A PROPOSED THICKNESS DESIGN PROCEDURE
FOR HIGH STRENGTH STABILIZED BASE (HSSB)
PAVEMENTS

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A Report of the Investigation of
Mechanistic Evaluation of Illinois
Flexible Pavement Design Procedures
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Illinois Cooperative Highway and Transportation Research Program

A Cooperative Investigation
conducted by the
TRANSPORTATION RESEARCH LABORATORY
DEPARTMENT OF CIVIL ENGINEERING
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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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A PROPOSED THICKNESS DESIGN PROCEDURE FOR HIGH STRENGTH STABILIZED BASE (HSSB) PAVEMENTS

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The basic concepts and the development of a proposed THICKNESS DESIGN PROCEDURE FOR HIGH STRENGTH STABILIZED BASE (HSSB) PAVEMENTS are presented. Traffic (IDOT traffic factor), subgrade modulus, HSSB design compressive strength, asphalt concrete surface thickness, and design reliability factors are considered.

ILLI-PAVE based design algorithms are utilized in the procedure. HSSB fatigue consumption is the design criteria.

The procedure can be easily modified to accommodate conditions other than those considered in the design procedure presented in Appendix A.

Mechanistic Design
Stabilized Bases
Flexible Pavements

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IHR-510

MECHANISTIC EVALUATION OF ILLINOIS
FLEXIBLE PAVEMENT DESIGN PROCEDURES

Project Advisory Committee

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ACKNOWLEDGEMENTS/DISCLAIMER

This research report is based on the results of Project IHR-510 - Mechanistic Evaluation of Illinois Flexible Pavement Design Procedures. IHR-510 is sponsored by the Illinois Department of Transportation (Division of Highways) and the U.S. Department of Transportation (Federal Highway Administration).

The contents of this research report reflect the views of the authors. The contents do not necessarily reflect the official views or policies of the Illinois Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.
INTRODUCTION

High strength stabilized base (HSSB) course materials (pozzolanic-aggregate-mixtures, cement-aggregate-mixtures, soil-cement, etc.), are utilized in many Illinois flexible pavements. Current Illinois DOT design policy requires a stabilized base if the structural number is greater than 3.0 (Bureau of Local Roads and Streets) or 3.5 (Bureau of Design). The typical pavement section, Figure 1, includes a minimum thickness asphalt concrete surface course over the stabilized base. In some low-volume traffic applications, only a surface-treatment may be constructed.

Cementitious stabilizers typically increase compressive strength, shear strength (large increase in cohesion), tensile strength (flexural and split tensile), and modulus of elasticity. Freeze-thaw and moisture resistance are significantly enhanced by stabilization. HSSB material durability should be considered in the mixture design process. Previous University of Illinois research (1) proposed procedures and concepts for evaluating freeze-thaw durability.

For HSSB materials, the controlling thickness design criterion for the stabilized material is the flexural stress at the bottom of the layer. A recent TRRL report (2) summarizing an extensive study of lean concrete bases in flexible pavements substantiated the validity of using flexural stress and flexural strength as indicators of "cracking" type distress.

A brief summary of the strength, modulus, and fatigue properties for cementitiously stabilized materials was presented in a previous project report (3). The structural response and performance of the stabilized layer (for a given wheel loading) are influenced by the flexural strength, modulus, and thickness of the stabilized layer and subgrade resilient modulus. Stabilized
materials of the same quality (strength, modulus) should display similar structural responses. Thus, HSSB thickness design concepts are independent of material type.

Concepts for a mechanistic based thickness design procedure for high strength stabilized base pavements were presented in Reference 3. The concepts were based on stabilized layer fatigue consumption and an ILLI-PAVEx-based algorithm for estimating flexural stress at the bottom of the HSSB layer.

**DESIGN APPROACH**

Pavements with high strength stabilized bases can be designed using an "intact slab" approach. The pavement may initially develop transverse shrinkage cracks, but an adequate stabilized layer design thickness prevents significant additional cracking (particularly longitudinal cracking - see Ref. 2) under traffic loading.

Costigan and Thompson (4) summarized and analyzed the response and performance of nine cement-stabilized structural sections subjected to channelized traffic. Longitudinal cracking (starting at a transverse crack) indicated the initiation of structural failure. Wang and Kiliareski (5) noted similar cracking patterns in cement stabilized sections trafficked in the Penn State Test Track. AASHO Road Test cracking progression studies for thin and structurally inadequate nonreinforced jointed PCC sections (see Figure 125 in Ref. 6) indicated structural failure initiated with longitudinal cracking in the wheel path.

