Evaluating the Cracking Resistance of a Superpave 5 mix and a Conventional Superpave Mix Using the Illinois Flexibility Index Test

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Executive Summary

Cracking is a major distress that adversely affects the performance of asphalt concrete (AC). It can result from environmental loading in the form of thermal cracking (low temperature cracking) or due to repeated heavy traffic loading which leads to fatigue cracking. Regardless of the cause, the material properties greatly impact the initiation and propagation of a crack. The Illinois Flexibility Index Test (I-FIT) was developed at the University of Illinois at Urbana-Champaign to capture the overall cracking resistance of AC mixtures at intermediate temperatures.

A conventional Superpave mix designed at 4 percent air voids and tested at 7 percent air voids was evaluated against a Superpave 5 mix that is designed and tested at 5 percent air voids. The results show an increase in fracture energy and strength for the new mix, but a reduced flexibility index (FI) compared to the control mix. The lower air void is responsible for increased stiffness which led to a lower FI. Overall, Superpave 5 mix performed better than the control mix. Further research is however required to determine the long-term cracking resistance of both mixtures after aging.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Compaction of asphalt concrete (AC) is a control process used to attain a stable and durable pavement. An optimal air void content is crucial for good AC pavement performance. Low in-place air voids can result in rutting and shoving, while high air voids allow water and air to penetrate into the pavement leading to an increased potential for water damage, oxidation, raveling, and cracking (Brown et al 2004).

Current Superpave design philosophy requires compaction of AC at 4% air voids in the laboratory and satisfying all AASHTO M323 limits. The mixture is then placed at 7% air voids in the field with the assumption that it will be compacted to the design air void content by the traffic. However, many AC mixtures do not reach the target air void several years into service. Twenty-Five Superpave mixes were analyzed four years into service in Alabama and the results indicated an average air void content of 5.9% with only three mixes having air voids below the target (Watson et al 2005).

Laboratoire Centrale des Ponts et Chausees (LCPC) in France developed a mix design method in the 1970s that specifies the same air void content for both design and construction (Moutier 1982). This is the basis for the new mix design approach that is referred to as Superpave 5. Recently, AC has been designed and constructed with 5% air voids without lowering the effective binder content by varying the aggregate gradation of the mixture (Hekmatfar et al 2015). The modified mix uses the same field compactive effort and number of passes as the conventional superpave mix. However, the researchers recommend lowering the number of gyrations to attain the higher design air voids.

This study focuses on comparing the intermediate temperature cracking resistance of conventional Superpave and superpave 5 mixes using the Illinois Flexibility Index Test (I-FIT).

1.2 OBJECTIVE AND SCOPE

The main objective of this study is to evaluate the cracking resistance of conventional Superpave and Superpave 5 mixes at intermediate temperature using the I-FIT. The test will capture the impact of the increased density (lower air voids) for the modified mix design approach.

1.3 OVERVIEW OF THE REPORT

This report consists of four chapters. Chapter 2 summarizes the properties of the two AC mixes, their constituent materials, and the testing program. Chapter 3 discusses the results from the I-FIT test conducted. Finally, Chapter 4 summarizes the main findings of this study.

CHAPTER 2: MATERIALS AND TESTING PROGRAM

I-FIT tests were performed using laboratory designed AC mixes. The following section discusses the materials used in the two mixtures.

2.1 ASPHALT MIXTURES

A typical AC mixture used in illinois was selected as the control mix and is referred to as N70-10. The mixture was designed at 70 gyrations to attain the $4\pm0.5\%$ target air voids and contained 10% reclaimed asphalt pavement (RAP) that had an asphalt binder replacement (ABR) of 7.4%. Both mixes were designed using the same number of gyrations in order to have air voids as the only variable. Complex modulus testing, which was out not in the scope of this project, is recommended by proponents of Superpave 5 to determine the appropriate number of gyrations at five percent air void that would yield the same stiffness as the conventional mix.

2.1.1 Aggregates

The same aggregates were used for both mixes and are shown in Table 1.

Table 1. Details of the Aggregates Used in the Project

	N70-10				
Gradation Type	Coarse	Fine	Fine	Fine	Coarse
Producer name	Prairie	Prairie	Scharf	Omni	Cross
Plant location	Manteno, IL	Manteno, IL	Hayworth, IL	Decatur, IL	Rantoul
Source no.	50912-06	50912-06	51130-06	3916-03	3916-03
Material Type	Limestone	Limestone	Natural Sand	Fly Ash	RAP

The material producers and the source numbers were obtained from Illinois Department of Transportation's 2018 specific gravity (G_{sb}) list for aggregates produced in the state. The coarse aggregates have 9.5 mm nominal maximum aggregate size (NMAS) while the fine aggregates have NMAS of 4.75 mm with the exception of the mineral filler.

