CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

Project Summary Report 0-4382-S
Project 0-4382: Establish an Acceptable Pavement Thickness Tolerance to Allow for Non-Destructive Continuous Concrete Pavement Thickness Measurements

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PROJECT SUMMARY REPORT

ACCEPTABLE CONCRETE PAVEMENT THICKNESS TOLERANCE

This research project was conducted to investigate if the current thickness tolerance for concrete pavements can be loosened and to provide TxDOT with the acceptable thickness tolerance so that non-destructive testing (NDT) methods can be used with confidence for thickness measurements.

TxDOT's current tolerance limit for concrete slab thickness was developed in the 1950s based on engineering judgment and experience; no additional study on tolerance limit has been conducted since. The tolerance limit is currently 5 mm (0.2 in.) for full payment. This tolerance limit is too tight to allow use of existing NDT methods for slab thickness determination because these methods are not as accurate as direct measurement from coring. If the current tolerance can be shown to have minimal impact on the pavement performance, then the tolerance limit can be loosened so that NDT methods can be used for thickness determination. NDT methods are less time-consuming and more cost-effective than coring. Moreover, the slab thickness measured continuously by NDT methods will represent the pavement more adequately than spot-checking by coring.

In this research, the sensitivity of pavement performance to slab thickness has been investigated based on various models including the AASHTO model, a mechanistic distress prediction model, and fatigue failure models. The controlling performance indicator from the sensitivity study has been compared with the measured variability of pavement thickness in the field, and to the accuracy of the NDT devices. From these comparisons, a reasonable tolerance limit of the slab thickness has finally been obtained.

What We Did ...

This research was conducted with four different phases as follows:

- Review of current thickness tolerance limits for concrete pavements in Texas and other states.
- Sensitivity analysis of concrete pavement thickness based on various models such as the AASHTO model, mechanistic distress prediction model, and fatigue failure models.
- Investigation of field variability of concrete pavement thickness and accuracy of NDT devices.
- Determination of acceptable thickness tolerance.

The thickness tolerance

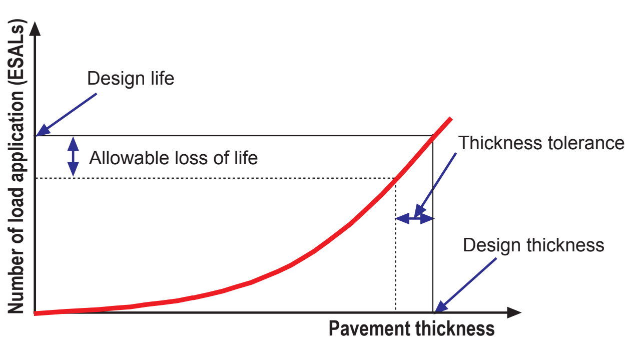
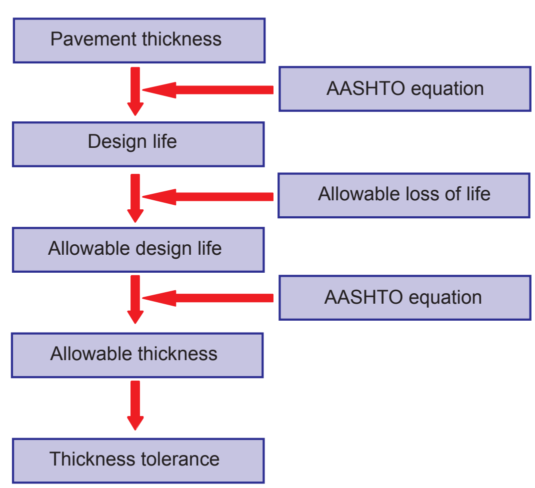


Figure 1: Thickness Tolerance Determination with AASHTO Equation



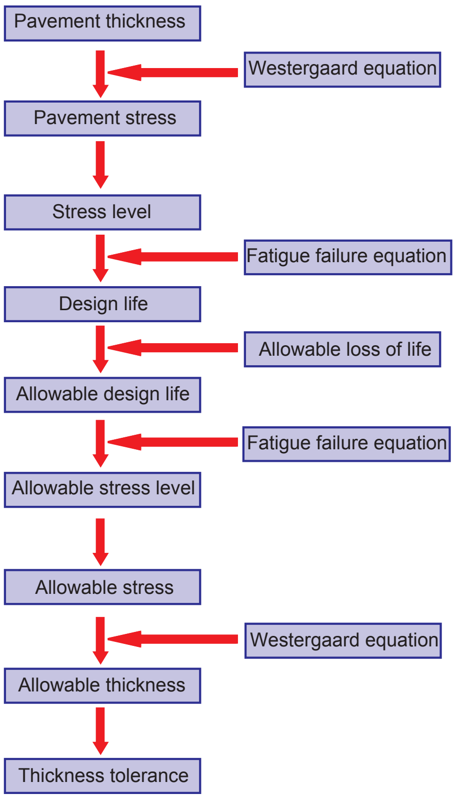


Figure 2: Thickness Tolerance Determination with Fatigue Failure Equations

limits and corresponding penalties should be related to the loss of pavement life caused by the thickness deficiency. Three different approaches have been used to find the relationship between the pavement thickness deficiency and the loss of pavement design life. The first is based on the change in present serviceability index (PSI) to predict the pavement life, which includes the AASHTO pavement life prediction equation. The second is based on the fatigue failure, which includes a number of fatigue failure equations. The third is based on distresses such as cracks and punchouts, which can be predicted by mechanistic models.