A recent Transport and Road Research Laboratory study (2) based on extensive field survey data for "lean concrete roads" also indicated that structural failure initiates with "longitudinal cracks in the wheel path." TRRL suggests," it is preferable for heavily trafficked roads to use a design
that is sufficiently strong to resist longitudinal cracking." It is apparent
that the critical thickness design criterion for the HSSB layer is longitudinal
cracking based on edge/corner wheel loading conditions.

Stabilized base thickness design is based on flexural fatigue consumption
and edge loading conditions. Asphalt concrete surface requirements vary.
Portland Cement Association recommendations (7) for soil-cement bases are shown
in Table 1. The Asphalt Concrete surface thickness requirements in Table 2
were developed from current Illinois DOT design policy.

Fatigue Behavior

A HSSB pavement layer is susceptible to fatigue failure. For a given
magnitude of repeated flexural stress, the pavement can sustain a specific
number of applications before HSSB cracking occurs. The number of load
applications increases as the magnitude of the HSSB flexural stress decreases.
Figure 2 is a recommended (3) stress ratio (SR) vs. log number load
applications to cracking failure for HSSB. SR is equal to the flexural
stress/flexural strength.

Strength - To estimate HSSB strength at a given time, it is necessary to
establish the strength-degree day (DD) relation for the mixture and quantify
the expected field curing conditions. To quantify field curing conditions, the
available degree days (40°F base is recommended) in the pavement location is
required. Pavement temperature - air temperature algorithms (see Table 3) and
the Illinois climatic data base (8) can be utilized to estimate pavement degree
days for various Illinois locations.
Laboratory and/or field studies are required to establish the strength-DD relation. Experience with the HSSB material mixture may also be used to supplement the strength-DD information. Laboratory data should be adjusted for mixing efficiency (lab vs field strength) and field compaction levels to realistically reflect field conditions.

Periodic field coring/compressive strength testing operations are effective in characterizing strength-DD relations. A recent Portland Cement Association study (9) indicated the "Clegg Hammer" and the "Proceq Hammer" provide reasonable estimates of in-situ field strength.

Some typical strength-DD relations are shown in Figure 3. The relations are quite variable and must be characterized for HSSB thickness design calculations. Some mixtures develop strength at a moderate rate over a sustained period of time while others show rapid initial strength increase and then achieve only moderate additional strength increases. Typically, the 28-day moist cured (72°F) compressive strength of a cement-stabilized mixture is approximately 1.5 x the 7-day strength. Further strength increases are obtained with additional curing.

Compressive strength testing is normally utilized in HSSB mixture design activities and field cores are frequently obtained for subsequent compression testing. For thickness design purposes, HSSB flexural strength can be estimated as 20% of the compressive strength (3).

Flexural Stress - Flexural stress (for interior 9 kip wheel loading) is estimated from the following algorithm (3):

\[
\log = 2.49 - 0.07 \text{TEQ} + 0.0001 \text{E} - 0.0083 \text{ER1} \quad (1)
\]

Required inputs are subgrade resilient modulus (ER1, ksi), HSSB modulus (E, ksi) and thickness (T, inches). The asphalt concrete (AC) modulus (E_{AC}, ksi), and the HSSB modulus (E) are used to convert the AC thickness (T_{AC}) to an equivalent HSSB thickness, TEQ.
\[ \text{TEQ} = T + T_{AC} \sqrt[3]{E_{AC}/E} \]  

(2)

AC modulus is primarily a function of the pavement temperature as illustrated in Figure 4 for typical Illinois Class I mixtures. The Asphalt Institute Equation (10), can be utilized to establish an \( E_{AC} \) - mix temperature relation for a specific mixture. A plot of \( E_{AC}/E \) vs \( \sqrt[3]{E_{AC}/E} \) is shown in Figure 5. For typical Illinois AC mixtures and pavement temperature fluctuations, a \( E_{AC}/E \) value of 0.5 is recommended for general HSSB design calculations although at times a higher value would be indicated. PCA recommendations (7) support the general validity of the 0.5 "equivalency." Thus Equation 2 becomes:

\[ \text{TEQ} = T + 0.5 \ T_{AC} \]  

(3)

For thickness design purposes, the HSSB modulus can be estimated from compressive strength data (3). A recommended modulus/compressive strength relation is shown in Figure 6. As HSSB strength increases, the modulus will also increase.