Similarly, the mixture gradations are shown in Figure 1. The combined blends of the mixes have 9.5mm NMAS and the percentage passing the primary control sieve for N70-10 and Superpave 5 are 39.7 and 39.1 respectively. Similarly, the percentage passing the No. 200 sieve are 5.1 and 4.3 respectively. The mixes are coarse graded and satisfied AASHTO M323 specifications.

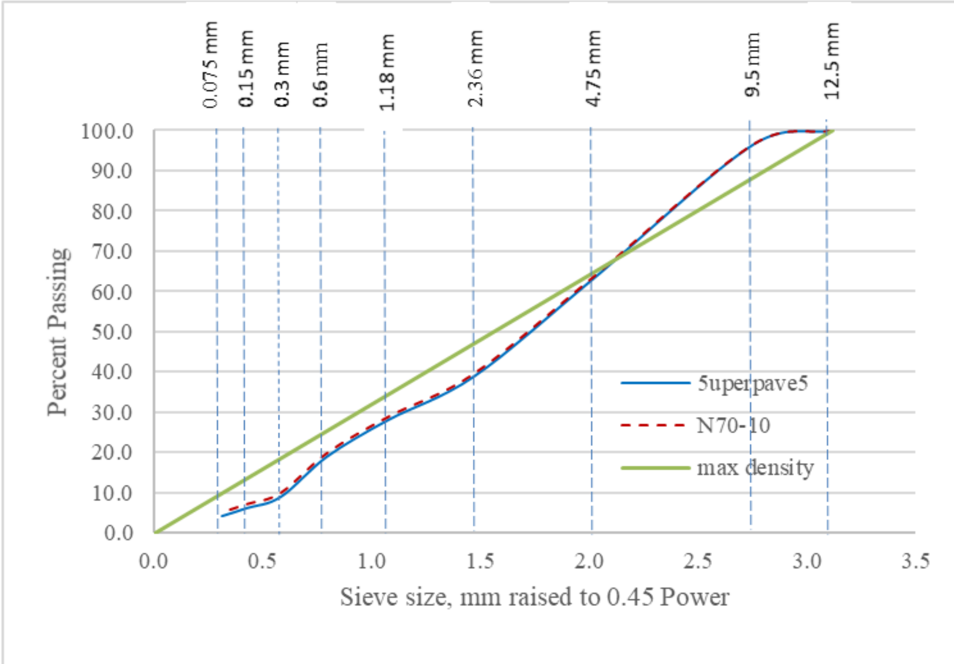

Figure 1. Aggregate Blend Gradations for the Two AC Mixes.

2.1.2 Asphalt Binder

A styrene butadiene styrene (SBS) modified binder from Emulsicoat Inc. with characteristics per AASHTO M320 shown in Table 2 was used for both mixes.

Table 2. Asphalt Binder Grade

RV	Temperature	Viscosity (Pas)	Torque
	135	0.553	11.1
Mass loss (%)	-0.123		
G*/sinδ	Temperature	Original	RTFO
	64	1.243	3.135
	70	0.686	1.646
G*sinδ	Temperature	DSR	
	16	4791	
	13	6592	
BBR	Temperature	Stiffness (Mpa)	m-value
	-18	209	0.307
	-24	321	0.249
Superpave Grade		64-28	
True Grade		66.2-28.67	

2.2 ASPHALT MIXTURE VOLUMETRICS

Volumetrics of the two laboratory designed mixes are summarized in Table 3. The control mix is appropriate for use as a surface course on roads with 3 to 10 million design equivalent single axle loads (ESALs). In addition, the Superpave 5 mix had lower percent asphalt absorbed (P_{ba}) and a decreased percent effective asphalt binder (P_{be}) compared to the conventional mix.

