COMPARATIVE ANALYSIS OF CRACKING AND RUTTING CHARACTERISTICS OF ASPHALT MIXES

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

Asphalt mixtures are subjected to several distresses in the field, including cracking, rutting, permanent deformation and moisture damage. Several tests and parameters are used to evaluate the resistance of asphalt mixtures to these types of distresses. In this study, laboratory-mixed laboratory-compacted test specimens, along with nine loose mixtures from new paving projects in Idaho, were tested and evaluated in the laboratory. The rutting evaluations used in this study included Hamburg wheel tracking and asphalt pavement analyzer tests. Flexibility index, fracture energy, cracking resistance index, strain energy release rate (J_c), and the indirect tensile test were used to assess the resistance of asphalt mixtures to cracking. The Hamburg test was also used to evaluate moisture susceptibility. The results indicate that some performance tests are sensitive to binder type and content. While asphalt mixtures collected in the field and tested in the laboratory exhibited good resistance to rutting and moisture damage, some mixtures had poor resistance to cracking. In addition, the parameters used to assess cracking exhibited high variability (flexibility index), while others (cracking resistance index) exhibited less variability. A good correlation between some cracking parameters (flexibility index and cracking resistance index) in ranking test asphalt mixtures from the best to worst was found, while others (i.e., flexibility index and J_c) showed no correlation. Based on the results of this study, the cracking resistance index is recommended over the flexibility index to evaluate the cracking resistance of asphalt mixtures to cracking.

Keywords: Hot mix asphalt, rutting performance, fatigue cracking, and moisture damage.

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DEDICATION

To my loving mother who always supported me and encouraged me to come this far.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Overview

Rutting, cracking, and moisture damage are common distresses in asphalt pavements. Asphalt mixtures that satisfy Superpave volumetric mix design requirements (NHI, 2000) still experience distresses in the field. There is a need to develop and evaluate performance measures for asphalt mixtures to ensure adequate resistance to these various distresses. This study is part of a larger research effort funded by Idaho Transportation Department (ITD) to develop performance measures and propose thresholds to evaluate the resistance of asphalt mixtures to rutting and cracking on roadways in Idaho. This study focuses on evaluating the performance of laboratory-produced mixtures with different mixture characteristics as well as various loose mixtures collected from new paving projects across Idaho with the focus on laboratory assessments of rutting, fatigue cracking and moisture damage.

Rutting is defined as a longitudinal surface depression in the wheel path (Miller and Bellinger, 2014). Several causes can lead to rutting in asphalt pavements, including consolidation of the pavement layers or subgrade due to traffic, insufficient compaction, or insufficient thickness design. Researchers have developed standard laboratory test methods to evaluate the resistance of asphalt mixtures to rutting. These tests include dynamic modulus, flow number, and flow time conducted using the asphalt mixture performance test (AMPT) (Kaloush et al., 2003). Other tests and devices used to evaluate rutting include the Hamburg wheel tracking device (HWTD) and asphalt pavement analyzer (APA) (Izzo and Tahmoressi 1999; Choubane et al., 2000)

Fatigue cracking is a common pavement distress that occurs mainly due to heavy and repeated traffic loading and/or inadequate structural design. Fatigue cracking is also called alligator cracking and is comprised as a series of interconnected cracks that in a later stage may develop larger pieces (Miller and Bellinger, 2014). If no treatment is applied, fatigue cracking will lead to pavement failure eventually. Fatigue cracking may also lead to other distresses such as moisture damage. There are several testing methods that have been used to assess the resistance of asphalt mixtures to cracking, including the semicircular bending (SCB) test, the indirect tensile (IDT) test, the direct tension test, and the beam fatigue test.

Moisture damage of asphalt mixtures refers either to the loss of bond between the aggregate surface and the asphalt binder (adhesive failure) or to the loss of bond within the binder (cohesive failure; Kiggundu and Roberts, 1988). Moisture enters pavement systems through various mechanisms, including infiltration of surface water, diffusion of moisture vapor, and capillary rise of subsurface water. Moisture damage leads to stripping (loss of binder), raveling (loss of aggregates), cracking, and permanent deformation. There are different test methods used to evaluate moisture susceptibility of asphalt mixtures, including the Hamburg test, the boiling water test, the immersion compression test, the Lottman test, and the modified Lottman test.

1.2 Problem Statement

Several tests and parameters are proposed to evaluate the resistance of asphalt mixtures to rutting and cracking and moisture damage. There is a need to assess the sensitivity of these proposed performance parameters to mixture properties (i.e., binder type and grade) and to determine the variability of test results. In addition, there is a need to assess the relationship between various parameters in ranking asphalt mixtures in terms of their resistance to cracking. This study included various performance tests. The rutting tests considered in this study included Hamburg wheel tracking and APA tests. Cracking parameters including flexibility index, fracture energy, cracking resistance index, strain energy release rate (J_c), and indirect tensile test were used. The Hamburg test was also used to measure moisture susceptibility. Both laboratory-produced mixtures, as well as plant-produced mixtures, were tested in this research study to search for candidate test methods to address cracking and rutting in Idaho.

1.3 Study Objectives

There are four main objectives of this study as follows:

- Select proper test methods and parameters to evaluate the performance of asphalt mixtures used in Idaho in terms of resistance to rutting, cracking, and moisture damage.
- Study the effect of mix properties (i.e., binder type and grade) on performance.

- Examine the variability of various test methods and parameters to identify the ones with low variability to assess cracking resistance.
- Study the relationship between various parameters in ranking asphalt mixtures in terms of their resistance to cracking.

1.4 Thesis Organization

This thesis consists of five chapters. Chapter 1 provides an introduction to the study and discusses the research motivation, problem statement, and objectives. Chapter 2 is a review of the literature on previous studies conducted on fatigue and rutting characteristics of asphalt mixtures and includes a discussion of various test methods and parameters that are commonly used to characterize fatigue cracking. Current practices and standards adopted by various states are also reviewed and documented. The literature review also summarized various tests used to assess rutting resistance and threshold limits developed by various states. Chapter 3 describes the laboratory-mixed laboratory-compacted (LMLC) test samples, plant- mixed laboratory-compacted (PMLC) test specimens, and sample preparation and testing.

Chapter 4 presents the results of the cracking tests, examines the variability of test results, and assesses the correlation between various parameters in terms of ranking the mixtures to resist cracking. Chapter 5 presents the results and a discussion of the rutting and moisture damage assessment. Chapter 6 provides a summary of the main findings and outcomes of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the main findings of the literature review conducted to document the current tests used by various transportation agencies to evaluate cracking, rutting, and moisture damage of asphalt mixtures. It also reviews the specification limits set by different states for these tests. These tests include the semicircular bending tests and indirect tensile test to characterize cracking behavior, while the Hamburg wheel tracking test and asphalt pavement analyzer are used to characterize rutting. These tests are often used by various State DOTs since they were found to correlate well with field performance as will be discussed in this chapter.

2.2 Cracking Tests

2.2.1 Semicircular Bending Test (SCB)

The Semicircular Bending Test (SCB) is used to characterize the fatigue cracking behavior of asphalt pavements (Figure 2.1). In this procedure, a semicircular asphalt mixture specimen is positioned with the flat side on two rollers that are covered with a friction reducing material. A load is applied along the vertical diameter of the specimen. The load and displacement are measured during the duration of the test. This test is also called the three point monotonically increasing compressive loading test, which induces tension in the bottom zone of a semicircular specimen.

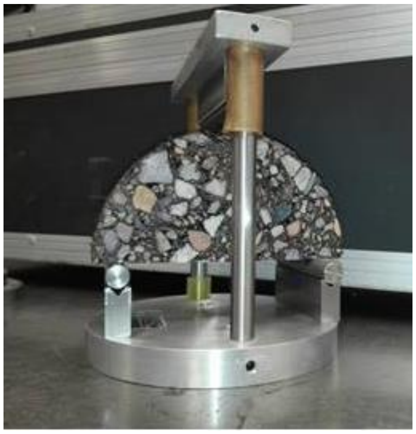

Figure 2.1 Semi-circular bending loading frame

Figure 2.1 depicts the concept of SBC test. The American Association of State Highway and Transportation (AASHTO) has published a detailed description of the procedure under designation TP 124-16 (AASHTO 2016). In this test, a semi-circular test specimen with the dimensions shown in Figure 2.1 is prepared (150±1 mm in diameter and 50±1 mm thick). The distance between the steel rollers is 120±0.1 mm.

The Louisiana Department of Transportation (LDOTD) adopted the SCB test as a performance measure for their Hot Mix Asphalt (HMA) mixtures. As per their designation LDOTD TR – 330-14, the specimens are tested at three different notch depths; 25.4 mm, 31.8 mm and 38 mm. The fracture parameter J-integral (J_c), which was developed by Rice (1968), is used to analyze the load-deflection plot. Critical strain energy from semicircular bending test, J_c represents the slope of strain energy per unit depth versus notch depth as presented in Equation 2.1. Several researchers have shown that, J_c is influenced by aggregate type, shape, gradation and texture, asphalt binder content (e.g.,Bayomy and Abdo, 2006), loading rate (e.g.,Li and Marasteanu, 2010), notch length and test temperature (e.g.,Nsengiyumva, 2015).

$$J_c = - (1/b)\ (du/da) \qquad \text{Eq 2.1}$$

where,
A = notch depth (mm)
B = specimen thickness (mm)
U = strain energy to failure. It is equal to the area under the load-deflection plot
du/da = rate the change in strain energy per notch depths. (J/m)

Al-Qadi et al. (2015) introduced the term Flexibility Index (FI) to better describe the fracture properties of asphalt mixtures, which has been adopted by the Illinois Department of Transportation (IDOT). The Illinois Flexibility Tester (IFIT) is based on the semicircular bending test. The difference is that it calculates FI from the load deformation curve. Equation 2.2 presents the FI calculation. Higher values of FI correspond to good fracture resistance.

$$FI = [G_f/abs(m)]\times A \qquad \text{Eq 2.2}$$

where,

FI = flexibility Index

A = factor is used for unit conversion and scaling equal to 0.01

abs (m) = absolute value of post-peak slope (kN/mm)

G_f = fracture energy (J/m^2)

$$G_f = W_f / Area_{lig} \qquad \text{Eq 2.3}$$

where,

W_f = work of fracture (joules)

$Area_{lig}$ = ligament area = (r – a) x t) (mm^2)

r = specimen radius (mm)

a = notch length (mm)

t = specimen thickness (mm)

Kaseer et al. (2018) developed an alternative cracking parameter to differentiate asphalt mixtures called the Cracking Resistance Index (CRI), which is defined by the ratio of fracture energy G_f (J/m^2) and absolute maximum peak load (P_{max}) as shown in Eq 2.4. Higher CRI values correspond to asphalt mixtures with better resistance to cracking; however, there is not yet a recommended threshold value for CRI since it is a new parameter.

$$CRI = G_f / abs(P_{max}) \qquad \text{Eq 2.4}$$

where,

CRI = cracking resistance index

G_f = fracture energy (J/m^2)

abs(P_{max}) = absolute value of peak load (kN)

P_{max} = maximum load in the load deformation curve (kN) (Figure 4.10)

2.2.2 Indirect Tensile (IDT) Test

The indirect tensile (IDT) test measures the strength of asphalt samples. The American Society for Testing and Materials International (ASTM) designation D-6931 (ASTM, 2012) describes the detailed procedure. The test is performed at 25°C and a constant loading rate of 50 mm/min until the specimen fails. The test is quick and simple to perform.

Figure 2.2 Indirect Tensile (IDT) Test loading frame

The IDT strength is calculated as presented in Equation 2.5.

$$S_T = 2F/\ (3.14\ hd) \qquad \text{Eq 2.5}$$

where,

S_T = Indirect tensile strength, (kPa)
F = Total applied vertical load at failure (kN)
h = Height of specimen, mm (in)
d = Diameter of specimen, mm (in)

2.3 Review of Cracking Related Parameters

2.3.1 Semicircular Bending Test: Critical Strain Energy (J_c)

Kim et al. (2012) evaluated Louisiana asphalt mixes in terms of SCB-J_c values. Five laboratory asphalt mixes and more than 20 field projects were studied. They grouped the test mixtures by sample type, Nominal Maximum Aggregate Size (NMAS), traffic level (Level 1 and Level 2), aging condition, production method, and binder type (PG 64-22, PG 70-22, and PG 76-22). The performance grade (PG) of asphalt binders was represented by two numbers. The first number was the average seven-day maximum pavement design temperature (°C), while the second temperature was the minimum pavement design temperature (°C) (NHI 2000). A PG 64-22 binder can used where the average seven-day maximum pavement temperature is 64°C, and the minimum pavement design temperature is -22°C. The authors found that the SCB-J_c values of laboratory mixes correlated well with field performance. Based on the results of their study, Kim et al. (2012) recommended that the SCB test method be used to estimate cracking performance of asphalt pavements.

Cooper et al. (2016) evaluated the SCB-J_c test to characterize cracking behavior of Louisiana asphalt mixes. Both laboratory asphalt mixtures and field cores were tested at three notch depths: 25.4 mm, 31.8 mm, and 38 mm. They were compacted at 7.0 ± 0.5% air void. The temperature was maintained at 25°C, and loading rate was 0.5 mm/min. They concluded that the computed J_c values for gyratory compacted specimens and field cores were not correlated. The researchers also found that binder with high temperature grade (e.g., PG 76) produced higher J_c values. They recommended a minimum J_c value of 0.6 kJ/m^2 for mixtures with binder PG grade of 76 or greater, and a J_c value of 0.5 kJ/m^2 for mixtures with binder PG grade less than 76.