Subgrade \( E_{RI} \) can be established from lab testing, local experience/information, NDT testing, or estimated from soil classification data (11). Thompson et al (12) proposed the \( E_{RI} \) relationships shown in Table 4 for use in designing low-traffic volume airfield pavements. The flexural stress estimate is not sensitive to the \( E_{RI} \) input.

Examination of Equation 1 indicates that \( \sigma \) is primarily controlled by TEQ. Assuming a typical value for \( E_{RI} \) of 3 ksi and estimating \( E \) from compressive strength (see Fig. 6), Equation 1 is simplified to:

\[ \log \sigma = 2.515 + 0.0001S - 0.07 \ \text{TEQ} \]  

(4)

where:

- \( \sigma \) = flexural stress, psi
- \( S \) = compressive strength, psi
Considering the precision with which HSSB field strength-DD relations can be estimated and the general variability of traffic loading conditions, subgrade \( E_{R1} \), etc, Equation 4 is acceptable for routine design activities.

The interior flexural stress (Equation 1 or 4) is increased by 50% to account for edge loading and HSSB transverse cracking effects (3). \( \sigma_F \), the "design flexural stress" \( \sigma_F = 1.5 \sigma \), is used in calculating SR for HSSB thickness design.

**HSSB Layer Thickness**

The development of the algorithms for predicting HSSB layer flexural stress was based on the assumptions that 1) there is "full bonding" between the AC surface and the HSSB layer, and 2) the HSSB layer is an intact-homogenous full depth layer. A recent Transport and Road Research Laboratory report (2) indicated that, "for the best performance cemented roadbase should be laid in a single layer." The TRRL field survey data indicated the superior performance of "single-layer" vs "two-layer" construction. The degree of "bonding" achieved between the HSSB layers was probably the key contributing factor.

If the required HSSB layer thickness exceeds the single-lift thickness that can be adequately constructed (primarily a full-depth adequate density consideration), special construction procedures may be needed to achieve acceptable layer bonding.
Curing Time Effects

Examination of the input parameters in Equation 1 indicates the importance of the curing time variable. HSSB strength and modulus increase with curing time; freeze-thaw action may affect a strength decrease; and AC modulus fluctuates with temperature. Thus, the load stresses also change with time. For these reasons, it is difficult to calculate a SR for a "particular time" and accurately predict the pavement life for several years hence. The application of many load repetitions at a high SR (which may occur in the early curing stages when HSSB strength is low) will effect considerable fatigue consumption. It is important to note in Figure 2 that the fatigue algorithm is a semi-log relation.

The time-dependent HSSB behavior lends itself to an iterative approach. For a small time increment, the changes in critical HSSB properties (strength/modulus) during that increment are small. It is possible to calculate the SR for that small time increment, apply Miner's fatigue theory to calculate the "incremental fatigue damage" incurred, and then move to the next time step. Total "Fatigue Damage" is the summation of the incremental damage as defined by Equation 5.

\[
\text{Fatigue Damage} \% = \sum_{i=1}^{n} P_i \\
P_i = \left(\frac{N_i}{N_{Ti}}\right)100
\]

where:

- \( P_i \) - Percent fatigue life consumption for the ith period
- \( N_i \) - Number of 18k SAL applied during ith period
- \( N_{Ti} \) - Number of load applications to failure estimated from Figure 2.
- \( n \) - Time periods considered
Crack initiation is expected at 100% fatigue consumption. Additional load repetitions are required to propagate the crack through the thickness of the HSSB layer (3).

**Design Reliability Considerations**

Design reliability data for HSSB pavements are very limited. Analysis of recent TRRL research (2) indicates the traffic for "50% probability of survival" is approximately 3.5 to 4 times the traffic for "85% probability of survival." Previously developed IHR-510 "MULTIPLIER" factors for FULL-DEPTH ASPHALT CONCRETE PAVEMENTS and CONVENTIONAL FLEXIBLE PAVEMENTS are shown below.

<table>
<thead>
<tr>
<th>&quot;Multiplier&quot;*</th>
<th>Design Reliability**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50 (AVERAGE)</td>
</tr>
<tr>
<td>2</td>
<td>80 (INTERMEDIATE)</td>
</tr>
<tr>
<td>3</td>
<td>92 (HIGH)</td>
</tr>
</tbody>
</table>

*The "Multiplier" is applied to the IDOT Traffic Factor (TF). If the TF is 1 \((1 \times 10^6\) 18k SAL) a pavement designed for \(2 \times 10^6\) SAL would have an 80% probability of sustaining \(1 \times 10^6\) SAL without failure. To achieve 92% reliability, the pavement would be designed for \(3 \times 10^6\) SAL.

