# Caution of Indirect Tensile Strength-Only Specifications for Asphalt Mixtures

February 5, 2019

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## Abstract

*Indirect tensile strength at 25℃ can be a mis-leading property for asphalt mixtures and yet it is used sometimes to describe a mixture's performance. While indirect tensile strength test at 25℃ is sensitive to changes in mixture properties such as air voids, asphalt binder content, binder grade, aggregate properties (angularity, texture, etc.), the resulting indirect tensile strength does not always equate to positive field results. In other words, high tensile strength alone does not always relate to improved cracking resistance. Other cracking tests are discussed that will provide better, field correlated, data rather than relying on a single strength property such as indirect tensile strength to define mixture performance.*

## Background

The indirect tensile strength (ITS) test has been used to characterize hot mix asphalt mixtures for over 40 years. Indirect tensile strength uses a common sample orientation know as Indirect Tensile or IDT orientation, Figure 1. The sample orientation has been used to characterize moisture damage in hot mix asphalt by measuring the dry strength and a conditioned strength. The indirect tensile test was developed further during the Strategic Highway Research Program (SHRP) in order to perform creep testing at low temperatures and strength testing at low temperatures. In the past 10 to 15 years, intermediate temperature indirect tensile creep and strength testing along with resilient modulus has been used to determine an energy ratio to predict top down cracking. More recently, researchers have been using the data from an ITS test and analyzing the data in such a way to determine a cracking index (NCAT and TTI) at 25 °C and 50-mm/minute.

Figure 1. Indirect Tensile (IDT) Test Jig by Controls Group

ITS has been standardized in ASTM D 6931. In Section 4 "Significance and Use", it states, "that ITS may be used to evaluate the relative quality of asphalt mixtures in conjunction with laboratory mix design testing and for estimating the potential for rutting or cracking. However, the cracking and rutting data that the ASTM standard refers to, is the research that performed at a different loading rate (12.5-mm/min) and test temperature (-10 °C for cracking and 40 °C for rutting). The results can also be used to determine the potential for moisture damage (loading rate of 50-mm/min and 25 °C test temperature)." AASHTO T322 has be used to evaluate the low temperature creep and strength properties of HMA. The loading rate of the low temperature strength testing is 12.5-mm/min at various test temperatures (-40 °C to 0 °C) depending on the performance grade of the asphalt binder.

The data generated in Figure 2 were generated from plant produced mix from the FHWA WMA/High Recycled ALF Mixtures [1]. Additional information on the experiment can be found in Ozer *et al*. The data set shows that there is a weak correlation ($R^2 = 0.449$) between strength (at 25 °C) and ALF cycles to failure. The data shown in Figure 3 is from a low temperature cracking national pooled fund study [2]. Again, there is a weak correlation ($R^2=0.106$) between indirect tensile strength at -10 °C and field cracking. Finally, the data in Table 1 is from NCHRP Report 465 that compares MnRoad, ALF and WesTrack research pavement performance to indirect tensile strength at 13 and 21 °C (or 55 and 70 °F as shown in the table) [3, 4]. The correlation between indirect tensile strength at 10 °C and cracking performance depends upon the location, but the correlation is "very poor" to "fair".