In another study, Mohammad et al. (2012) analyzed the relationship between SCB-J_c values of hot mix asphalt and their corresponding field performance at nine field sites in Louisiana. For the plant-mixed, laboratory-compacted asphalt mixtures, the SCB-J_c values at an intermediate temperature were determined. Corresponding cracking data were obtained from the Louisiana PMS database collected by the automated road analyzer (ARAN) system. The authors observed that the asphalt mixture with the highest J_c value exhibited the lowest cracking rate. They also noted that SCB measured J_c values showed a good correlation with field cracking performance.

Elseifi et al. (2012) studied the fatigue and cracking performance of a number of asphalt mixtures with high recycled asphalt pavement (RAP) content using SCB-J_c and compared results with test results of dissipated creep strain energy (DCSE). The samples were prepared following Louisiana DOTD Designation TR – 330-14. The authors studied two conventional mixes with 0% RAP made with PG 64-22 and PG 76-22 binders. In addition, they prepared other mixtures with different RAP content: the first was made with PG 64-22 binder and incorporated 40% RAP, while the other mixtures used PG 76-22 binder and 15% RAP. They found that mixes with polymer-modified binders performed better against cracking than the mixes with unmodified binders. In addition, the mixtures with high RAP content were more brittle than the mixtures without RAP. The results of the two test procedures – SCB-J_c and DSCE -- were also found to be in agreement.

2.3.2 Semicircular Bending Test: Flexibility Index (FI)

Al-Qadi et al. (2015) evaluated the use of the Flexibility Index (FI) as a cracking resistance parameter compared to fracture energy. They found that FI can capture more changes in asphalt mixture properties (e.g., changes due to RAP/RAS content) than fracture energy. In their study, 11 laboratory-designed mixes, 22 plant mixes, and numerous field cores collected from nine districts in Illinois were evaluated. The mixtures were prepared using asphalt binder with different grades, including PG 70-22, PG 64-22, PG 58-28, and PG 52-34. The mixes were designed as per Illinois modified AASHTO M 323 specifications. The study concluded that the FI values from laboratory compacted samples correlated well with the FI values from the field performance data. Based on the results of this study, the researchers proposed thresholds for FI values as presented in Table 2.1.

Table 2.1 Flexibility Index (FI) performance criteria (after Al-Qadi et al., 2015)

Asphalt Concrete Mixture	**Flexibility Index (FI)**	**Fracture Energy (J/m^2)**
Best Performing Category	6.5-10	2300-2600 J/m^2
Intermediate Performing Category	$6.5 \geq FI \geq 2$	2000-2300 J/m^2
Poor Performing Category	Less than 2	Less than 2000 J/m^2

Ozer et al. (2016a) also measured the flexibility index for asphalt mixtures and correlated it with field performance. The field performance was assessed after accelerated loading at the FHWA Turner-Fairbank Accelerated Loading Facility (ALF) in McLean, Virginia. They tested five plant-produced and eight lab-produced asphalt mixtures that contained varying amounts of RAP and reclaimed asphalt shingles (RAS). They conducted the SCB test at various temperatures ranging from 12°C to 25°C and loading rates from 6.25

to 50 mm/min. They found that the fracture energy increased with the increase in test temperature and loading rate. The authors proposed thresholds for the Fl as presented in Table 2.2.

Table 2.2 Flexibility Index (FI) performance criteria (after Ozer et al. 2016a)

Asphalt Concrete (AC) Mixture	**Flexibility Index (FI)**
Best Performing Category	> 6.7
Intermediate Performing Category	6.7≥FI≥2
Poor Performing Category	< 2

In a similar study, Ozer et al. (2016b) calculated the fracture energy and FI for 11 laboratory-prepared asphalt concrete specimens with different RAP and RAS content. They proposed threshold values for stiff and flexible mixtures, soft and flexible mixtures, stiff and brittle mixtures, and soft and unstable mixtures, as summarized in Table 2.3.

Table 2.3 Flexibility Index (FI) threshold criteria (after: Ozer et al. 2016b)

Mixture Classification	**Acceptance**	**Flexibility Index (FI)**
Stiff and Flexible	Acceptable and High Performance (I)	FI > 10
	Acceptable (II)	FI > 6
Soft and Flexible	Crack Retardant Interlayer Type of Mixes	FI > 10
Stiff and Brittle	Reject	FI < 6
Soft and Unstable	Reject	FI > 6

2.3.3 Indirect Tensile (IDT) Test

Walubita et al (2013) investigated the effect of binder content on the IDT strength of asphalt mixtures. They considered three asphalt contents (4.5%, 5% and 5.5%) and one mix (Type D mix with PG 70-22 and limestone aggregate). The authors observed that, the IDT strength decreased with binder content. The strength value decreased from 586 kPa to 517 kPa when the binder content increased from 4.5% to 5%; however, they noticed that the IDT strength was higher at 5.5% binder content (758 kPa). They related these results to the sinking of IDT loading strips into soft asphalt mixtures as an effect of the higher binder content of 5.5%.

Kim and Wen (2002) performed the IDT creep test and IDT strength test on eight fine and coarse mixtures in the laboratory. They validated the test results with field cores sampled from WesTrack. They used digital image correlation (DIC) over a conventional LVDT or strain gauge system and determined fracture energy. Poisson’s ratio was calculated from the IDT creep test, which later was used as an input to calculate the fracture energy from the IDT strength test. They found that the fracture energy calculated at 20˚C correlated well with field performance. From the field cores, the observation was that the higher the fracture energy, the greater the resistance to cracking.

The Minnesota Department of Transportation (Marasteanu et al., 2012) investigated the effect of temperature on IDT strength values. Field cores were collected from nine field sections across Minnesota. The authors tested specimens with air voids of 4% and 7%. For test specimens with 4% air voids, they found that the IDT strength decreased with the decrease in the test temperature. However, they did not find any decisive behavior for test specimens with 7% air voids.

2.4 Rutting Tests

2.4.1 Hamburg Wheel Tracking Test

The Hamburg Wheel-Tracking Device (HWTD) was developed in Hamburg, Germany. It is used to evaluate of HMA mixture for both rutting and moisture susceptibility. It simulates traffic loads using steel solid rolling on test specimens. Specimens are tested under dry conditions to reflect rutting resistance and are also tested in a water bath to introduce moisture effects. The test setup is shown in Figure 2.3. Two solid steel wheels are used to apply load on a rectangular slab or gyratory samples. The deformation (rut depth) in the test specimen is measured after each pass. The test procedure is published in AASHTO designation T-324.

Figure 2.3 Hamburg Wheel Tracking Device

HWTD shows good repeatability within test replicates (Izzo and Tahmoressi, 1999) and found to simulate field conditions (Lu and Harvey, 2006). Many states have adopted this test as a performance measure test to evaluate the resistance of asphalt mixtures to rutting and moisture damage. Table 2.4 shows the pass/fail criteria used by various transportation agencies including the Texas Department of Transportation (TXDOT), Washington State Department of Transportation (WSDOT), Colorado Department of Transportation (CODOT), Louisiana Department of Transportation (LADOT) and Montana Department of Transportation (MTDOT).

2.4.2 Asphalt Pavement Analyzer (APA)

The Asphalt Pavement Analyzer (APA) is the updated version of the Georgia loaded wheel tester (GLWT), which is developed by the Georgia Department of Transportation (GDOT). It is a laboratory accelerated loading system that simulates traffic loading. The rutting test is performed in accordance with AASHTO T 340. Four cylindrical specimen with 150 mm diameter and 75±2 mm height are used. Stainless steel concave wheels are used to apply load on rubber hoses. The test specimens are preheated for 6 to 24 h. The tested temperature is selected based on binder grade. The rut depth is recorded after each cycle and the average rut depth is calculated after 8,000 cycles.

Table 2.4 HWTD pass/fail criteria (TxDOT 2004, TxDOT 2009, WSDOT 2016, CODOT 2015, LADOT 2016, MTDOT 2014a, MTDOT 2014b)

DOT	**Test procedure**	**Pass/Fail criteria: Minimum # of Passes**		
TXDOT	Tex-242-F	PG grading	Limits, @12.5 mm rut depth tested @50ºC	
		<PG 64	10000	
		PG 70	15000	
		>PG	20000	
WSDOT	AASHTO T 324	15,000 Passes@10 mm rut depth tested @50ºC		
CODOT	CP-L 5112	10,000 @ 4mm rut depth tested		
LADOT	AASHTO T 324	Mixture Type	Design Level	Criteria: Max rut depth @50ºC
		Incidental Paving and ATB	1	10mm@ 10,000pass
		Wearing and Binder Course	1	10mm @20,000 pass
		Wearing and Binder Course	2	6 mm @20,000 pass
		Base Course	1	12mm @10,000 pass
MTDOT	MT 334-14	Minimum # of Passes@13mm rut depth for PG 58-28,64-22,64-28 and 70-28: 10000 passes for mix design, 15000 passes for produced plant mix,		

Choubane et al. (2000) correlated APA data with field rutting measurements. The results confirmed that the APA test is a good test to evaluate the resistance of asphalt mixtures to rutting. Skok et al. (2003) recommended that the Minnesota Department of Transportation (MNDOT) to adopt the APA as a rutting test. Brown et al. (2001) suggested using minimum of 8 mm after 8000 cycles as pass criteria for rutting. Currently, the Georgia Department of Transportation (GDOT), Alabama Department of Transportation (ALDOT), New Jersey Department of Transportation (NJDOT) and Virginia Department of Transportation (VDOT) are using this test as a performance measure for rutting. Table 2.5 summarizes the pass/fail criteria and test procedure adopted by various transportation agencies.

Table 2.5 APA rutting test pass/fail criteria (GDOT 2005, GDOT 2013, ALDOT 2001, NJDOT 2007, VDOT 2018)

DOT	**Test procedure**	**Pass/Fail criteria:** **Maximum rut depth@ 8,000 loading cycles**
(GDOT)	GDT115	• 7 mm for mix design level A • 6 mm for mix design level B • 5 mm for mix design level C and D
ALDOT)	ALDOT-401	• 4.5 mm For ESAL range “E” mixes (1.0x107 < ESALs < 3.0x107)
NJDOT	AASHTO T 340	• 7 mm High RAP, PG 64-22, Surface and intermediate Course, • 6 mm for Binder-Rich Intermediate Course • 5 mm For Bottom-Rich Base Course • 4 mm High RAP, PG 76-22, Surface and intermediate Course, • 3 mm For Bridge Deck Waterproofing Surface Course
VDOT	VTM-110.	• 7 mm for mix designation A • 5.5 mm for mix designation D • 3.5 mm for mix designation E

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

Laboratory asphalt mixture test samples were prepared for performance testing including rutting, moisture damage, and cracking. Chapter 3 provides information about the asphalt mixtures evaluated in this study along with description of sample preparation and testing methods.

3.2 Test Asphalt Mixtures

Laboratory-Mixed Laboratory-Compacted (LMLC) samples as well as Plant-Mixed Laboratory-Compacted (PMLC) test samples were prepared for testing in this study. The LMLC mixtures had different levels of flexibility thus having different rutting and fatigue characteristics, whereas the PMLC are typical mixtures produced in Idaho. They were collected in 2017.

3.2.1 Laboratory Mixed Laboratory-Compacted (LMLC) Mixtures

Six Laboratory-Mixed Laboratory-Compacted (LMLC) were prepared in the laboratory. Table 3.2 presents the characteristics of the LMLC mixtures. They were prepared using two binder types, modified binder (PG 58-34) and (PG 70-28) (both the binder types were obtained from Idaho Asphalt Supply Inc.), one aggregate type (basalt), and one aggregate gradation (SP3) with NMAS of 12.5 mm. The basalt was collected from an asphalt plant (POE Asphalt) in Whitman County, Washington. Different binder contents, which are optimum binder content (OBC), OBC-0.75%, and OBC+0.75%, were included for each binder type as presented in Table 3.1.

The SP3 mix is designed for traffic less than 10 million ESALs (Equivalent Single Axle Loads). The volumetric requirements for the SP3 mix are summarized in Table 3.2. Several volumetric design trials were performed to determine the optimum binder content (OBC) at 4% air voids. Figure 3.1 shows aggregate gradation used for the SP3 mix. Table 3.3 summarizes the volumetric mix design along with ITD criteria. The OBC was calculated as 5%.