The Traffic Multiplier approach is also utilized in the recent AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES (13). In the absence of data to the contrary and since the limited design reliability data for HSSB pavements are reasonably comparable to those developed in IHR-510, it is proposed to utilize the IHR-510 MULTIPLIERS shown above.
Summary

The design approach is comprehensive and simulates the complex strength development/curing time - traffic loading interactions. The precision of the thickness design approach is determined (to a large extent) by the degree of refinement devoted to developing the strength-curing time input information for the HSSB material.

DESIGN CRITERION DEVELOPMENT

The proposed thickness design procedure is predicated on the fatigue failure of an "intact" HSSB layer with a nominal AC surface course (maximum of approximately 4 inches). In this type of pavement structure, the AC radial strains are compressive and subgrade stresses are low. Thus, AC fatigue and subgrade rutting are not significant design criteria. The only thickness design criterion is fatigue consumption in the HSSB layer for considering longitudinal crack formation.

The fatigue relation (shown in Figure 2) and Miner’s approach to considering cumulative fatigue damage were previously presented. To limit early life fatigue consumption, HSSB thickness/strength must be adequate to effect a SR less than 0.65 or 0.60 prior to traffic loading. If the section is "overloaded" or "fatigued" or at an early age, the "intact slab" type structural behavior of the HSSB layer is significantly reduced.

Freeme et al (14) have documented effective modulus (measure of slab action) - traffic history relations for "strongly cemented" and "weakly cemented" pavement layers. Once "cracking" starts (other than initial transverse shrinkage cracking), the effective modulus decreases. As cracking progresses to the "small blocks" and then the "granular state", further large
effective modulus decreases are noted. Initial (precracked state) moduli range from approximately 2000 ksi to 500 ksi. At the "small block"/"granular state" the effective moduli are reduced to the 70 ksi - 20 ksi range.

HSSB fatigue consumption is calculated for the early life (first 56 days/8 weeks of traffic loading) of the pavement and also checked for total load (design life) applications. Since the fatigue consumption criterion is based on "crack initiation," it is a conservative approach. Additional load repetitions would be required to achieve "crack propagation" through the HSSB layer.

COMMENTS/SUMMARY

A HSSB thickness design procedure based on fatigue consumption of the HSSB layer subjected to edge loading conditions has been developed. The procedure is presented in Appendix A. It is apparent that HSSB material strength and layer thickness are the DOMINANT INPUTS!

HSSB Field Strength

HSSB material field strength is influenced by many factors such as:

1. Component material variability
2. Mixture proportions
3. Production efficiency
4. Compacted density
5. Curing time
6. Curing temperature
7. (Degree days; 5 and 6 combined)
8. Curing moisture content
9. Freeze-thaw activity
10. Etc.
The difficult task of establishing a priori the field-cured strength-time relation during pavement design is obvious.

In current practice, a "design strength" is established. For example:

1. IDOT assigns coefficients to cement stabilized material on the basis of a "7-day compressive strength that can be reasonably expected under field conditions";

2. The new AASHTO Guide (13) also assigns cement treated base coefficients on the basis of 7-day strength;

3. IDOT uses a 14-day cure at 72°F to characterize lime-fly-ash (LFA) and cement-fly-ash (CFA) stabilized aggregate materials; and

4. The Portland Cement Association thickness design procedure (7) for soil-cement pavements indicates the 28-day compressive strength is appropriate;

5. In the design of PCC pavement, the 28-day moist-cured flexural strength is frequently utilized in design.

Since the strength-curing relations for HSSB materials may be quite different, it is desirable to evaluate a HSSB material on its individual merits. A classification of the HSSB materials based on their cured strength-DD relations is a possible approach. "Early", "intermediate", and "long-term" strength development potential would be considered.

It is apparent that considerable additional consideration must be directed to establishing the field cured strength-time relation during the design procedure implementation phase. Material specifications, material selection, laboratory mixture design procedures and criteria, specifications, and policy items impact this very important issue.
Other Factors

Historical performance and maintenance data for HSSB pavements should be considered in establishing policies for utilizing HSSB pavements. The proposed HSSB thickness design procedure is based on an intact-slab/flexural fatigue consumption approach. Other factors also influence the overall HSSB pavement performance. The performance of transverse cracks and HSSB material "break-down" at transverse cracks have always been major concerns. Increased pavement deflections may contribute to more rapid transverse crack breakdown and accompanying decreased load transfer at cracks, and increased potential for subgrade erosion/pumping. The recently implemented Illinois DOT policy for "sawing and sealing" joints in lime-fly ash and cement-fly ash base construction will hopefully ameliorate the "joint problem."