Table 3. Volumetric Properties of the Two AC Mixes

Mix Name	Superpave 5	N70-10
% AB	6.2	6.2
Blend G_{sb}	2.611	2.613
G_{mb}	2.355	2.372
G_{mm}	2.474	2.470
Air Voids (%)	4.8	4.0
VMA (%)	15.4	14.9
VFA (%)	68.8	73.3
Dust Ratio	0.93	1.08
G_{se}	2.727	2.731
P_{ba} (%)	1.67	1.71
P_{be} (%)	4.60	4.74

2.3 TESTING PROGRAM

I-FIT specimens with 7$\pm$0.5% air voids for the control mix and 5$\pm$0.5% air voids for Superpave5 were sawn from 180 mm tall performance pills and are summarized in Table 4. The specimens were tested within a week of preparation to eliminate impacts of mixture aging.

Table 4. Percent Air Voids for the Specimens Tested.

Test	Sample	Superpave5	N70-10
IFIT	1	4.5	6.9
	2	4.8	6.8
	3	5.0	6.7
	4	5.1	6.8
Average		4.9	6.8

CHAPTER 3: RESULTS AND DISCUSSION

3.1 I-FIT RESULTS

The I-FIT test is a monotonic, semi-circular bending fracture test performed at 25°C that is practical for use at the mixture design level. The test was conducted per AASHTO TP-124 using SGC samples of diameter 150±1 mm that were trimmed to a thickness of 50 ± 1 mm and cut in half resulting in a semi-circular shaped specimen. A notch of 15 ± 1 mm depth and 1.5 ± 0.1 mm width was cut on the flat rectangular surface. The specimen was conditioned at 25°C in a water bath and then placed onto the test fixture. A load line displacement (LLD) at a rate of 50 mm/min was applied throughout the test, and the variation of the load with the displacement measured.

A typical output of the I-FIT is shown in Figure 2. The area under each of the curves represents the work of fracture and the dots on post peak portion of the curves indicate the inflection point. The slope at the inflection point is a physical indication of how brittle a material is because a rapid unloading after crack initiation is related to a brittle response, while a gradual unloading indicates material ductility. The red curve is typical of brittle mixes containing recycled materials while the black curve represents ductile behavior characteristic of mixes with only the original binder. The FI is calculated as the ratio of the work of fracture to the absolute value of the post peak slope as follows:

$$FI = A \times \frac{G_f}{|m|} \tag{1}$$

where, A is calibration coefficient, G_f is fracture energy, and m is the slope at the inflection point.

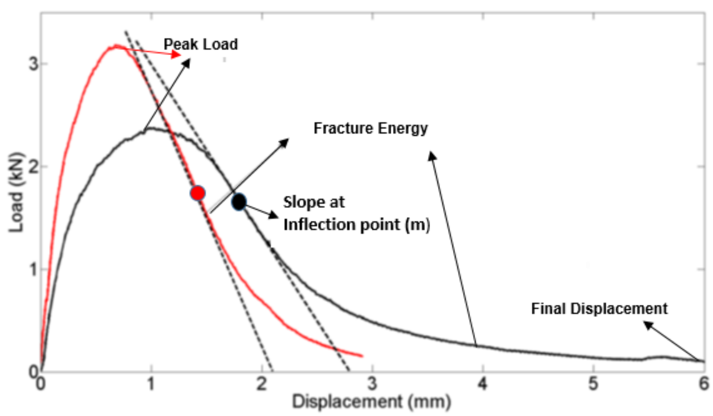

Figure 2. Typical IFIT Output Showing Important Parameters.

Figure 3 shows the average IFIT results for both mix types. Superpave 5 has higher FE and strength, but lower FI than the control mix due to a steeper slope. Superpave 5 therefore has a more brittle response than N70-10. The secant modulus, calculated as the ratio of the peak load to the corresponding displacement, which was successfully used as a proxy to stiffness (Al-Qadi, et al., 2017) captures the increased brittle behavior of the new mix. Superpave 5 has an average secant modulus of 5.0 KN/mm while the control mix has 3.0 KN/mm. Increase in stiffness was expected since the new mix was designed at the same number of gyrations as the control, but at a lower air void content. Researchers determined that regardless of the temperature, the modulus of a mix with constant asphalt volume increases with decreasing air voids (Witzack and Fonseca 1996).