Table 3.1 Laboratory-Mixed Laboratory-Compacted mixture characteristics

Mixture ID	Binder Type	Binder Content	Mix Type	NMAS
70-4.25%	PG 70-28	4.25%	SP3	12.5 mm
70-5%	PG 70-28	5.00%		
70-5.75%	PG 70-28	5.75%		
58-4.25%	PG 58-34	4.25%		
58-5%	PG 58-34	5.00%		
58-5.75%	PG 58-34	5.75%		

Table 3.2 Superpave mix gradation criteria (after: ITD design standard specification 2017)

Mixture Type	SP3
Design ESALs (millions)	$1 \leq 10$
Gyratory Compaction Gyrations for N_{ini} Gyrations for N_{des} Gyrations for N_{max}	 7 75 115
Relative Density, %Gmm@ N_{ini}	≤89.0
Relative Density, %Gmm@ N_{des}	96.0
Relative Density, %Gmm@ N_{max}	≤98.0
Air Voids, $\%V_a$	4.0
Dust to Binder Ratio Range	0.6-1.2
Voids Filled with Asphalt (VFA) Range, Percent	65-75

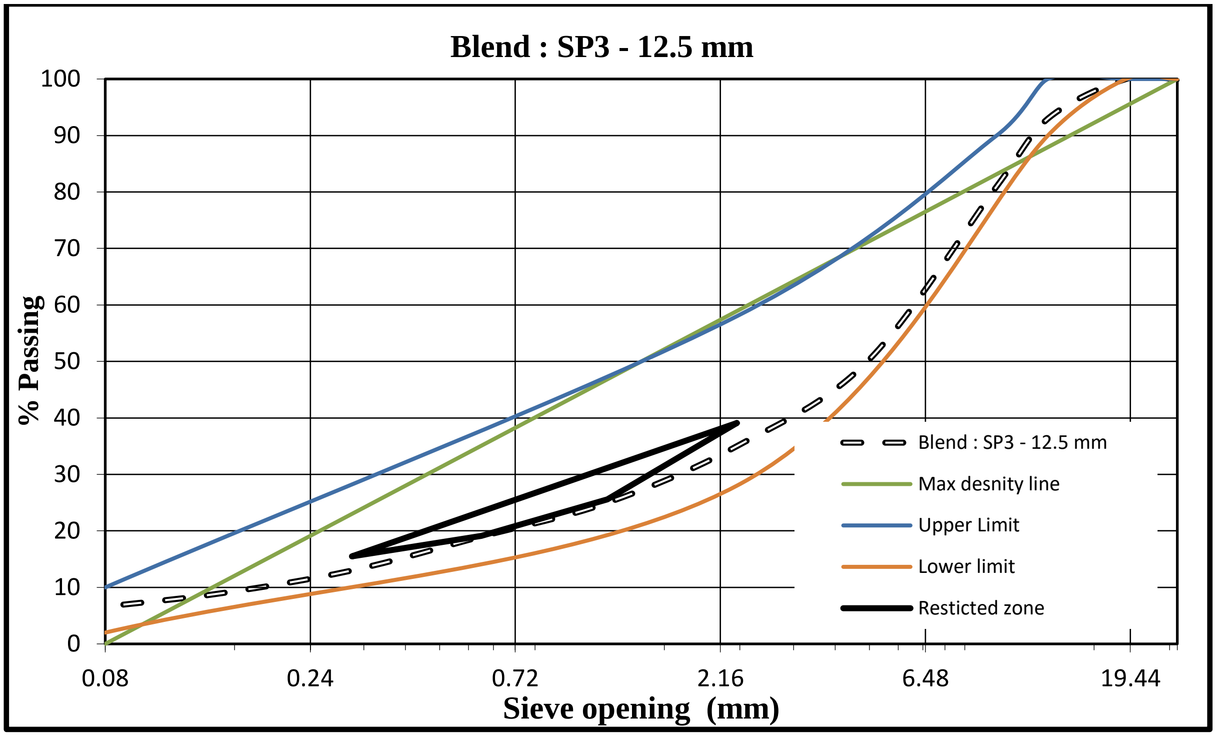

Figure 3.1. Aggregate gradation (percent aggregate passing vs. sieve opening)

Table 3.3 Summary of the volumetric mix design for LMLC

Parameter	Value	ITD Criteria
Pb% @ 4% air voids	5%	--------
VMA (%)	15.82	>13
VFA (%)	74.21	65-75
Dust ratio (D/B)	1.13	0.6-1.2
% Gmm @$N_i n_i$	86.42	<89

3.2.2 Plant Mixed Laboratory-Compacted (PMLC) Mixtures

The State of Idaho has six districts. Loose asphalt mixes from new paving projects were collected from five of these districts as presented in Table 3.4. The loose mixtures were sampled by the Idaho Transportation Department (ITD) staff and delivered to the laboratory at the University of Idaho. These mixtures have different characteristics as summarized in Table 3.4. The mixtures included two mix designs (SP3 and SP5), nominal maximum aggregate size (NMAS) of 12.5 mm and 19.0 mm, binder performance grade (PG), binder content, and percent reclaimed asphalt pavement (RAP), as documented in Table 3.4. Tables A.1 through A.9 in Appendix A provided detailed mix designs for all loose mixtures. Table 3.5 provides the project ID and location of each paving project where these mixtures were used.

Table 3.4 Plant-Mixed laboratory-Compacted (PMLC) sample characteristics

District	Project ID	Mix Type	NMAS, mm	Design PG	Virgin PG	Binder (%)	RAP (%)
1	D1L1	SP-5	12.5	64-28	58-34	5.30	30
2	D2L1	SP-3	12.5	70-28	64-34	5.70	50
3	D3L1	SP-3	12.5	70-28	52-34	5.23	50
3	D3L2	SP-3	12.5	70-28	64-34	5.20	30
3	D3L3	SP-3	12.5	64-28	58-34	5.30	30
3	D3L4	SP-3	12.5	70-28	64-34	5.30	30
3	D3L5	SP-5	12.5	76-28	70-34	5.30	29
5	D5L1	SP-5	19.0	70-28	70-28	4.80	29
6	D6L1	SP-5	12.5	64-34	64-34	5.40	0

Table 3.5 Locations of the paving projects

District	Project ID	Project Key No.	Location
1	D1L1	KN 19002	I-90,Northwest Blvd to Sherman Ave. CDA and US-95, Cocolalla CR Br,Bonner CO
2	D2L1	KN 19187	US-12. Arrow Br to Big canyon creek Br
3	D3L1	KN 13463	SH-44./JCT I84 to star
3	D3L2	KN 19412	US20. Borchers Ln to locust grove
3	D3L3	KN 13924	SH-67. MP0 TO JCT 51,EKLMORE CO
3	D3L4	KN 13935	FY16 Capital maintenance ACHD
3	D3L5	KN 18723	I-84, Cleft to MP90, Elmore co
5	D5L1	KN 13103	I-15. Sands RD upass to IC #89, Bingham co
6	D6L1	KN 19543	Spalding br. To US 12/SH-3

3.3 Sample Preparation

The test samples were prepared in accordance with AASHTO T 312. All the test samples were compacted using a Superpave Gyratory Compactor (SGC). Samples for rutting tests were prepared as per AASHTO T324 (Hamburg samples) and AASHTO T 340 (APA

Samples). The cracking samples were prepared as per ASTM D6931 (IDT), AASHTO TP 124 (SCB-FI) and DOTD-D TR-330-14 (SCB J_c). The samples were prepared in the Asphalt and Materials Laboratory of the University of Idaho. The maximum theoretical specific gravity (Gmm) was measured according to ASTM D6857, and the bulk specific gravity (Gmb) was measured according to ASTM D6752. Percent air voids were measured for each test sample using Equation 3.1, as the target air void was set as 7±0.5% for all OF the laboratory-prepared test samples.

$$\text{Percent Air Void} = (1 - \text{Gmb}/\text{Gmm}) \times 100 \tag{3.1}$$

where,

Gmb = bulk specific gravity

Gmm = theoretical maximum specific gravity

The loose mixtures were conditioned at the compaction temperature in the oven prior to compaction using the Superpave gyratory compactor. Test specimens of different sizes were prepared for various performance tests. Table 3.6 summarizes the sample sizes for various tests.

Table 3.6 Test sample configurations

Test	Sample Thickness (mm)	Sample Diameter (mm)	Notch length (mm)
APA Jr.	75±1	150±1	N/A
Hamburg	60±1	150±1	N/A
SCB Jc	57±1	150±1	25.4, 31.8, 38
SCB IFIT	50±1	150±1	15
IDT	50±1	150±1	N/A

A total number of 270 test samples were prepared to conduct various performance tests as presented in Table 3.7. The first six projects are LMLC as described in Section 3.3 and Project No. 9 to 15 are PMLC as described in Section 3.4.

Table 3.7 Number of test samples for various performance tests

Project No.	**Projects**	**Test types and no. of replicates**					
		SCB-J_c	SCB-FI	IDT	HWTT	APA	Total
1	70-28_4.25%	5	2	3	4	4	18
2	70-28_5%	5	2	3	4	4	18
3	70-28_5.75%	5	2	3	4	4	18
4	58-34_4.25%	5	2	3	4	4	18
5	58-34_5%	5	2	3	4	4	18
6	58-34_5.75%	5	2	3	4	4	18
7	D1L1	5	2	3	4	4	18
8	D2L1	5	2	3	4	4	18
9	D3L1	5	2	3	4	4	18
10	D3L2	5	2	3	4	4	18
11	D3L3	5	2	3	4	4	18
12	D3L4	5	2	3	4	4	18
13	D3L5	5	2	3	4	4	18
14	D5L1	5	2	3	4	4	18
15	D6L1	5	2	3	4	4	18
Total		75	30	45	60	60	**270**

3.4 Test Procedures

3.4.1 Cracking Tests

3.4.1.1 Semicircular Bending J_c Test (SCB-J_c)

The test specimens for the SCB-J_c test had a thickness of 57±1 mm and a diameter of 150±1 mm. Each sample was cut into two semicircular specimens. The test was conducted in accordance with DOTD Designation TR- 330-14. In this procedure, the specimen is loaded monotonically until failure. The load and deformation are continuously recorded, and the critical strain energy rate J_c is determined. Three notch depths are included (25.4 mm, 31.8 mm and 38 mm). The width of the notch is maintained to be within 3.0 ± 0.5 mm. The test temperature is maintained at 25^oC and the loading rate is 0.5 mm/minute. The test specimens are conditioned for two hours before testing. Figure 3.2 shows the SCB-J_c loading frame. The specimen is positioned in the setup on two rollers on both edges having the notched side down in the center. Once the specimen is placed on the bottom support and conditioned for the mentioned time periods, a preload of 4.5 kg is applied to the specimen. Upon starting the test, the specimen is subjected to gradual loading at a rate of 0.5 mm/min. During the test, load versus displacement is recorded. The test is terminated once the load falls below 0.1 kN. The data is then collected and analyzed as discussed in Chapter 2 (Equation 2.1).

Figure 3.2 SCB J_c test setup

3.4.1.2 Semicircular Bending Test - Flexibility Index (SCB-FI)

The test specimens for the SCB Flexibility Index (SCB-FI) have a thickness of 50±1 mm and diameter of 150±1 mm. Each sample is cut into two halves to create two semicircular specimens. The test temperature is maintained at 25˚C, and the loading rate is 50 mm/min. The test specimens are conditioned for two hours before testing. The SCB-FI loading frame looks the same as the SCB-J_c loading frame as shown in Figure 3.2; the only difference is the span between the two sample support rods. It is 127 mm for the SCB-J_c (DOTD Designation TR- 330-14) and 120 mm for the SCB-FI (AASHTO TP 124). The specimen is positioned in the setup on two rollers on both edges having the notched side down in the center. Once the specimens are conditioned, a small contact load of 0.1 ± 0.01 kN is applied. During the test, load versus displacement is recorded. The test is terminated once the load falls below 0.1 kN. The data is then collected and analyzed as described in Chapter 2 (Equation 2.2).

3.4.1.3 Indirect Tensile (IDT) Test

The IDT test is conducted according to ASTM D6931. The test is conducted by loading a cylindrical specimen across its vertical diametral plane at a specified rate of deformation and test temperature. The IDT test specimens are 50±1 mm in thickness and

150±1 mm in diameter. Three replicates are prepared form each mixture. The specimens are placed in an environmental chamber for 2 h at 25°C prior to testing. Once a specimen is placed in the loading frame and conditioned, a constant rate of vertical deformation is applied on the sample. The deformation rate as per the standard is 50 mm/min. The test is terminated upon fracture of the specimen. The load-deformation curve is recorded and used for analysis. The test is conducted using a Material Testing System (MTS) machine as shown in Figure 3.3. Table 3.8 presents a comparison between cracking tests.

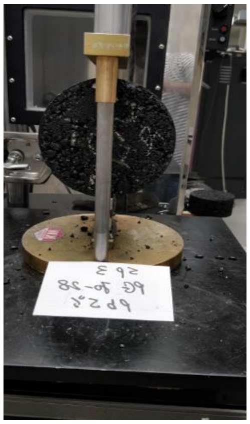

Figure 3.3 IDT test setup inside an environmental chamber of MTS

Table 3.8 Comparison between cracking tests

Performance criteria	**Cracking Tests**		
Test name	SCB-J_c	SCB-FI	IDT
Test type	Fracture	Fracture	Fracture
Testing protocol	DOTD Designation TR-330-14	AASHTO TP 124	ASTM D6931
Specimen shape	Semi-circle	Semi-circle	Cylindrical
Test temperature (°C)	25	25	25
Specimen thickness (mm)	57	50	50
Loading control	Control displacement rate	Control displacement rate	Control displacement rate
Loading rate	0.5 mm/min	50 mm/min	50 mm/min
Conditioning time (hour)	2	2	2
Notch depth (mm)	25.4, 31.8 and 38 mm	15	N/A

3.4.2 Rutting Tests

3.4.2.1 Asphalt Pavement Analyzer (APA)

The APA test is conducted according to AASHTO T 340 (Figure 3.4). The APA test specimens have a thickness of 75±1 mm and diameter of 150±1 mm. The dimensions are the same for both the LMLC specimens and PMLC specimens. The APA test is conducted at a temperature corresponding to the higher Performance Grade (PG) of asphalt binders used in preparing the asphalt mixtures. The test specimen is conditioned for 6 h at the specified test temperature before testing, as the standard stated the conditioning time frame to be within 6 to 24 h. After placing the APA sample holder inside the chamber with samples a first vertical calibration is done. The loading cell is calibrated to induce 689.5± 34.5 kPa on both wheels. The hose pressure gap reading is set as designated in AASHTO T 340.

The air pressure in the APA test hoses is checked using a testing gauge. The test gauge is connected to the end of the hose. The pressure is maintained to be within the range of 689 kPa ± 34 kPa. Once the test is started after the preconditioning time, one test takes about 3 h to complete 8,000 cycles. The rutting depth is recorded along the number of passes automatically using the APA software. Once the test is completed, the wheels automatically gets retracted. Figure 3.4 shows the Asphalt Pavement Analyzer (APA) Jr, used in this study.