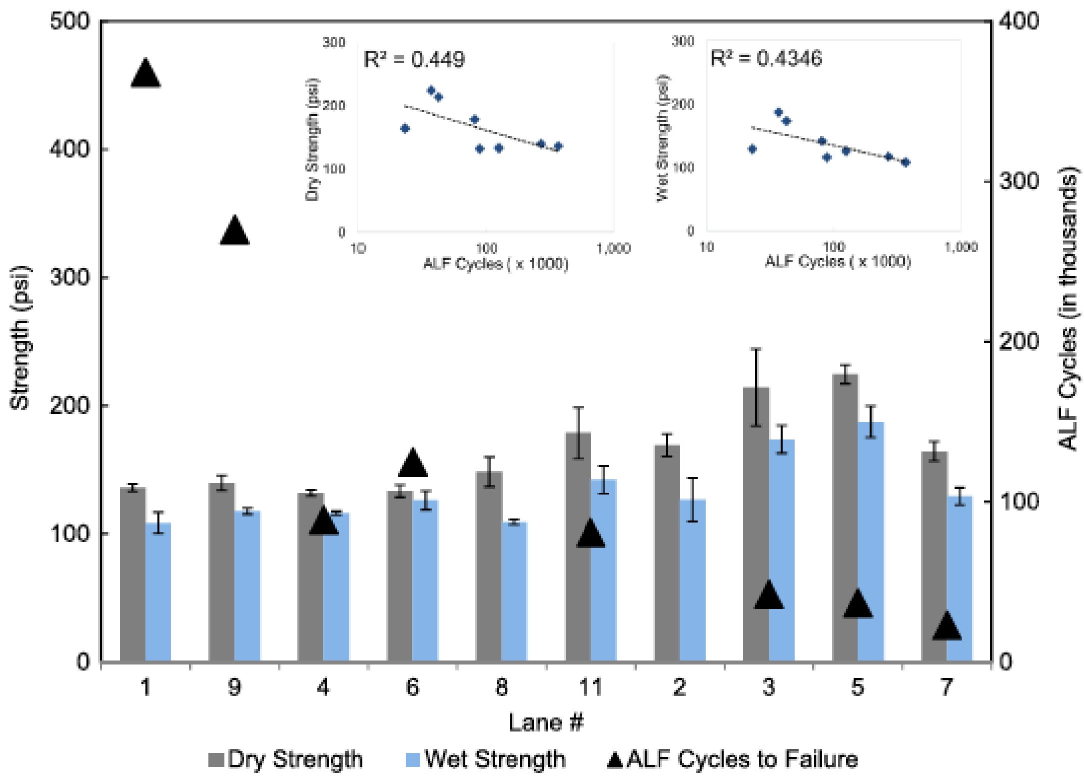


*Figure 2. Correlation of IDT Strength (Dry and Wet) to ALF Cycles to Failure*

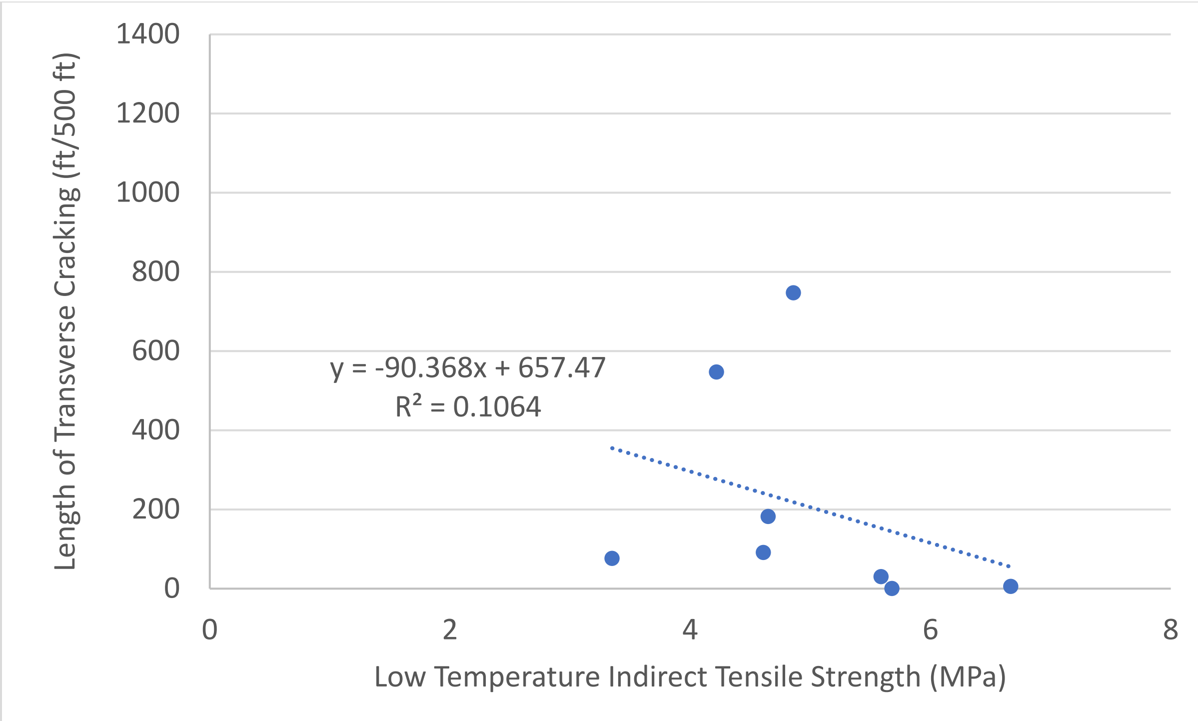


*Figure 3. Correlation of IDT Strength (Low Temperature) to Length of Transverse Cracks*

