at obtuse angles to the direction of traffic flow to help with load transfer. If the joint is properly skewed, the left wheel of each axle will cross onto the leave slab first and only one wheel will cross the joint at a time, which results in lower load transfer stresses (see Figure ٢.٢٨).

Figure ٢.٢٥: Rigid Pavement Showing Contraction Joints

Figure ٢,٢٦: Missing Contraction Joint

(The middle lane contraction joint was not sawed resulting in a transverse slab crack. The outer lanes have proper contraction joints and therefore, no cracking)

Expansion Joints

An expansion joint is placed at a specific location to allow the pavement to expand without damaging adjacent structures or the pavement itself. Up until the ١٩٥٠s, it was common practice in the U.S. to use plain, jointed slabs with both contraction and expansion joints (Sutherland, ١٩٥٦). However, expansion joint are not typically used today because their progressive closure tends to cause contraction joints to progressively open (Sutherland, ١٩٥٦). Progressive or even large seasonal contraction joint openings cause a loss of load transfer — particularly so for joints without dowel bars.

Dowel Bars

bars that provide a mechanical connection between slabs without restricting horizontal joint movement. They increase load transfer efficiency by allowing the leave slab to assume some of the load before the load is actually over it. This reduces joint deflection and stress in the approach and leave slabs.

Dowel bars are typically ٣٢ to ٣٨ mm (١.٢٥ to ١.٥ inches) in diameter, ٤٦٠ mm (١٨ inches) long and spaced ٣٠٥ mm (١٢ inches) apart. Specific locations and numbers vary by state, however a typical arrangement might look like Figure ٢.٣٤. In order to prevent corrosion, dowel bars are either coated with stainless steel (see Figure ٢.٣٥) or epoxy (see Figure ٢.٣٦). Dowel bars are usually inserted at mid-slab depth and coated with a bond-breaking substance to prevent bonding to the PCC. Thus, the dowels help transfer load but allow adjacent slabs to expand and contract independent of one another. Figure ٢.٣٦ shows typical dowel bar locations at a transverse construction joint.

Figure ٢,٣٦: Dowel Bars in Place at a Construction Joint- the Green Color is from the Epoxy Coating

Reinforcing Steel

Reinforcing steel can also be used to provide load transfer. When reinforcing steel is used, transverse contraction joints are often omitted (as in CRCP). Therefore, since there are no joints, the PCC cracks on its own and the reinforcing steel provides load transfer across these cracks. Unlike dowel bars, reinforcing steel is bonded to the PCC on either side of the crack in order to hold the crack tightly together.

Typically, rigid pavement reinforcing steel consists of grade ٦٠ (yield stress of ٦٠ ksi (٤١٤ MPa) No. ٥ or No. ٦ bars (ERES, ٢٠٠١). The steel constitutes about ٠.٦ - ٠.٧ percent of the pavement cross-sectional area (ACPA, ٢٠٠١) and is typically placed at slab mid-depth or shallower. At least ٦٣ mm (٢.٥ inches) of PCC cover should be maintained over the reinforcing steel to minimize the potential for steel corrosion by chlorides found in deicing agents (Burke, ١٩٨٣).

Tie Bars

Tie bars are either deformed steel bars or connectors used to hold the faces of abutting slabs in contact (AASHTO, ١٩٩٣). Although they may provide some minimal amount of load transfer, they are not designed to act as load transfer devices and should not be used as such (AASHTO, ١٩٩٣). Tie bars are typically used at longitudinal joints (see Figure ٢.٣٧) or between an edge joint and a curb or shoulder. Typically, tie bars are about ١٢.٥ mm (٠.٥ inches) in diameter and between ٠.٦ and ١.٠ m (٢٤ and ٤٠ inches long).