Figure 3.4 Photograph of the Asphalt Pavement Analyzer (APA) Jr.

3.4.2.2 Hamburg Wheel Test

The Hamburg wheel tracking test (HWTT) is conducted in accordance with AASHTO T 324. This test protocol also measures the potential for moisture damage effects as the specimens are submerged in the temperature-controlled water during the loading. The Hamburg test specimens have a thickness of 60±1 mm and diameter of 150±1 mm. The dimensions were the same for both the LMLC and the PMLC specimens. Two pairs of specimens are tested at each time. The samples are inserted in HDPE (high density polyethylene) mounting molds. The test temperature of the water bath is maintained as 55^{o}C per AASHTO T 324 during the test. The test samples are preconditioned for 30 min. Steel wheel rollers (17 mm wide) are operated directly back and forth over cylindrical specimens. The load on the wheel is maintained at 71.7±0.5 kg. The wheel typically makes 52 ± 2 passes across the specimen per minute. A linear variable differential transducer (LVDT) capable of measuring the depth of the impression (rut) of the wheel at the center ± 12.7 mm along the length of the wheel path is integrated into the system to measure the rut depth. The wheel tracking device is stopped upon the completion of 20,000 passes or if the maximum rutting depth of 12.5 mm is reached. The rutting data versus the number of passes is collected for analysis. The Hamburg wheel tracking can also be used to assess the moisture damage of asphalt mixtures. The testing was conducted using the APA Jr but different wheels were used as shown in Figure 3.5. Table 3.9 provides a summary of the test parameters of APA in comparison to the Hamburg wheel.

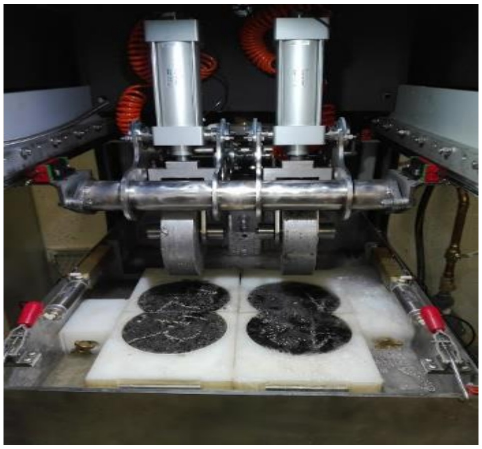

Figure 3.5. Photograph of the Hamburg Wheel Tracking Tester (HWTT) Setup

Table 3.9 APA Jr. and Hamburg rutting test configurations

Criteria	**Rutting Tests**	
Test name	HWTT	APA
Test type	Traffic load simulator	Traffic load simulator
Standards	AASHTO T 324	AASHTO T 340
Specimen shape	Cylindrical	Cylindrical
Test temperature (°C)	50	High temperature of Binder grade (PG)
Specimen thickness (mm)	60	75
Conditioning time (h)	1	6
Performance index	Rut depth @ 20000 cycles	Rut depth @ 20000 cycles

3.5 Statistical Analysis

To compare the test results of LMLC and PMLC, an analysis of variance (ANOVA) at the 95% confidence interval along with Tukey's honestly significant differences (HSD) were performed. ANOVA is used to compare the mean of individual projects with each other to observe whether there is any significant difference in test outcomes. The Tuckey's HSD test designates a set of letters (A to Z). The groups that do not share a same letter are significantly different. Appendix B provides all of the statistical analysis data performed in this study.

CHAPTER 4

CRACKING PERFORMANCE AND ANALYSIS

4.1 Introduction

This chapter compares the cracking performance of various parameters for both LMLC and PMLC mixtures. Several tests and parameters were examined to evaluate the resistance of test asphalt mixtures to cracking. These tests included the indirect tensile strength test (IDT), semicircular bending Louisiana J_c test, and semicircular bending Illinois flexibility index tests (I-FIT). This section also examines the variability of the test parameters as well as the correlation between various parameters in ranking the test mixtures in terms of their resistance to cracking.

4.2 Indirect Tensile (IDT) Strength Test

Figures 4.1 shows the load-deformation curve of project D6L1 from the IDT test. Data were fitted using a tenth-degree polynomial function. Figure 4.1 shows the load (kN) versus displacement (mm) curve along with the fitted lines. It also shows the point of maximum load (P_{max}), pre-peak inflection point, post-peak inflection point, and the terminal load, which were mathematically defined. Fracture energy was calculated using Equation 2.3 as introduced in Chapter 2. Flexibility Index (FI), Crack Resistance Index (CRI) and Indirect Tensile (IDT) Strength were calculated using Equations 2.2, 2.4 and 2.5, respectively from the load-deformation curve.

Figures 4.2 and 4.3 show the IDT fracture energy (G_f-IDT) and IDT strength as for the LMLC specimens, respectively. As Figure 4.2 shows, for both binders, fracture energy increased with an increase in binder content. The results also showed that the deformation at failure increased with binder content. Although the maximum load at failure may have decreased with the increase in binder content, the fracture energy increased with binder content due to the increase in deformation. For binder grade effect, PG 70-28 had a higher fracture energy compared with PG 58-34 for asphalt mixtures prepared with 5.75% binder content. The results showed that there is a significant difference in the fracture energy for asphalt mixtures prepared with 5.75% of PG 70-28 binder compared to mixtures prepared with the same binder grade at different binder contents (i.e., 4.25% and 5%). Also, there is a significant difference in the fracture energy for asphalt mixtures prepared using PG 58-34 binder at 4.25% and 5.75% binder contents.

Figure 4.3 shows that PG 70-28 had higher fracture energy compared to PG 58-34 at the corresponding binder contents. In addition, there was no significant effect of binder content on fracture energy for both binder grades. It should be noted that PG 70-28 binder is considered stiffer compared to PG 58-34 since it has a higher performance grade. These results are in agreement with the findings by Walubita et al. (2013), where they did not find any significant change in IDT strength due to the change in binder content. In a similar study, Kim et al. (2012) did not find any significant effect for binder grade on IDT strength while the results of this study show that there is a significant effect.

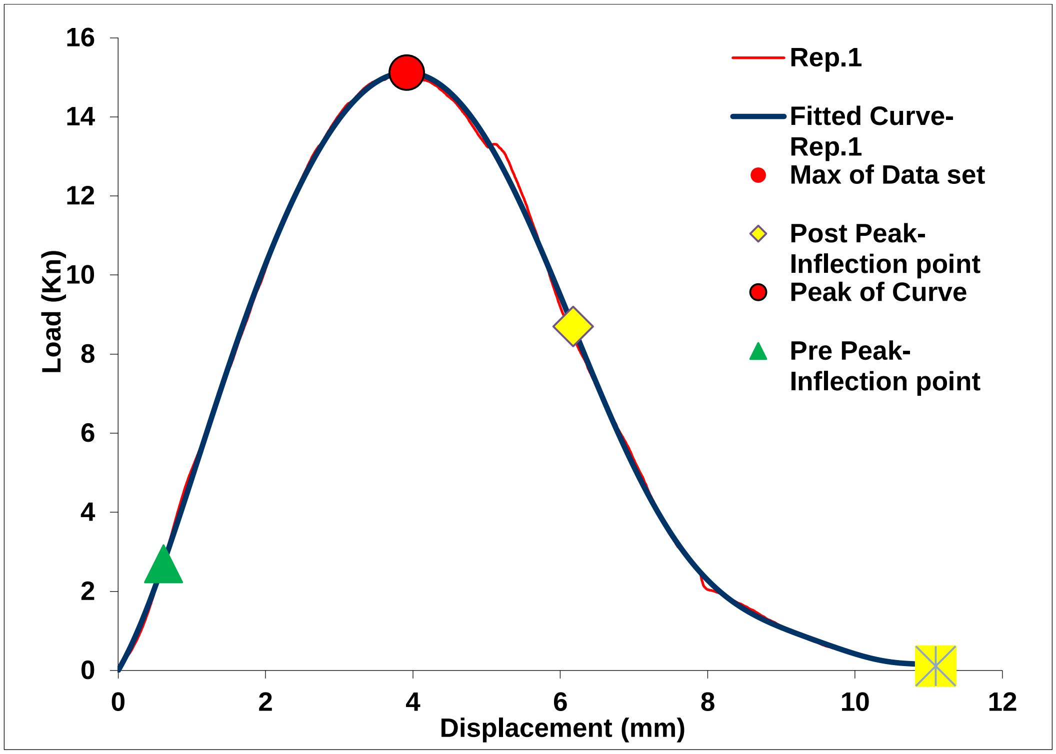

Figure 4.1 Load-deformation curve from IDT test for D6L1

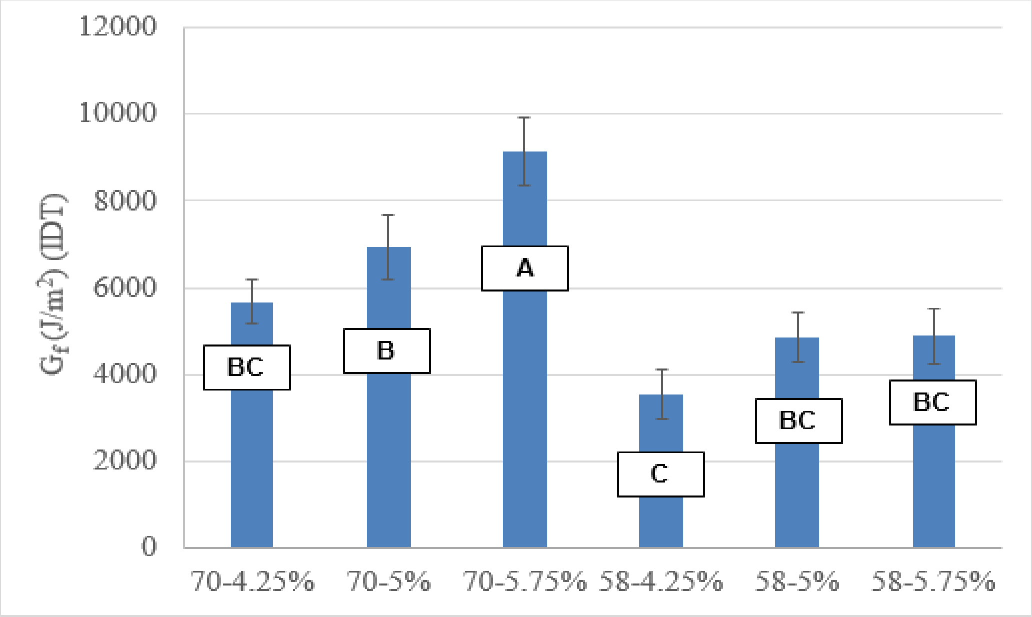

Figure 4.2 Fracture energy for LMLC computed from the IDT test

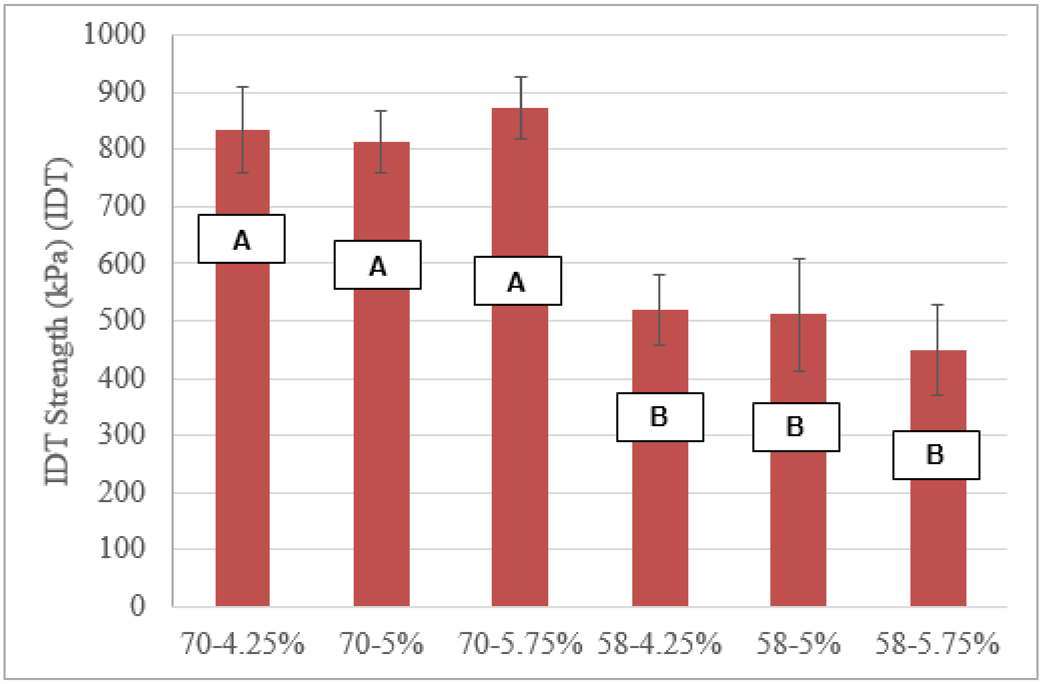

Figure 4.3 IDT strength for LMLC computed from the IDT test

Figure 4.4 shows the CRI-IDT calculated from the IDT test for the LMLC specimens. The CRI-IDT increased with binder content for both binder grades (PG 76-28 and PG 58-34) and there is a significant difference in CRI-IDT between mixtures prepared with 5.75% binder content compared to mixtures with 4.25% binder content. The results also show that binder grade did not have a significant effect on the CRI-IDT. Figure 4.5 shows the FI-IDT calculated from the IDT test for the LMLC specimens. Similar to CRI-IDT, the FI-IDT increased with binder content and mixtures prepared with 5.75% binder content had higher FI-IDT compared with those prepared at 4.25% binder content. The binder grade did not affect the FI-IDT at the corresponding binder contents.