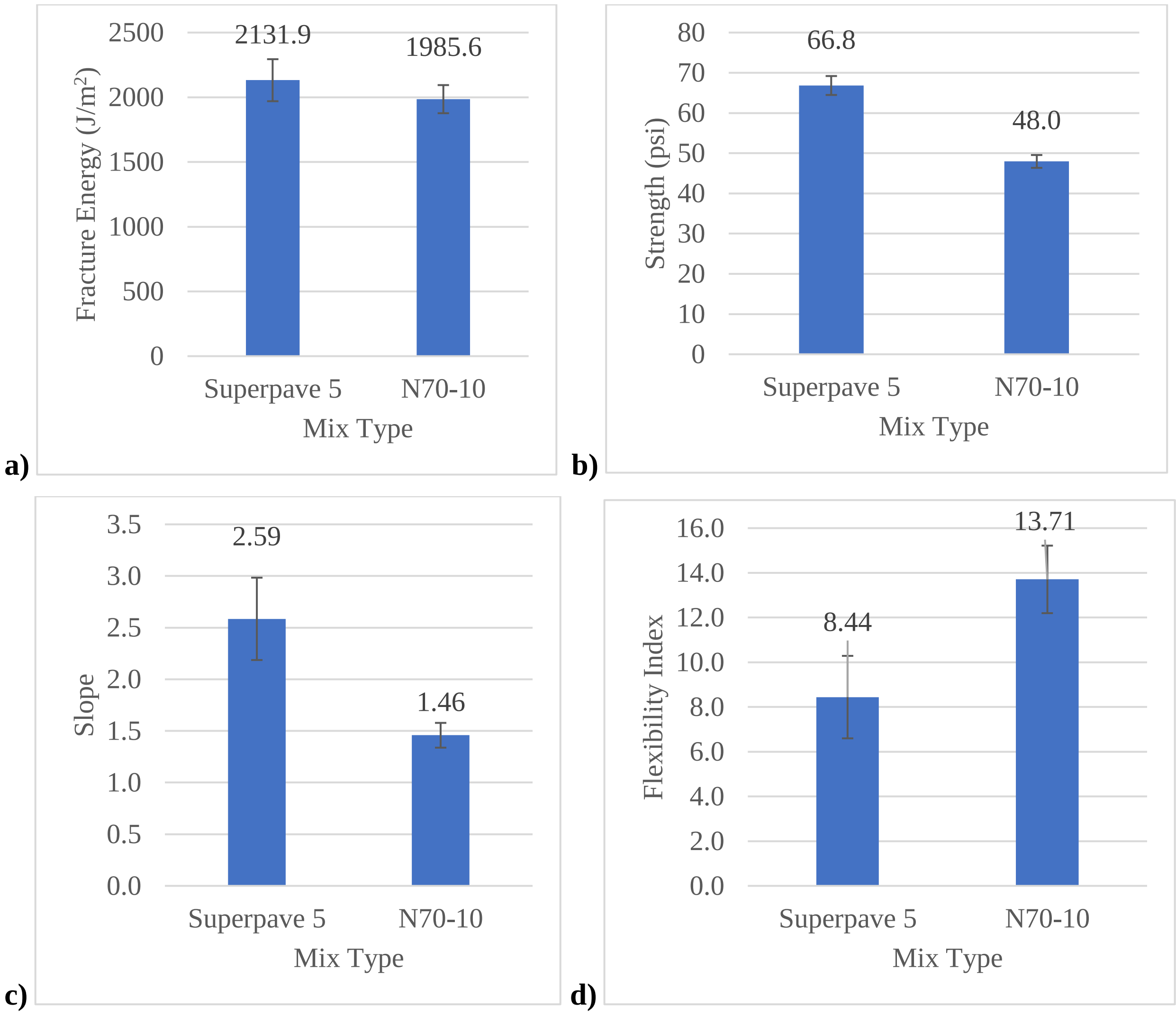

Figure 3. Average IFIT Results a) FE b) Strength c) Slope and d) FI

CHAPTER 4: SUMMARY AND CONCLUSSIONS

Cracking resistance of a conventional mix and a Superpave 5 mix were evaluated using I-FIT. The control mix was designed at 4% and tested at 7% air voids while Superpave 5 mix was designed and tested at 5% air voids. Both mixes were designed at 70 gyrations and used same constituent materials (aggregates and binder). The new mix had a higher fracture energy and strength, but a lower FI. The reduction in air voids resulted in an increase in mixture stiffness which led to a more brittle response captured by the higher slope from the I-FIT. The secant modulus which is a proxy to mixture stiffness shows the increased modulus of Superpave 5 which is believed to improve its rutting resistance. Since both mixes had FI greater than 8, which was shown to correlate to good field performance, means Superpave 5 has a better overall cracking resistance compared to the original mix. However, more research is required to understand impact of aging on the cracking resistance of both mixes.

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