Figure ٢.٣٧: Tie Bars Along a Longitudinal Joint

Jointed Reinforced Concrete Pavement (JRCP)

Jointed reinforced concrete pavement (JRCP, uses contraction joints and reinforcing steel to control cracking. Transverse joint spacing is longer than that for JPCP and typically ranges from about ٧,٦ m (٢٥ ft.) to ١٥,٢ m (٥٠ ft.). Temperature and moisture stresses are expected to cause cracking between joints, hence reinforcing steel or a steel mesh is used to hold these cracks tightly together. Dowel bars are typically used at transverse joints to assist in load transfer while the reinforcing steel/wire mesh assists in load transfer across cracks.

Crack Control: Contraction joints as well as reinforcing steel.

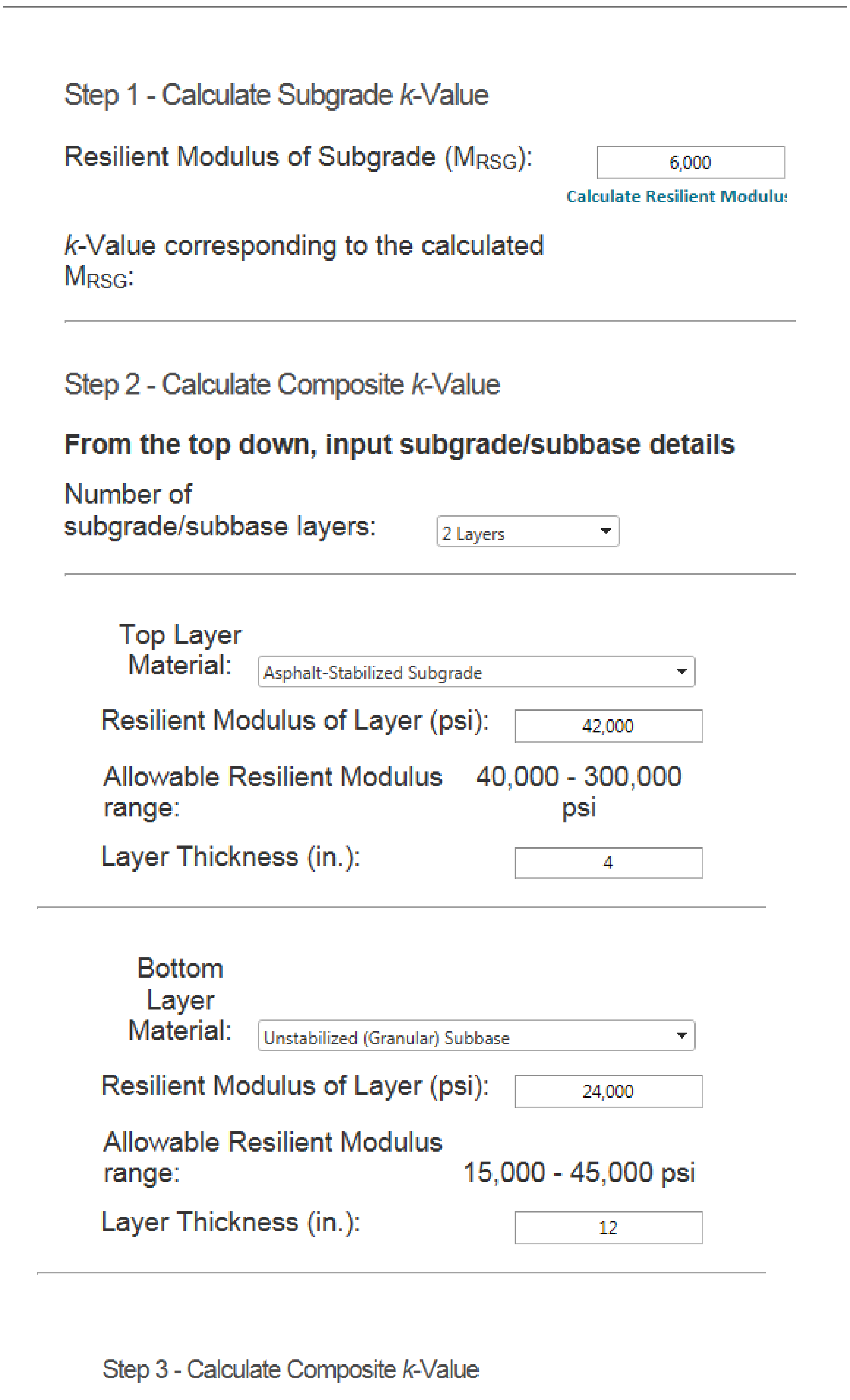
Joint Spacing: Longer than JPCP and up to a maximum of about ١٥ m (٥٠ ft.). Due to the nature of concrete, the longer slabs associated with JRCP will crack.