The concept of determining pavement thickness sensitivity to pavement life by using the AASHTO equation is illustrated in Figure 1. The pavement design life can be obtained from the pavement design thickness by using the AASHTO equation. Then, an allowable loss of the pavement life is selected, and the allowable design life is obtained by subtracting the allowable loss of life from the design life. The corresponding allowable pavement thickness can then be obtained by using the AASHTO equation inversely, and finally the thickness tolerance for the allowable loss of life can be obtained by subtracting the allowable thickness from the design thickness.

The concept of determining pavement thickness sensitivity to pavement life by using the fatigue failure equations is similar, as shown in Figure 2. Another concept for finding pavement thickness sensitivity to pavement life is based on distresses such as cracks and punchouts. If a pavement with a thickness deficiency does not induce more cracks as compared with the plan pavement, the thickness deficiency can be acceptable with this concept. To predict crack and punchout formations, a mechanistic model, CRCP-10, has been used.

What We Found ...

The findings of this research are as follows:

- The current thickness tolerance limits are independent of the design pavement thickness. If the same thickness deficiency is established for different design thicknesses, the contractor for the pavement with a thicker thickness should pay higher a penalty because the penalty is determined as a percentage of the contract price corresponding to the deficiency and the contract price for the thicker pavement is generally more expensive than that for the thinner pavement.
- The sensitivity analysis of the pavement thickness based on the AASHTO design equation to predict the pavement life shows that the tolerance increases as the thickness increases for a given percent allowable loss of design life. The relative (percent) tolerance remains almost constant when the pavement thickness is greater than about 10 inches. The tolerance increases as the elastic modulus of concrete decreases or the modulus of subgrade reaction increases. The relationship between the tolerance (both absolute and relative) and the percent allowable loss of life is almost linearly proportional.
- The thickness sensitivity analysis based on various power fatigue failure equations shows that the absolute tolerance increases and the relative tolerance remains almost constant as the pavement thickness increases for a given percent allowable loss of design life. The tolerance is affected little by the concrete elastic modulus and the modulus of subgrade reaction. Both the absolute and relative tolerances increase as the percent allowable loss of life increases, and the relationship is