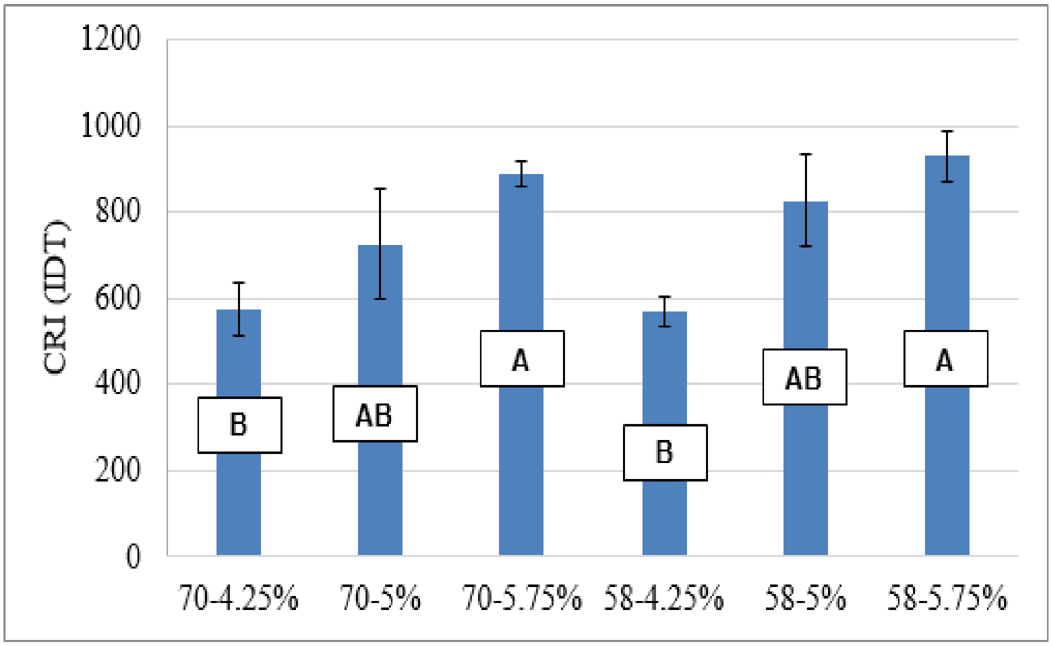

Figure 4.4 Cracking resistance index for LMLC computed from the IDT test

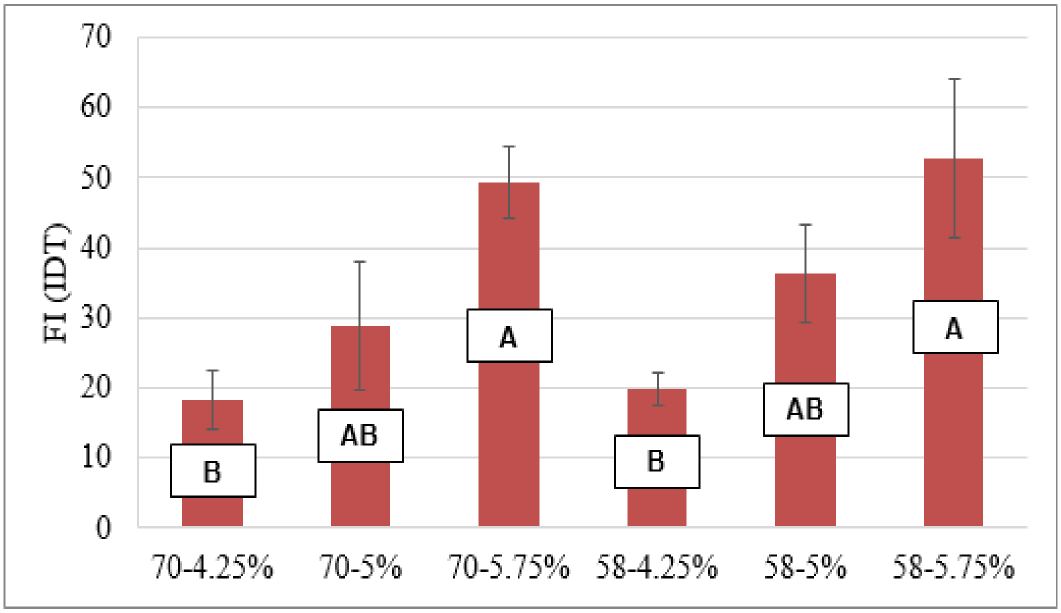

Figure 4.5 Flexibility index for LMLC computed from the IDT test

Figures 4.6 and 4.7 show the fracture energy and IDT strength for the PMLC specimens calculated from the IDT test. The D6L1 mixture had the highest fracture energy (10200 J/m^2), while D3L5 and D3L1 mixtures had lower fracture energies; 5250 J/m^2 and 5670 J/m^2, respectively. The mixture D6L1 with higher fracture energy had no RAP, while both D3L5 and D3L1 had 30% and 50% RAP, respectively. D2L1 had 50% RAP, but it also had higher binder content (5.7%), resulting in higher fracture energy compared to mixtures with RAP and less binder content (less than 5.3%). The fracture energy of D6L1 mixture is significantly different from the fracture energy of mixtures D3L5 and D3L1. The results also show that there was significant difference in IDT strength between D6L1 and D3L2.

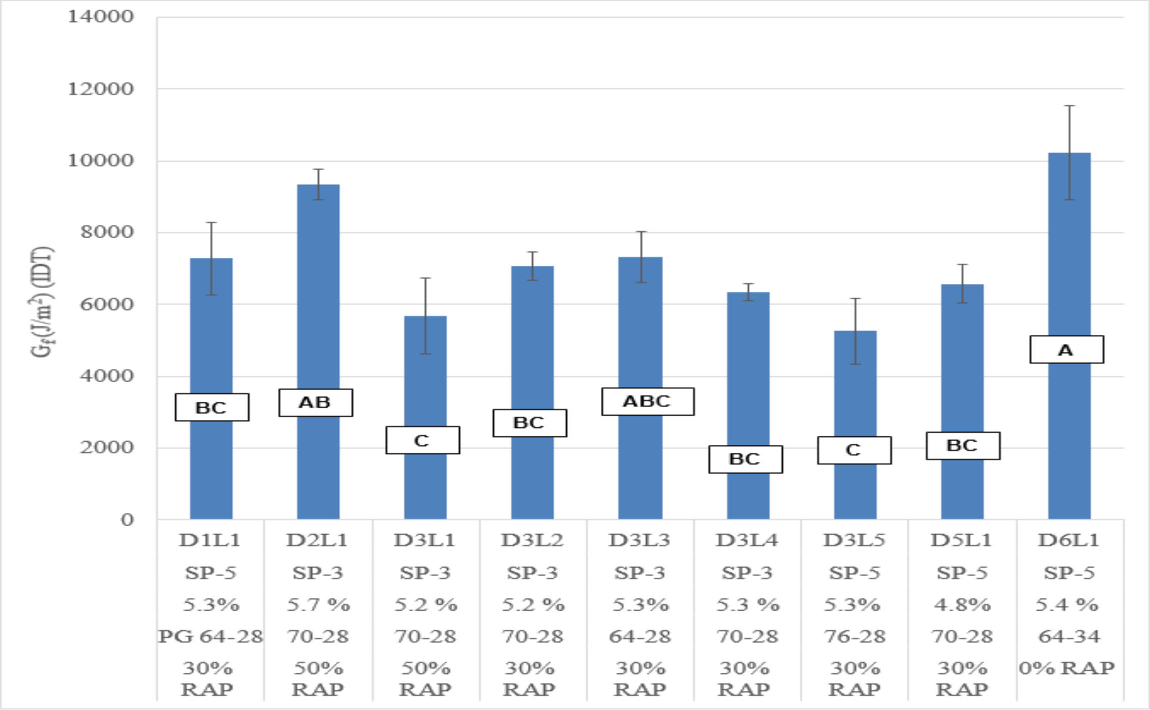

Figure 4.6 Fracture energy for PMLC computed from the IDT test

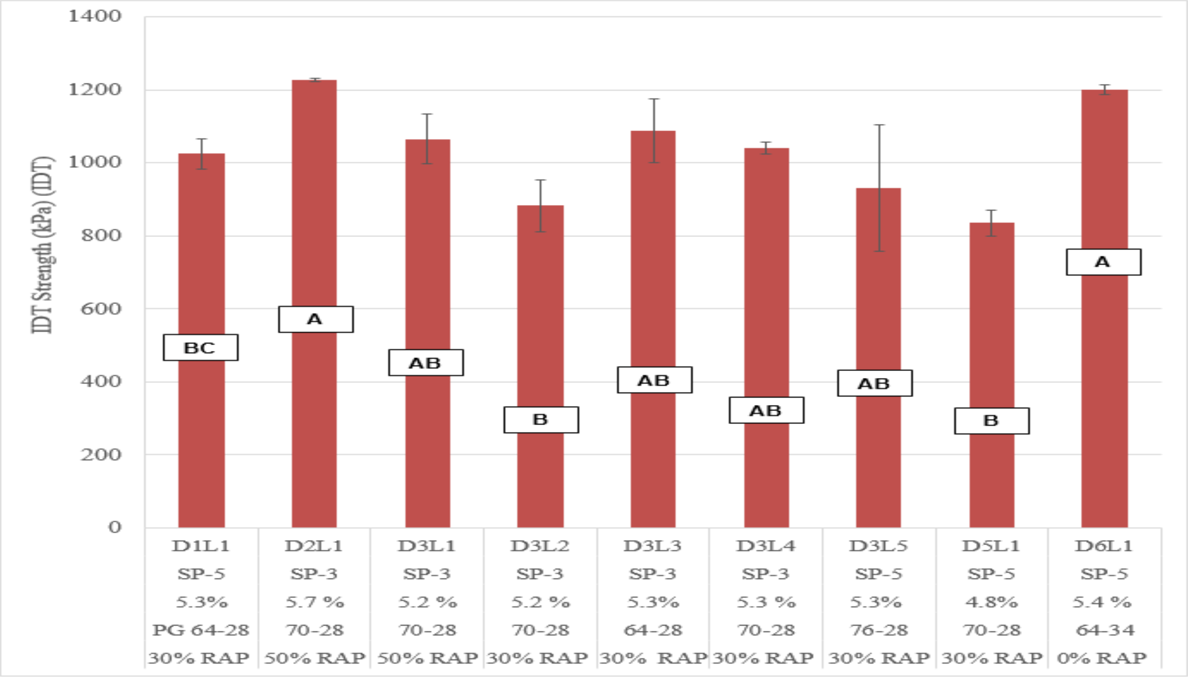

Figure 4.7 IDT strength for PMLC computed from the IDT test

Figures 4.8 and 4.9 indicate the CRI-IDT and FI-IDT values for the PMLC specimens calculated from the IDT test. The results showed that mixtures with higher FI-IDT had higher CRI-IDT (e.g., D.L1). In addition, the results demonstrated that the D6L1 mixture with no RAP had the highest FI-IDT, while both D3L5 and D3L1 had lower CRI-IDT and FI-IDT values. These findings are consistent with the fracture energy results shown in Figure 4.6. Higher CRI-IDT and FI-IDT values demonstrate higher resistance to cracking (Kaseer et al. 2018, Al-Qadi et al. 2015). D6L1 showed a significant difference in CRI-IDT values compared to D3L5 and D3L1, however, a significant difference in the FI-IDT was observed between D6L1 and D3L1 only. This is due to the high variability of the FI-IDT values.