Reinforcing Steel: A minimal amount is included mid-slab to hold cracks tightly together. This can be in the form of deformed reinforcing bars or a thick wire mesh.

Load Transfer: Dowel bars and reinforcing steel. Dowel bars assist in load transfer across transverse joints while reinforcing steel assists in load transfer across mid-panel cracks.

Other Info: During construction of the interstate system, most agencies in the Eastern and Midwestern U.S. built JRCP. Today only a handful of agencies employ this design (ACPA, ٢٠٠١).

In general, JRCP has fallen out of favor because of inferior performance when compared to JPCP and CRCP.



Step 1 - Calculate Subgrade *k*-Value

Resilient Modulus of Subgrade (M_{RSG}): 6,000

k-Value corresponding to the calculated M_{RSG}:

Step 2 - Calculate Composite *k*-Value

From the top down, input subgrade/subbase details

Number of subgrade/subbase layers: 2 Layers

Top Layer Material: Asphalt-Stabilized Subgrade

Resilient Modulus of Layer (psi): 42,000

Allowable Resilient Modulus range: 40,000 - 300,000 psi

Layer Thickness (in.): 4

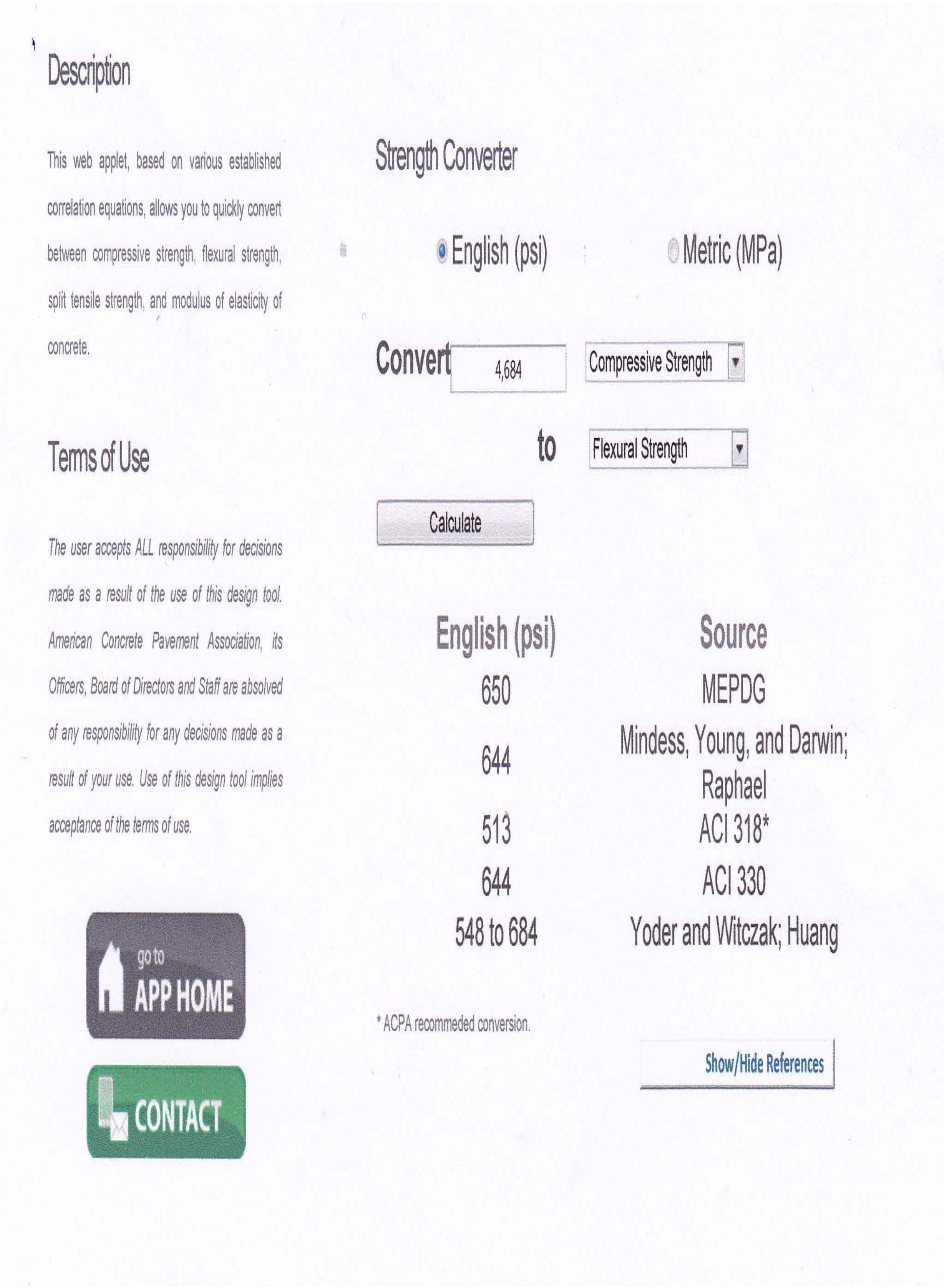
Bottom Layer Material: Unstabilized (Granular) Subbase