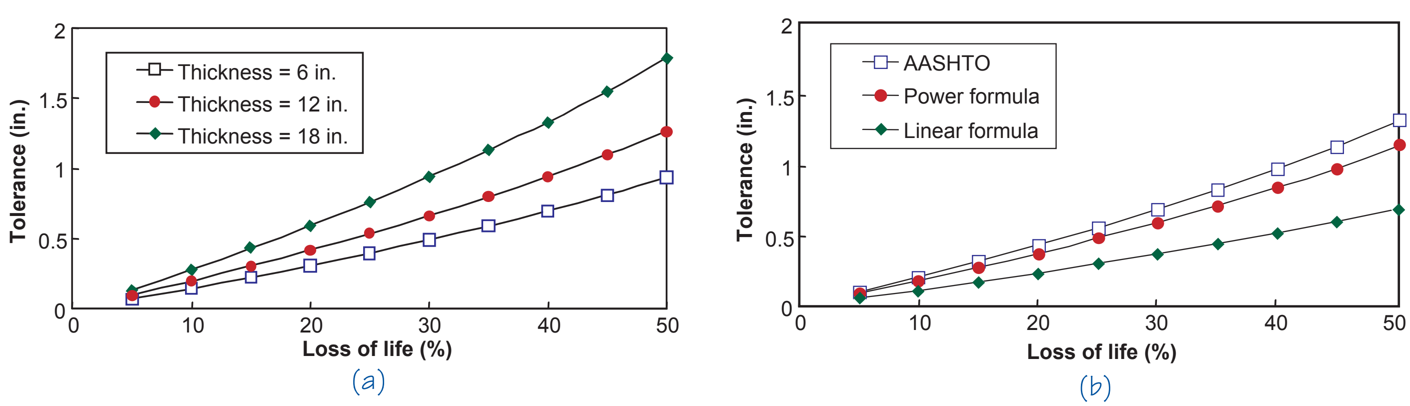


Figure 3: Relationship between Thickness Tolerance and Loss of Pavement Life

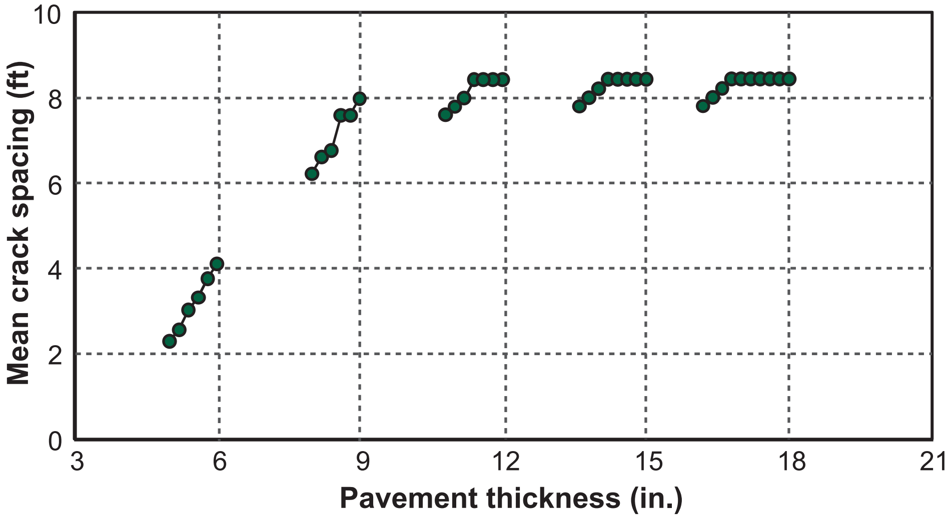


Figure 4: Sensitivity of Crack Spacing to Thickness Deficiency

almost linear.

- The thickness sensitivity study based on various linear fatigue failure equations shows that both the absolute and relative thickness tolerances increase with increasing the pavement thickness for a given percent allowable loss of life. The tolerance increases as the elastic modulus of concrete or the modulus of subgrade reaction increases. As the percent allowable loss of life increases, both the absolute and relative tolerances become larger, and the relationship is almost linear.
- The results from the sensitivity analysis based on the AASHTO equation and various fatigue failure equations show that the thickness tolerance increases as the pavement thickness increases and as the allowable loss of pavement design life increases, as shown in Figure 3.
- The sensitivity analysis of the pavement thickness based on distresses shows that as the pavement thickness increases, the thickness deficiency that induces more cracks becomes larger. The thickness deficiency of 0.2 in. does not affect the CRC pavement performance when the pavement thickness is greater than about 10 inches. The thickness deficiencies that do not affect the CRC pavement performance are 0.6, 0.8, and 1.2 in. (5, 5.3, and 6.7%) for 12-, 15-, and 18-inch-thick pavements, respectively, as shown in Figure 4.
- The field variability of the thickness shows that the average thickness is generally 3 to 7% larger than the design thickness and the average thickness difference from the average thickness is about 3%.
- The current ground-penetrating radar (GPR) system, a non-destructive testing device, generally slightly overestimates the pavement thickness. The relative average error of the measurement is about 2% of the pavement thickness.

The Researchers Recommend ...

The findings from this research clearly indicate that the current thickness tolerance limits can be loosened for thicker pavements. It is recommended that the thickness tolerance limits be dependent on the design thickness and the linearly proportional relationship between the tolerance and the design thickness be used. The payment adjustments should be dependent on the thickness deficiency and the linearly proportional relationship between the payment adjustment and the thickness deficiency may be used beyond the no-penalty tolerance limit. Several approaches would be acceptable for determining the payment adjustments to the thickness deficiency. One would be to use the current thickness deficiency adjustment table for a 10-inch pavement, with the relative tolerance limits used for other pavement thicknesses, because the current thickness tolerance was developed when the pavement thickness was mostly less than 10 inches. Then, a proposed thickness deficiency adjustment table can be obtained as shown in Table 1.

Table 1: Thickness Deficiency Adjustment Table

Deficiency in thickness (%)	Percent of contract unit price allowed
0 – 2	100
2 – 3	80
3 – 4	72
4 – 5	68
5 – 8	57

For More Details...

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The research is documented in the following reports:

4382-1 *Reconsideration of Thickness Tolerance for Concrete Pavements* October 2002

To obtain copies of a report: CTR Library, Center for Transportation Research,
(512) 232-3138, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status
January 2004

The Concrete Branch of the Construction Division of TxDOT is evaluating the recommendations of this project for implementation in TxDOT specifications. The recommendations of this project will be evaluated again in conjunction with the capabilities of a new generation Ground Penetrating Radar (GPR) that has greater accuracy in thickness measurements. Project 5-4414-01 is implementing the new GPR equipment. The Concrete Branch of the Materials and Pavements Section will be responsible for the future implementation.

For more information, contact: German Claros, P.E., Research and Technology Implementation Office, (512) 465-7403 or e-mail gclaros@dot.state.tx.us.

Your Involvement Is Welcome!

Disclaimer

This research was performed in cooperation with the Texas Department of Transportation and the U. S. Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement. The engineer in charge was Dr. B. Frank McCullough, P.E. (Texas No. 19914).

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