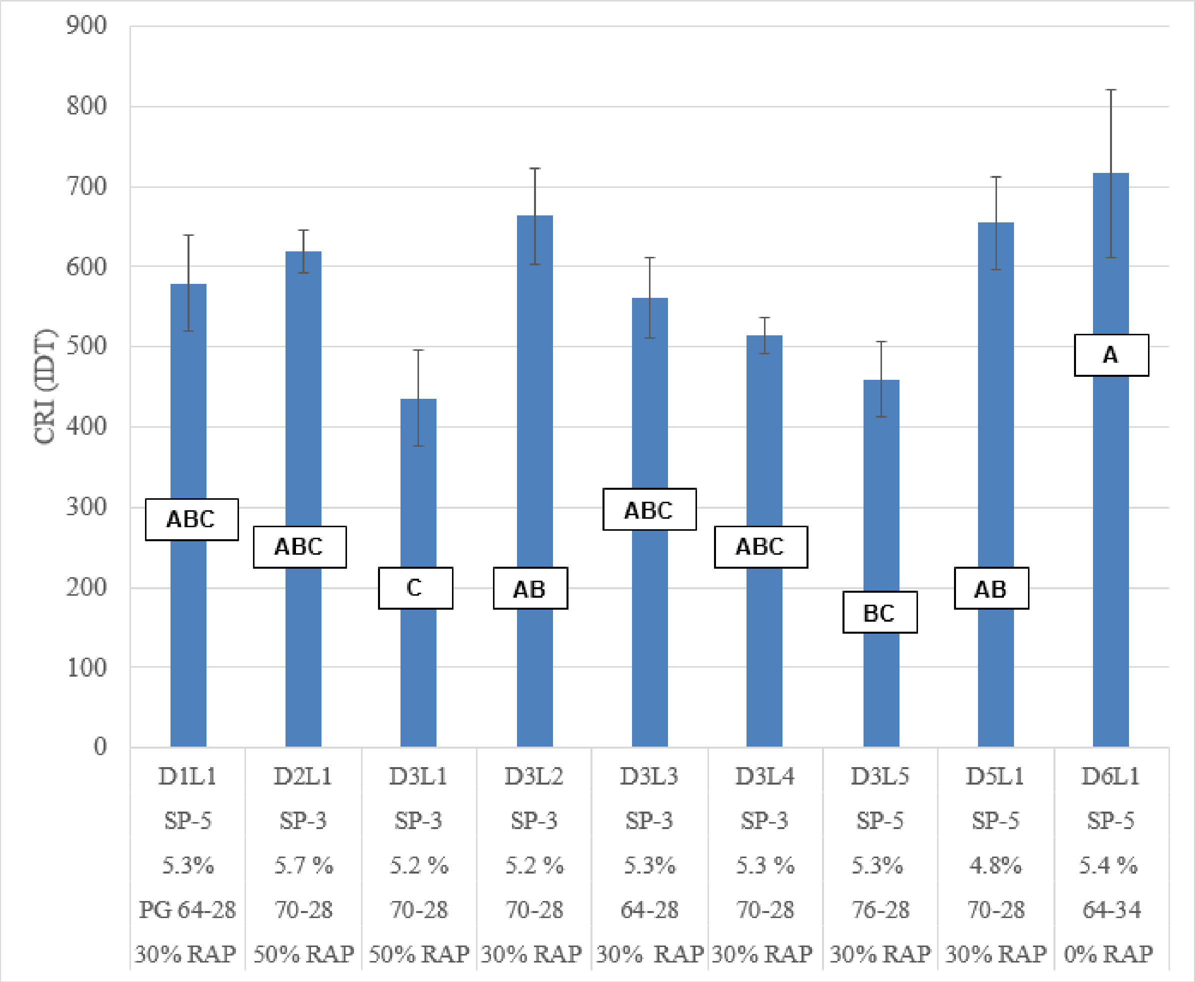

Figure 4.8 Cracking resistance index for PMLC computed from the IDT test

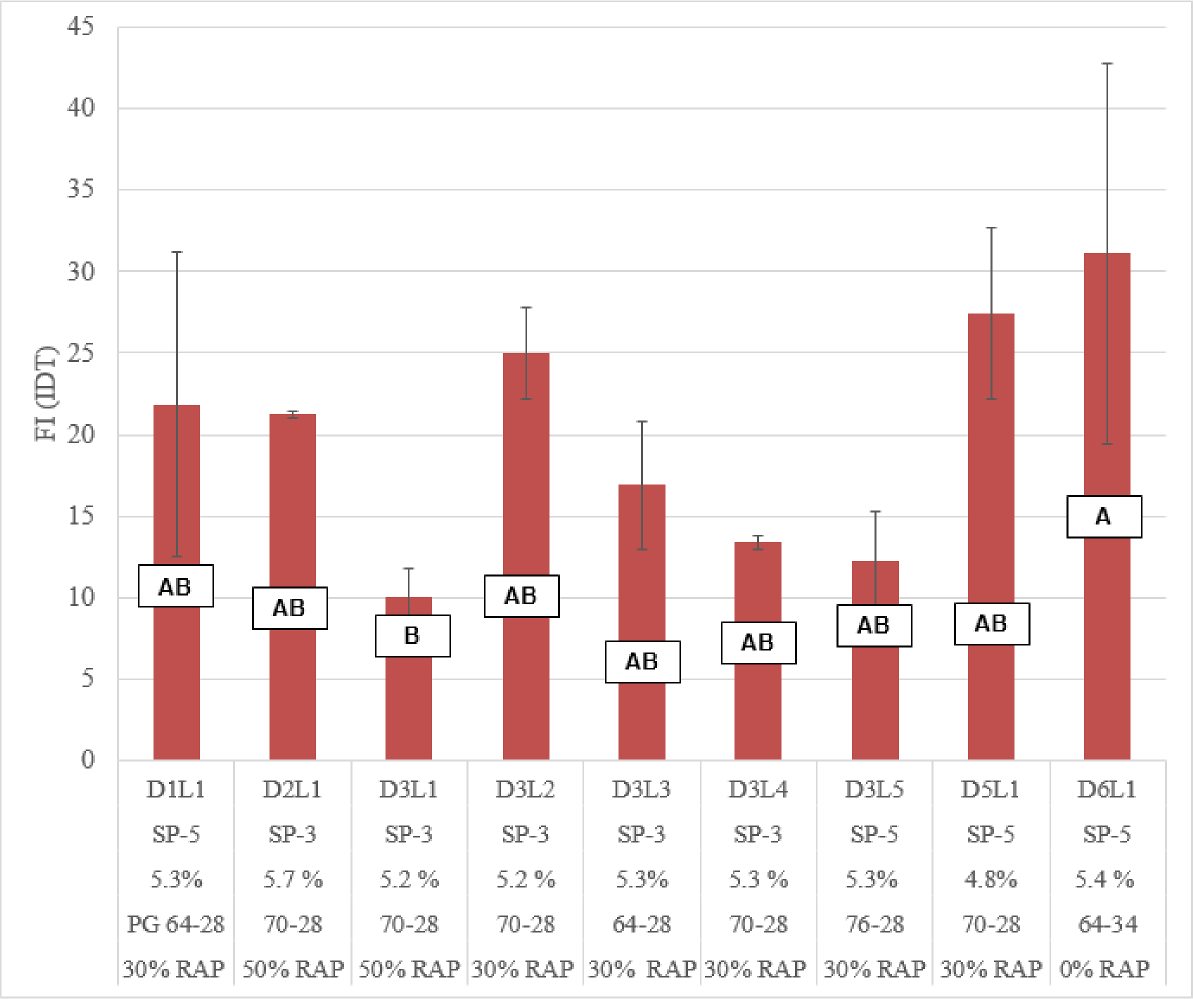

Figure 4.9 Flexibility index for PMLC computed from the IDT test

4.3 SCB Flexibility Index (FI)

As discussed in Chapter 2, this FI test is conducted on SCB test specimens at only one notch depth (15 mm). Similar to the IDT test, the data are fitted using the tenth-degree polynomial function. Figure 4.10 also shows the point of maximum load (P_{max}) or peak of the curve, pre-peak inflection point, post-peak inflection point, and the terminal load, which were mathematically defined. Fracture Energy, G_f (15 mm), Flexibility Index, FI (15 mm) and cracking resistance index, CRI (15 mm) were calculated using Equations 2.3, 2.2 and 2.4, as outlined in Chapter 2 from the SCB test. Figure 4.10 shows a typical load-deformation curve for SCB-FI test for the 70-28_5% mixture.

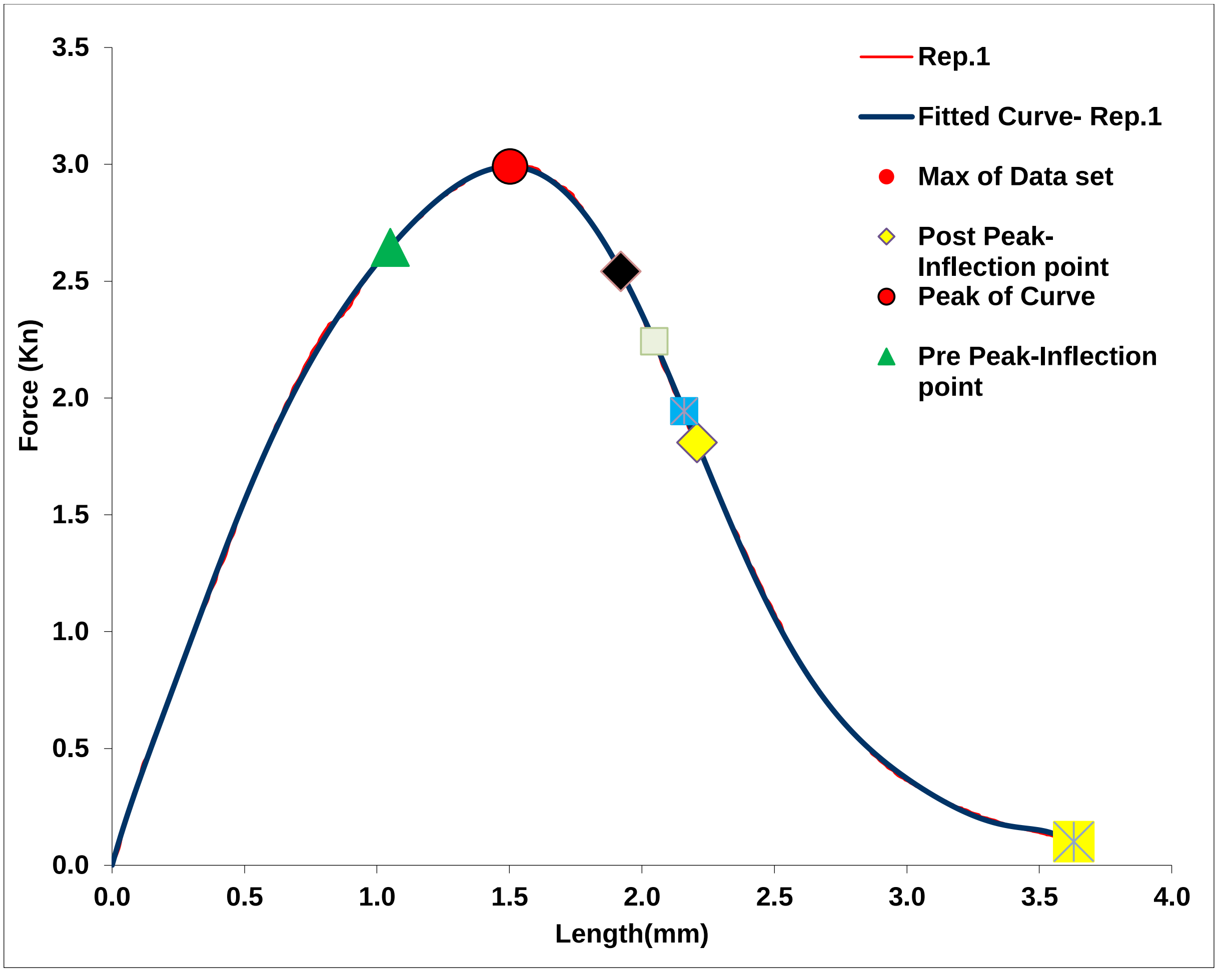

Figure 4.10 Load-deformation curve from SCB-FI test for 70-28_5%

Figures 4.11 and 4.12 show fracture energy, G_f (15 mm) and flexibility index, FI (15 mm) of LMLC from the SCB-FI test data. There was no effect of binder grade and binder content on fracture energy values of the LMLC mixtures (Figure 4.11). The FI (15 mm) increased with binder content for both binder types (PG 70-28 and PG 58- 34) as shown in Figure 4.12. In addition, softer binder (PG 58-34) showed higher FI (15 mm) compared to stiffer binder (PG 70-28) for mixtures prepared with 4.25% and 5.0% binder content. For PG 70-28, the FI (15 mm) for mixtures prepared with 5.75% binder content was higher than mixtures prepared with 4.25% binder content as one expects since asphalt mixtures become more flexible at higher binder content. Overall, all the LMLC mixtures performed well in terms of flexibility index thresholds proposed by Al-Qadi et al. (2015).

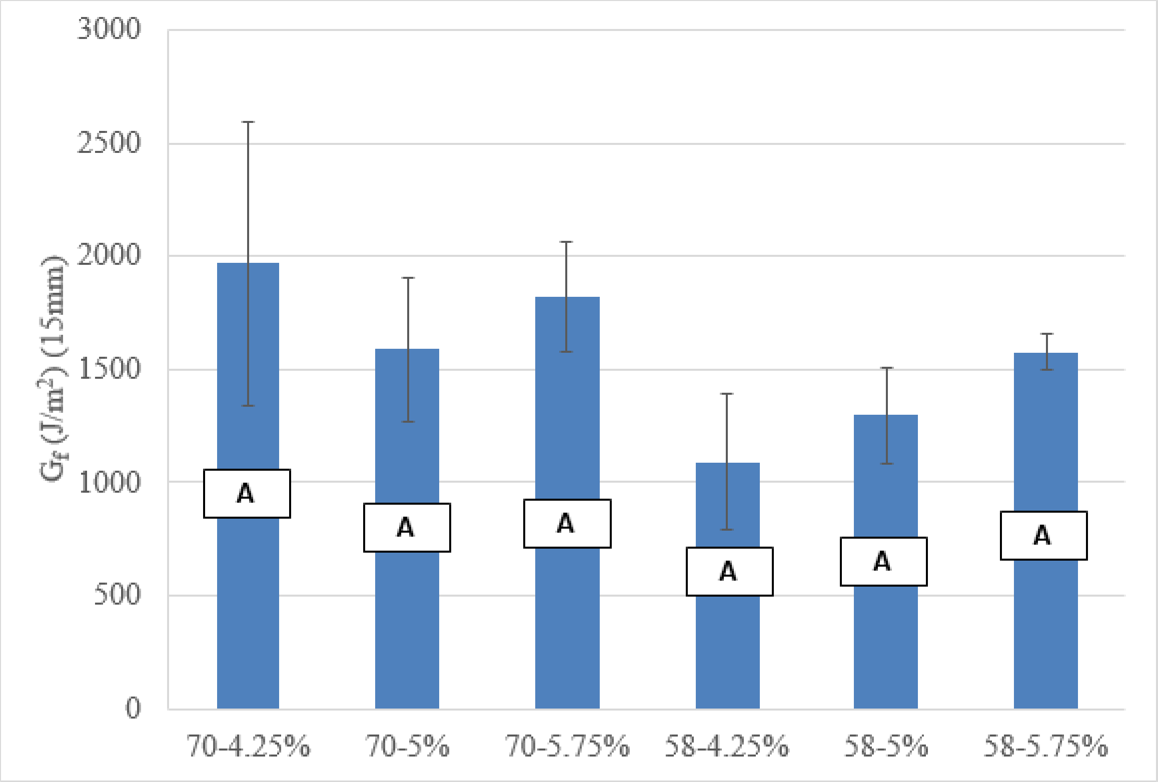

Figure 4.11 Fracture energy for LMLC calculated from SCB-FI test

Figure 4.13 shows CRI (15 mm) for LMLC calculated from the SCB-FI test. The CRI (15 mm) trend was in good agreement with the FI (15 mm) in which CRI (15 mm) increased with binder content. There was significant difference between CRI (15 mm) values for mixtures prepared with 5.75% binder content compared to those prepared with 4.25% binder content for both binder grades (PG 70-28 and PG 58-34). Kaseer et al. (2018), found that asphalt mixtures prepared with softer binder (PG 58-28) to have significantly higher FI (15 mm) and CRI (15 mm) compared to those prepared using a stiffer binder (PG 64-22) for long-term oven-aged samples. They also found that the binder content had no significant effect on FI (15 mm) and CRI (15 mm).