Resilient Modulus of Layer (psi): 24,000

Allowable Resilient Modulus range: 15,000 - 45,000 psi

Layer Thickness (in.): 12

Step 3 - Calculate Composite *k*-Value



Description

This web applet, based on various established correlation equations, allows you to quickly convert between compressive strength, flexural strength, split tensile strength, and modulus of elasticity of concrete.

Terms of Use

The user accepts ALL responsibility for decisions made as a result of the use of this design tool. American Concrete Pavement Association, its Officers, Board of Directors and Staff are absolved of any responsibility for any decisions made as a result of your use. Use of this design tool implies acceptance of the terms of use.

Strength Converter

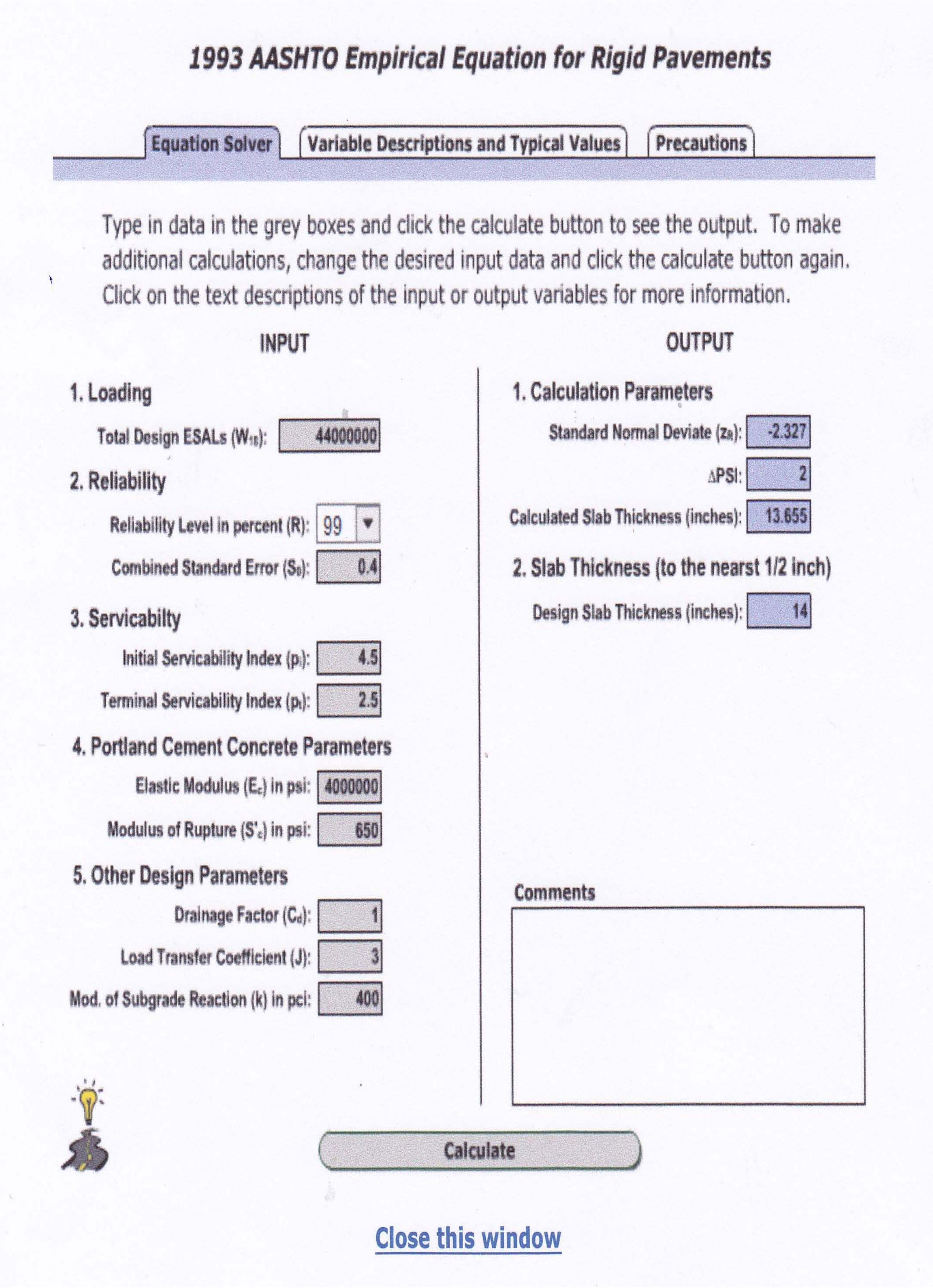
● English (psi) ○ Metric (MPa)

Convert 4,684 Compressive Strength

to Flexural Strength

English (psi)	Source
650	MEPDG
644	Mindess, Young, and Darwin; Raphael
513	ACI 318*
644	ACI 330
548 to 684	Yoder and Witczak; Huang

* ACPA recommeded conversion.



1993 AASHTO Empirical Equation for Rigid Pavements

Type in data in the grey boxes and click the calculate button to see the output. To make additional calculations, change the desired input data and click the calculate button again. Click on the text descriptions of the input or output variables for more information.

INPUT

1. Loading

Total Design ESALs (W_{18}): 44000000

2. Reliability

Reliability Level in percent (R): 99

Combined Standard Error (S_0): 0.4

3. Servicabilty

Initial Servicability Index (p_i): 4.5

Terminal Servicability Index (p_t): 2.5

4. Portland Cement Concrete Parameters

Elastic Modulus (E_c) in psi: 4000000

Modulus of Rupture (S'_c) in psi: 650

5. Other Design Parameters

Drainage Factor (C_d): 1

Load Transfer Coefficient (J): 3

Mod. of Subgrade Reaction (k) in pci: 400

OUTPUT

1. Calculation Parameters

Standard Normal Deviate (z_R): -2.327

ΔPSI: 2

Calculated Slab Thickness (inches): 13.655

2. Slab Thickness (to the nearst 1/2 inch)

Design Slab Thickness (inches): 14

Comments