Freeze-thaw durability considerations should also be considered. Current Illinois DOT policy should be reviewed in conjunction with future implementation activities concerning HSSB pavement design.
REFERENCES


### TABLE 1

PCA Bituminous Surface Thickness Recommendations

<table>
<thead>
<tr>
<th>Soil-Cement Thickness (inches)</th>
<th>Surface Thickness (inches)</th>
<th>Minimum Thickness (inches)</th>
<th>Non-Frost</th>
<th>Frost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>0.75 - 1.5</td>
<td></td>
<td>SBST*</td>
<td>DBST**</td>
</tr>
<tr>
<td>7</td>
<td>1.5 - 2</td>
<td></td>
<td>DBST</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>1.5 - 2.5</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>9</td>
<td>2-3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* SBST - Single bituminous surface treatment
** DBST - Double bituminous surface treatment
TABLE 2

Minimum Thickness for AC Surface Course*

<table>
<thead>
<tr>
<th>Structural Number</th>
<th>Minimum AC Thickness, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2.5</td>
<td>2</td>
</tr>
<tr>
<td>2.5 - 4.0</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 4.0</td>
<td>4</td>
</tr>
</tbody>
</table>

*Illinois DOT Bureau of Design and Bureau of Local Roads and Streets

TABLE 3

Stabilized Base Temperature Algorithms

For 3-inch asphalt concrete surface:

\[ T_{\text{mix}} = 2.9 + 1.08 \times AT \]

\[ R^2 = 0.996 \quad \text{SEE} = 1.2 \]

For bituminous surface treatment:

\[ T_{\text{mix}} = 1.15 \times AT - 0.8 \]

\[ R^2 = 0.996 \quad \text{SEE} = 1.4 \]

\[ T_{\text{mix}} \text{ - Temperature (°F) at mid depth of 12 inch stabilized base layer} \]

\[ AT \text{ - Air Temperature (°F)} \]


<table>
<thead>
<tr>
<th>AASHTO Soil Class</th>
<th>High Water Table*</th>
<th>Low Water Table**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Frost Penetration</td>
<td>Without Frost Penetration</td>
</tr>
<tr>
<td>A-4; A-5; A-6</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>A-7</td>
<td>2.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

* Water table seasonally within 24 inches of subgrade surface.

** Water table seasonally within 72 inches of subgrade surface.
Cohesive Soil Subgrade
$E_{Ri}$: Subgrade Resilient Modulus

$^*T_{AC}=0$ for a "Surface Treatment"

Figure 1. Typical Stabilized Base Pavement Section.
Figure 2. Recommended Stress Ratio-Fatigue Relation for High Strength Stabilized Base Materials.
Figure 3. Strength-Degree-Day Relations for Pozzolanic-Stabilized-Base (PSB) Materials.
Figure 4. Asphalt Concrete Modulus-Temperature Relations for Typical IDOT Class I Mixtures.
Equivalence Factor = \sqrt[3]{\frac{E_{AC}}{E_{HSSB}}}

Figure 5. Equivalence Factors for Asphalt Concrete Surface Course.
Figure 6. Recommended Modulus-Strength Relations for Cementitiously Stabilized Materials.
APPENDIX A

PROPOSED THICKNESS DESIGN PROCEDURE

FOR

HIGH STRENGTH STABILIZED BASE PAVEMENTS

DESIGN INPUTS

TF - Traffic Factor from the current IDOT Pavement Design Manual. TF is the number of equivalent 18 kip single axle loads (18k SALs) in millions (TF of 1 = 1x10^6). The thickness design procedure is based on 18k SALs and 80 psi tire pressure conditions.

SUBGRADE $E_{Ri}$ - Select a Design $E_{Ri}$ (ksi) from Table A-1 based on the AASHTO soil classification, water table location, and frost penetration conditions. The thickness design procedure is not sensitive to $E_{Ri}$. A reasonable $E_{Ri}$ estimate for many cohesive Illinois subgrade soils is 3 ksi. Other procedures (laboratory testing; clay content/PI based $E_{Ri}$ estimates; FWD data) can also be utilized to establish the design $E_{Ri}$.