*Table 1 Correlation of Indirect Tensile Strength to Cracking – Statistical Measures*

| TEST PARAMETER | PROJECT | MODEL TYPE | STATISTICAL MEASURE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TEST TEMP 55°F | | | | | TEST TEMP 70°F | | | | |
| | | | $S_e$ | $R^2$ | Se/Sy | Rational | Rating | $S_e$ | $R^2$ | Se/Sy | Rational | Rating |
| Tensile Strength | MnRoad | Linear | 181.55 | 0.04 | 1.133 | No | Very Poor | | | | | |
| | ALF | | | | | | | | | | Yes | |
| | WesTrack | Log. | 38.16 | 0.55 | 0.826 | Yes | Fair | | | | | |

As can been seen, indirect tensile strength alone (at 25°C) is be a mis-leading property. It is not a material property and is a function of the geometry of the specimen. While indirect tensile strength at 25 °C is sensitive to changes in air voids, asphalt binder content, binder grade, and aggregate properties (angularity, texture, etc.), high strength does not always equal better performance. In contrast to using ITS as a direct cracking parameter, Texas Department of Transportation, added a maximum tensile strength requirement (<1.4 MPa or 200 psi) on hot mix asphalt due to the over use of recycled materials (Recycled Asphalt Pavement-RAP and/or Recycled Asphalt Shingles-RAS). They added the maximum tensile strength to prevent mixture that could be too stiff and brittle.

## Proper Use of Specification to Specify Mixture Performance

Table 2 from NCHRP report 9-57 shows several cracking tests that have good correlation to field performance per Fujie Zhou, *et al* [5]. Note this table details the cracking test as it relates to the cracking distress. Nowhere in the list is indirect tensile strength mentioned as a material property/test of choice that is correlated to field performance. However, based on the distress type, the correct test can be selected from Table 2 with a good degree of confidence.

*Table 1 NCHRP 9-57 Laboratory Cracking Tests & Relationship to Field Performance*

| Test Name | Cracking Type | Test Standard | Cracking Parameter | Correlation to Field Performance |
|---|---|---|---|---|
| Disk-Shaped Compaction Tension [DC(T)] | Low temperature & reflection | ASTM D 7313 | Fracture Energy | Good correlation with low temperature cracking; validated at MnROAD |
| Semi-Circular Bend (SCB) | Low temperature | AASHTO TP 105 | Fracture Energy | Good correlation with low temperature cracking; validated at MnROAD |
| SCB | Bottom-up fatigue & top-down | ASTM D 8044 | Energy Release Rate | Fair correlation to field cracking from the Louisiana Pavement Management System. |
| SCB – IFIT | Bottom-up fatigue & top-down | AASHTO TP 124 | Flexibility Index | |
| Creep and Strength using Indirect Tension (IDT) | Low temperature | AASHTO T322 | Creep compliance and tensile strength | Creep compliance and tensile strength are inputs to TCModel. |
| Dissipated Creep Stain Energy (DSCE) using IDT | Top-down | University of Florida: $M_r$ test, $D_t$ test, and tensile strength test | Energy Ratio | Validated with field cores in FL study and confirmed at NCAT test track |
| Indirect Tensile Cracking Test at Intermediate Temperature (IDEAL-CT) using IDT | Bottom-up fatigue & top down | ASTM DXXXX | Cracking Index | |
| Thermal Stress Restrained Specimen (TSRST)/UTSST | Low temperature | | Fracture Temperature | Validated with test sections during SHRP. Moderate correlation with MnROAD test sections |
| Texas Overlay Test (OLT) | Reflection cracking & bottom-up fatigue | Tex-248-F | Cycles to Failure or fracture parameters | Good correlation with reflection cracking; validated in TX. CA, & NJ. Promising correlation with fatigue cracking; validated with FHWA ALF and NCAT Test Track |
| Flexural Beam Fatigue | Bottom-up fatigue | AASHTO T321 & ASTM D8237 | Cycles to Failure or fatigue equation | Correlation with bottom-up fatigue cracking; historically validated |
| Uniaxial Fatigue using Visco-Elastic Continuum Damage (S-VECD) | Bottom-up fatigue & top-down | AASHTO TP107 & TP79 | Fatigue equation and | Used with M-E PDGE or more advanced models such as FlexPAVE and FlexMAT. |