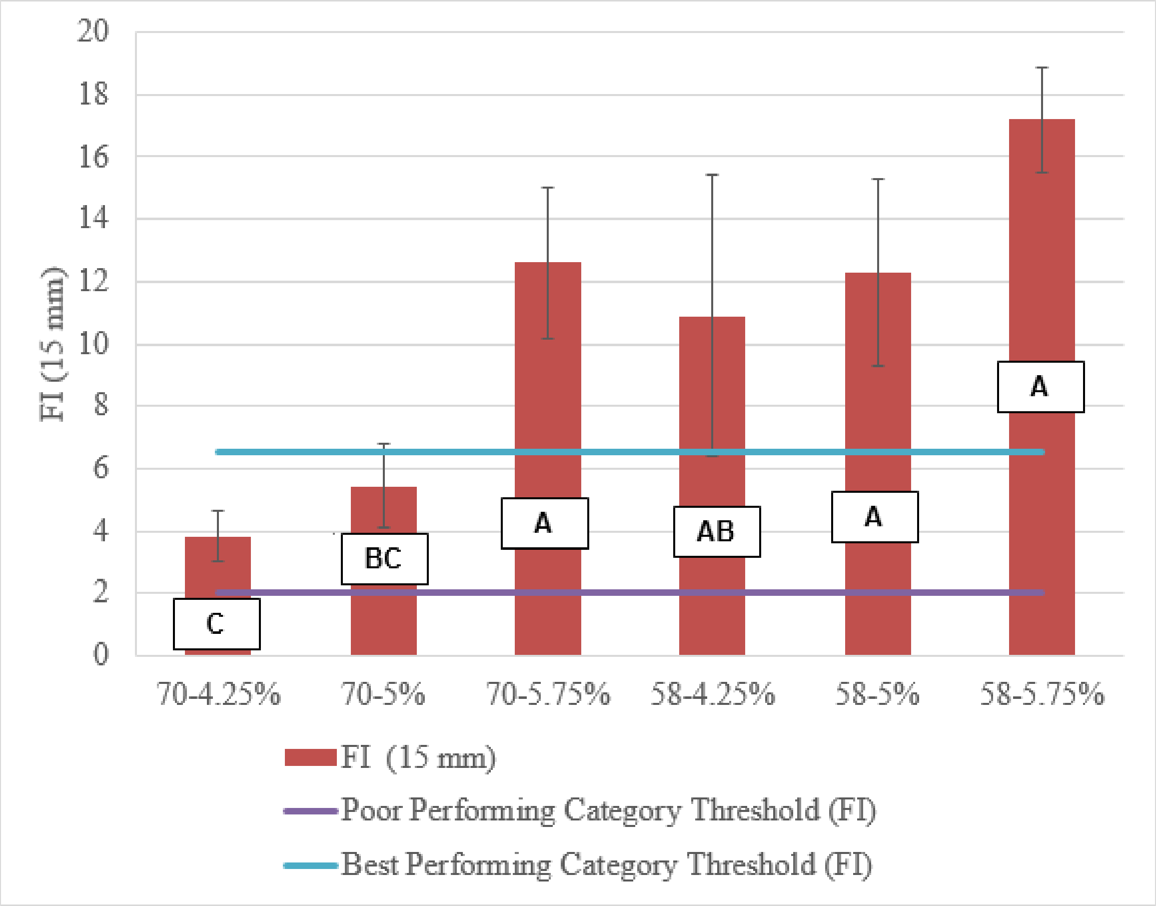

Figure 4.12 Flexibility index for LMLC calculated from SCB-FI test

Figures 4.14 and 4.15 show the G_f (15 mm) and FI (15 mm), respectively, for PMLC calculated from SCB-FI test. Consistent with the fracture energy results obtained from the IDT test, D6L1 had the highest value and D3L1 and D3L5 had the lowest. The difference in the fracture energy results between these three mixtures was significant, while the difference was insignificant for the rest of the mixtures. The FI (15 mm) results shown in Figure 4.15 were not consistent with previous findings from the fracture energy results as the FI (15 mm) for different projects are not statistically different. There was no significant difference in the FI (15 mm) results between the three mixtures (D6L1, D3L1, and D3L5). This could be due to the high variability of the FI (15 mm) test results as will be discussed later in this chapter.

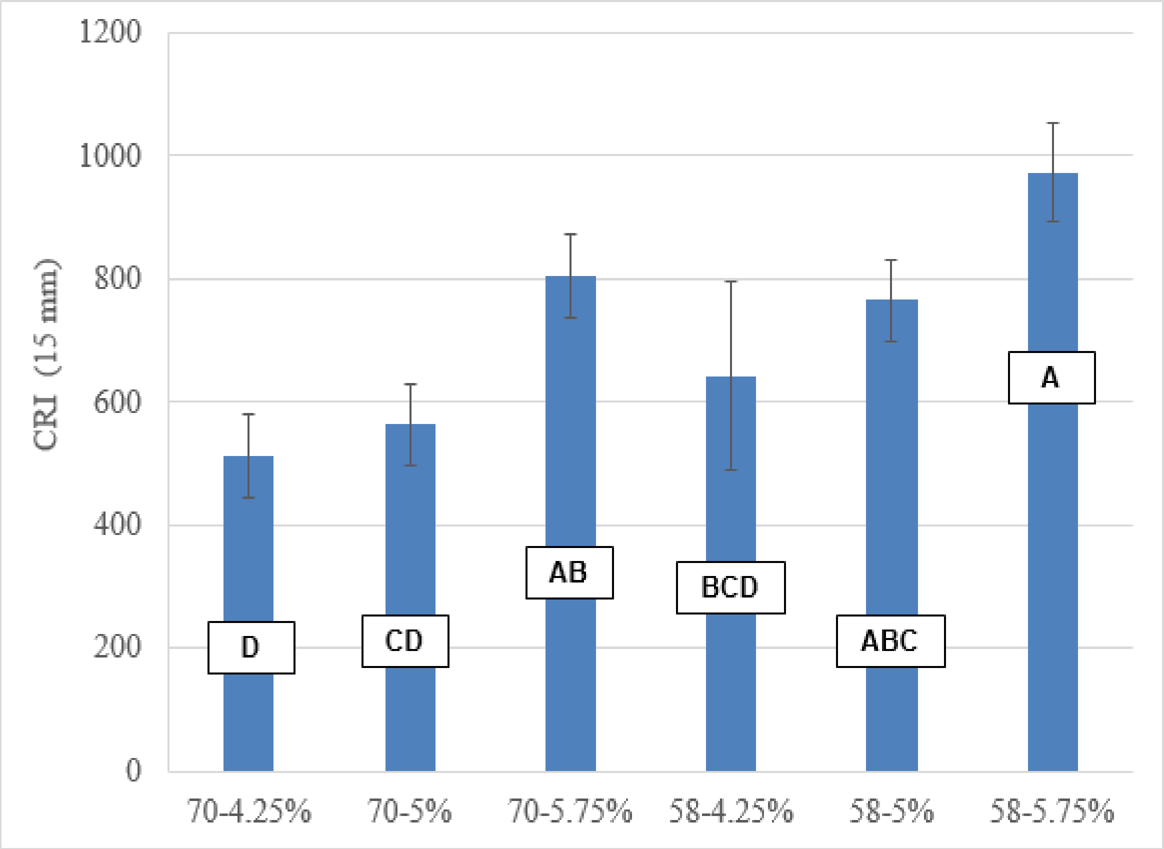

Figure 4.13 Cracking resistance index for LMLC calculated from SCB-FI test

According to Al-Qadi et al. (2015), test samples with FI (15 mm) less than 2 are expected to provide poor resistance to cracking, while samples with FI (15 mm) greater than 6.5 are expected to provide higher resistance to cracking. Based on these proposed limits, it is expected that D2L1, D3L1 and D3L5 would have less resistance to cracking in the field compared to other mixtures (e.g., D6L1, D3L2, D3L3 and D5L1). Meanwhile, it should be noted that there was a significant difference in FI (15 mm) for D3L5 only when compared to other mixtures (e.g., D5L1, D3L2, and D3L3).

The results of the CRI (15 mm) shown in Figure 4.16, demonstrate that there was a significant difference in the test results, especially for the mixtures D6L1, D3L1, and D3L5 mixtures which is consistent with the fracture energy results. The result showed that the effect of binder content, binder grade and RAP proportions are not significant on FI (15 mm) and CRI (15 mm).