HSSB FIELD STRENGTH-TIME RELATION - An in-situ field compressive strength-time (degree-day) relation must be projected. HSSB strengths at the time of "initial loading" and for the following 8 weeks are required inputs. Factors such as mixing efficiency, field compaction, strength-degree-day relations, available field curing degree days, etc. should be considered.

HSSB THICKNESS DESIGN PROCESS

A. Select a "DESIGN COMPRESSIVE STRENGTH" (CS, psi) from the HSSB Field Strength-Time relation. CS is the field compressive strength at the time of initial traffic loading.
B. Select an asphalt concrete (AC) surface course thickness ($T_{AC}$-inches), from Table A-2.

C. Determine the required HSSB thickness ($T$-inches) to achieve the initial loading STRESS RATIO indicated below.

<table>
<thead>
<tr>
<th>Traffic Factor</th>
<th>Initial Loading Stress Ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1</td>
<td>.65</td>
</tr>
<tr>
<td>.5</td>
<td>.65</td>
</tr>
<tr>
<td>1.0</td>
<td>.65</td>
</tr>
<tr>
<td>2.0</td>
<td>.60</td>
</tr>
<tr>
<td>5.0</td>
<td>.60</td>
</tr>
</tbody>
</table>

1. Select an initial HSSB layer thickness, $T$ (minimum recommended $T$ is 6 inches).

2. Use one of the following equations to estimate $\sigma$ the HSSB flexural stress (for interior loading conditions).

\[
\begin{align*}
\text{Log } \sigma & = 2.54 + 0.0001CS - 0.07 \text{ TEQ} - 0.0083 \ E_{RI} \\
\text{Log } \sigma & = 2.515 + 0.0001CS - 0.07 \text{ TEQ}
\end{align*}
\]

$CS$ - Field compressive strength, psi

$\text{TEQ} = T + 0.5 \ T_{AC}$

$T$ - HSSB layer thickness, inches

$T_{AC}$ - Asphalt concrete thickness, inches

$E_{RI}$ - Subgrade resilient modulus, ksi

3. Calculate $\sigma_F$ (the design flexural stress) from $\sigma_F = 1.5 \sigma$

4. Calculate the SR from:

\[
\text{SR} = \frac{\sigma_F}{\text{Modulus of Rupture}}
\]

Modulus of Rupture = $CS/5$

5. Iterate (by changing $T$) through the process until the initial loading stress ratio criterion is met.

* Stress Ratio based on the DESIGN COMpressive STRENGTH, CS
D. The HSSB mixture **must** be able to achieve the field compressive strength increases (from the time of initial loading) indicated below.

It is assumed that the strength increase is achieved at a uniform rate during the 8-week period.

<table>
<thead>
<tr>
<th>TF</th>
<th>Minimum Strength Increase, psi (56 day)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.23CS</td>
</tr>
<tr>
<td>0.5</td>
<td>0.37CS</td>
</tr>
<tr>
<td>1</td>
<td>0.44CS</td>
</tr>
<tr>
<td>2</td>
<td>0.40CS</td>
</tr>
<tr>
<td>5</td>
<td>0.52CS</td>
</tr>
</tbody>
</table>

E. For the design TF and RELIABILITY inputs, determine the allowable SR from Figure A-1. Calculate the SR for the 56-day field strength (from date of initial loading) and previously established T. Compare the 56-day SR with the Figure A-1 target value. Adjust T until the SR criterion is satisfied.

Note: If the SR at the time of initial loading is equal to or less than Figure A-1 Target Value, section D requirements are not needed.

* Compressive strength increase achieved during the 56-day period following the date of initial loading.

** CS-Design Compressive Strength
TABLE A-1
Estimated Subgrade $E_{RI}$ Values

Design Subgrade $E_{RI}$, ksi

<table>
<thead>
<tr>
<th>AASHTO Soil Class</th>
<th>High Water Table*</th>
<th>Low Water Table**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Frost Penetration</td>
<td>Without Frost Penetration</td>
</tr>
<tr>
<td>A-4; A-5; A-6</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>A-7</td>
<td>2.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

* Water table seasonally within 24 inches of subgrade surface.
** Water table seasonally within 72 inches of subgrade surface.

TABLE A-2
Asphalt Concrete (AC) Surface Thickness

<table>
<thead>
<tr>
<th>TF-Traffic Factor</th>
<th>Minimum AC Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.05</td>
<td>2</td>
</tr>
<tr>
<td>0.05 - 0.5</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 0.5</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure A-1. Stress Ratio-Traffic Factor Relations