| | | | | |
|---|---|---|---|---|
| | | | damage parameters | Validated with FHWA-ALF studies |
| Direct Tension (DT) | Bottom-up fatigue & top-down | Texas A&M University | Paris Law parameters or number of cycles | Correlation with bottom-up fatigue and top-down cracking being developed under several research projects. |

## A Better Approach

Again, the indirect tensile strength alone cannot predict performance such as cracking potential. However, when the strength curve is coupled with further analysis of the area under the load-strain curve and/the slope after reaching the peak tensile strength, a cracking index can be used. This analysis or similar is used by the Indirect Tensile Cracking Test at Intermediate Temperature (IDEAL-CT) and Semi-Circular Bend (SCB)-iFIT to predict cracking performance.

In order to fully understand a mixture, a "balanced mix design" or performance-based testing is needed where you select your materials based on permanent deformation and cracking lab predictions. A number of tests can be used to determine permanent deformation such as the Flow Number (FN), Hamburg Wheel Tracker (HWT), and Triaxial Stress Sweep Rutting in the AMPT. A cracking test or test(s) can be selected from above then can be added to ensure that the mixture is not too brittle. Finally, moisture damage can be quantified by using the Hamburg Wheel Tracker or using the moisture induced stress tester to condition samples and then perform indirect tensile strength, resilient modulus, or dynamic modulus after the conditioning. By using a suite of tests as listed above, the full picture of a mixture's potential performance can be better understood. In contrast, one test by itself could lead to a mixture that is designed for rutting or cracking resistance only.

## Summary

There are many cracking tests that one can select, however one must use engineering judgement when selecting the test to quantify the distress mode. The limits of the test must be determined using local materials and not just adopting the criteria from another state highway agency or research project. Local knowledge of asphalt mixture performance must be added to local test results. By doing this, one can better understand the proper limits of a test in order to reach the desired and reliable level of performance in that local area. Taking a balanced mix design approach will allow one to achieve the desired rutting resistance while maintaining cracking resistance (durability).

## References

[1] H. Ozer, I. Al-Qadi, P. Singhvi, J. Bausano, R. Carvalho, X. Li and N. Gibson, "Prediction of Pavement Fatigue Cracking at an Accelerated Testing Section Using Asphalt Mixture Performance Tests," *International Journal of Pavement Engineering*, vol. 19, no. 3, pp. 164-278, 2018.

[2] M. Marasteanu, A. Zofka, M. Turos, X. Li, R. Velasquez, X. Li, W. Buttlar, G. Paulino, A. Braham, E. Dave, J. Ojo, H. Bahia, R. C. Williams, J. Bausano, A. Gallistel and J. McGraw, "Investigation of Low Temperature Cracking in Asphalt Pavements - National Pooled Fund Study 776," MnDOT, St. Paul, 2007.

[3] M. W. Witczak, K. Kaloush, T. Pellinen, M. El-Basyouny and H. Von Quintus, "Simple Performance Test for Superpave Mix Design," NCHRP Report 465, Washington DC, 2002.

[4] J. Epps, "NCHRP Web-Only Document 111: Recommended Performance-Related Specification for Hot-Mix Asphalt Construction: Results of the WesTrack Project," US DOT and FHWA, Washington DC, 2000.

[5] F. Zhou, D. Newcomb, C. Gurganus, S. Banihashemrad, M. Sakhaeifar, E. Sug Park and R. Lytton, "Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures: An Experimental Design," NCHRP 9-57, Washington DC, 2016.