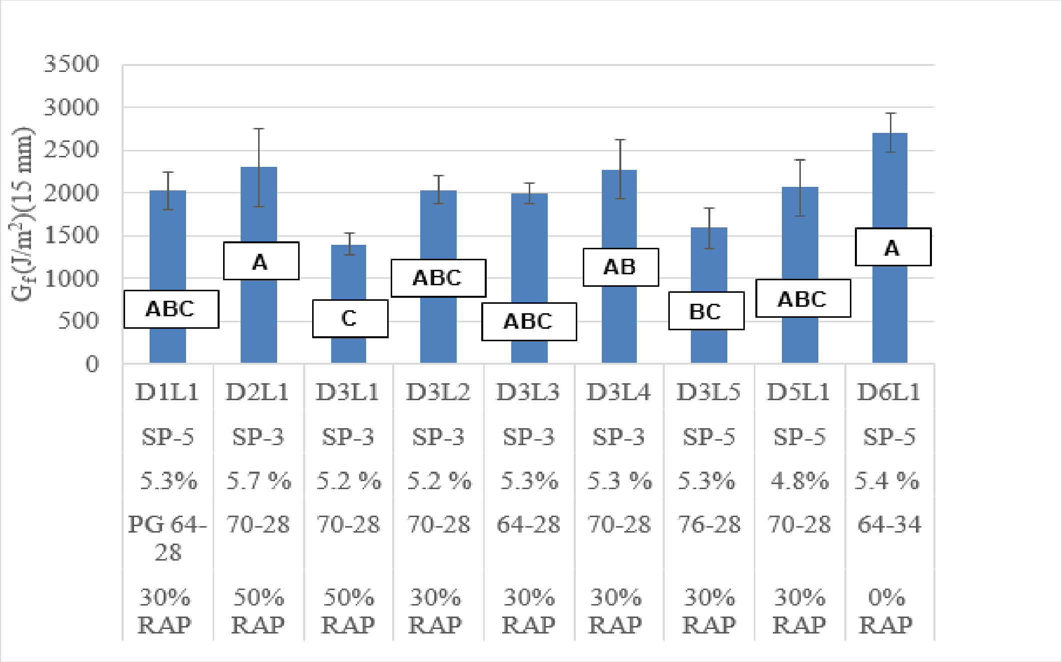

Figure 4.14 Fracture energy for PMLC calculated from the SCB-FI test

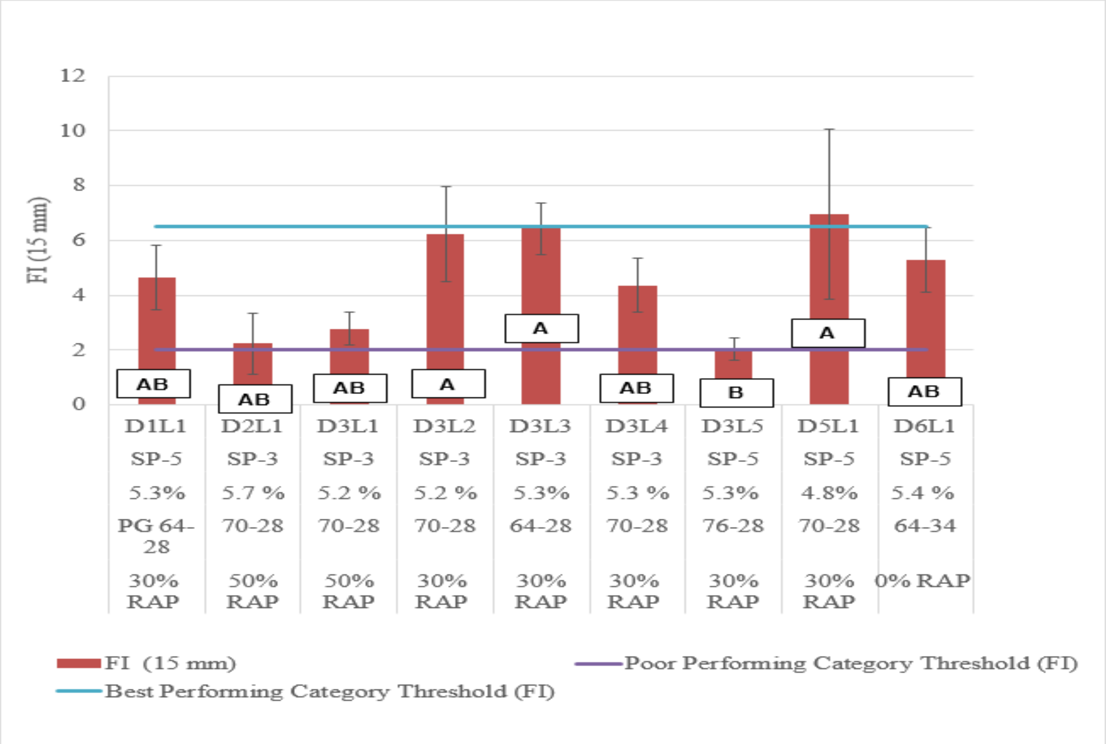

Figure 4.15 Flexibility index for PMLC calculated from the SCB-FI test

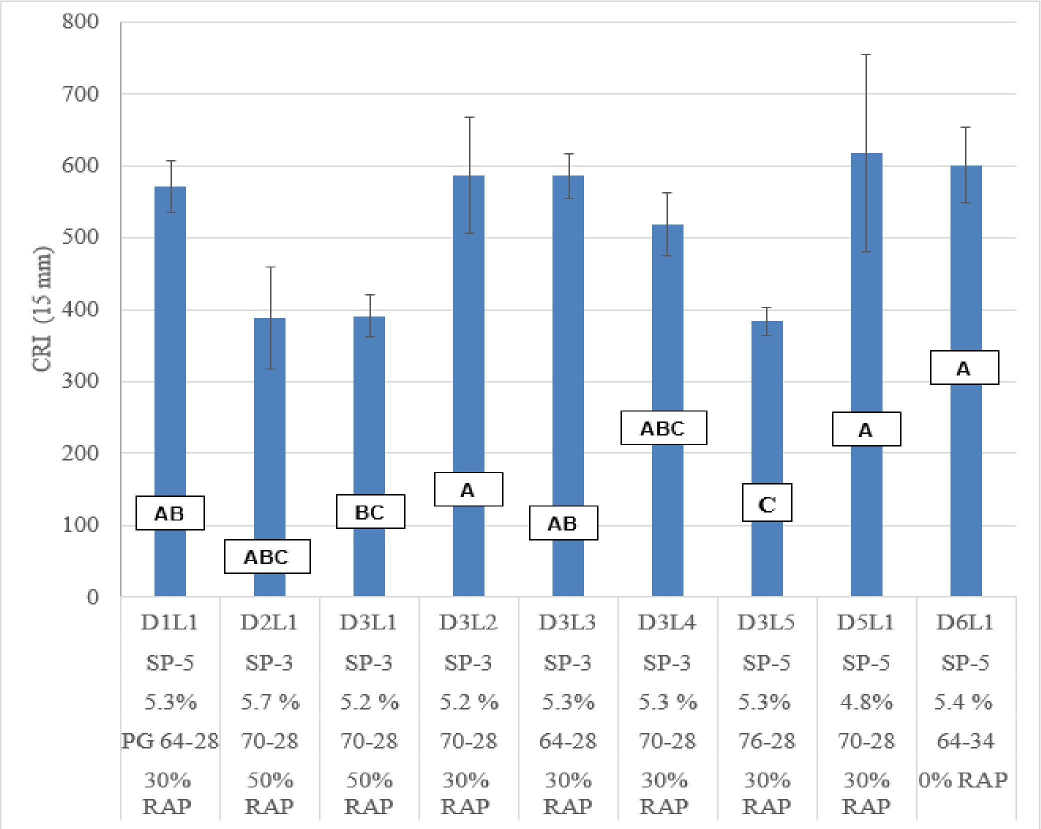

Figure 4.16 Cracking resistance index for PMLC calculated from the SCB-FI test

4.4 SCB Critical Strain Energy (J_c)

Figure 4.17 shows typical load-deformation curves for project 70-28-4.25%, at three different notch depths (25.4 mm, 31.8 mm and 38 mm) from the SCB-J_c test. In the SCB-J_c test, the area under the curve until peak load is determined for each notch depth. The strain energy decreases with notch depth, while the slope indicates the critical strain energy (J_c) (Figure 4.18). The strain energy is determined using Equation 2.1.

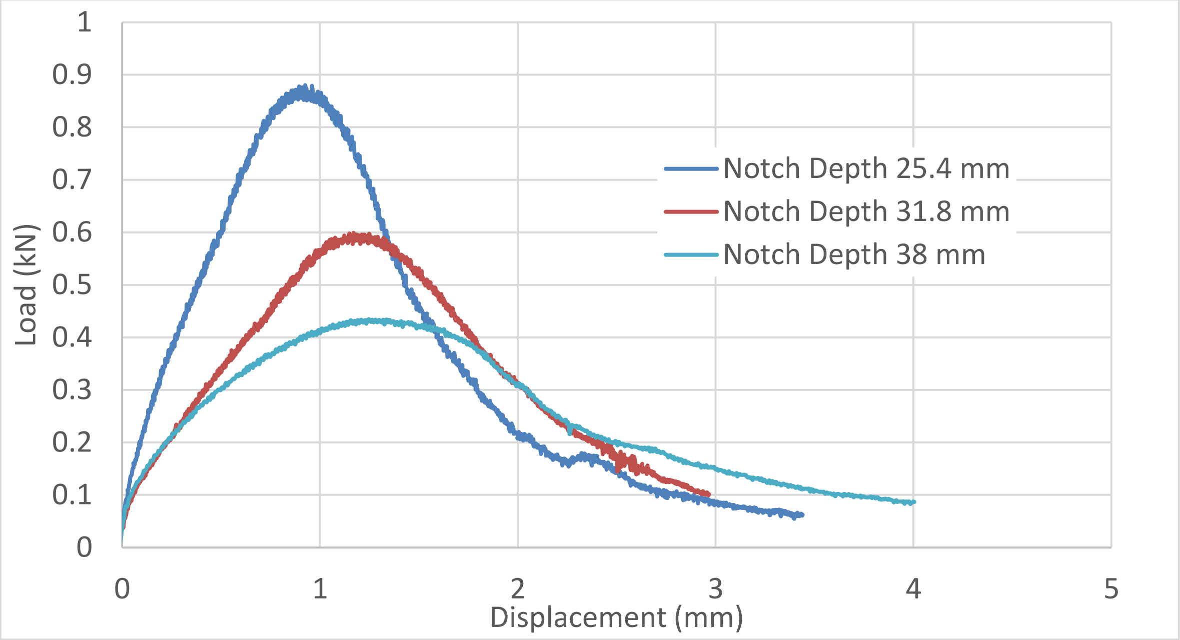

Figure 4.17 Plot of SCB-J_c load-deformation curves at different notch depths for project 70-28-4.25%

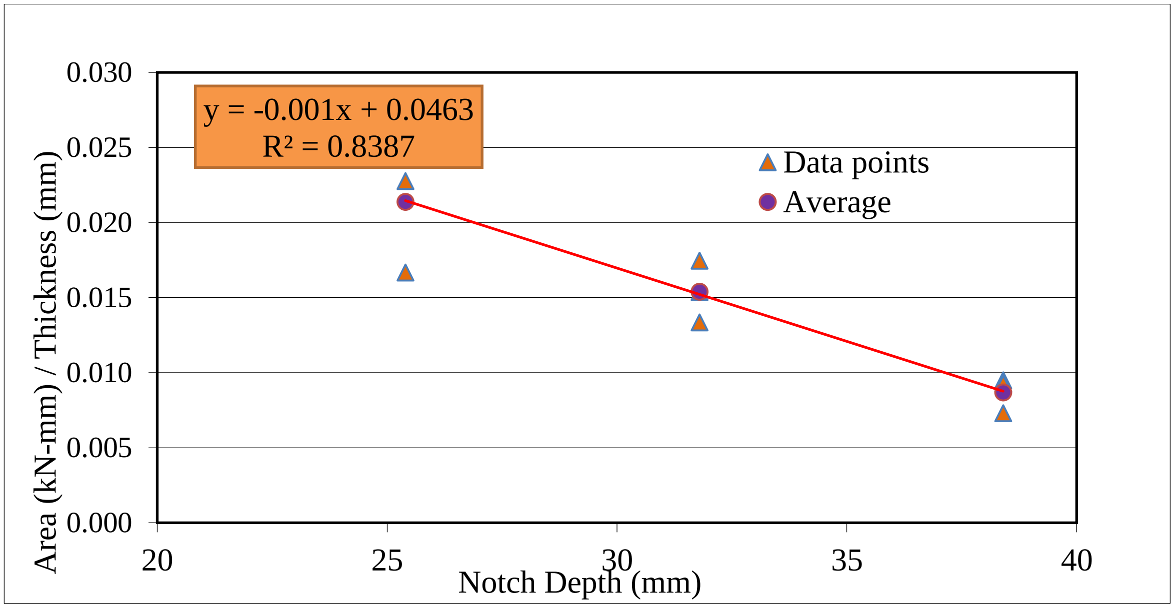

Figure 4.18 Variation of strain energy with different notch depth for project D6L1

Figure 4.19 shows fracture energy for different notch depth, binder content and binder grade for LMLC specimens calculated from the SCB-J_c test. The fracture energy from the SCB- J_c test did not show a trend with the increase in binder content. In addition, the binder grade and notch depth were found to have no effect on the fracture energy values for both binder grades (PG 70-28 and PG 58-34). These results are consistent with the fracture energy calculated from SCB-FI where there was no significant effect for binder grade and binder content on fracture energy.

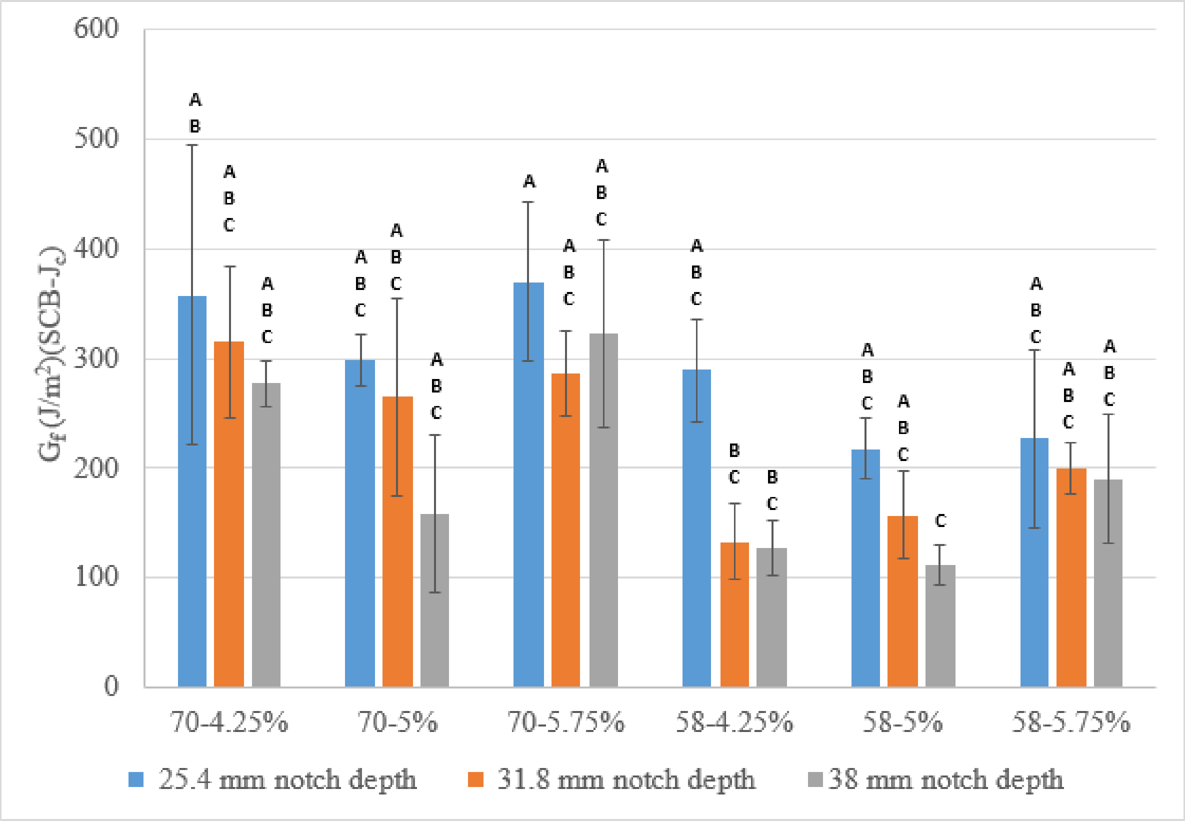

Figure 4.19. Fracture Energy for different notch depth for LMLC calculated from the SCB-J_c test

Figure 4.20 shows the CRI values for different notch depth, binder content and binder grade for LMLC specimens. The binder content had no effect on the CRI for both the binder grades (PG 70-28 and PG 58-34). In addition, the effect of notch depth on CRI was found to be insignificant. Based on the results, it is not recommended to calculate CRI from the SCB-J_c test since the CRI value did not show sensitivity to changes in asphalt mixture properties (e.g., different binder grade and binder content).

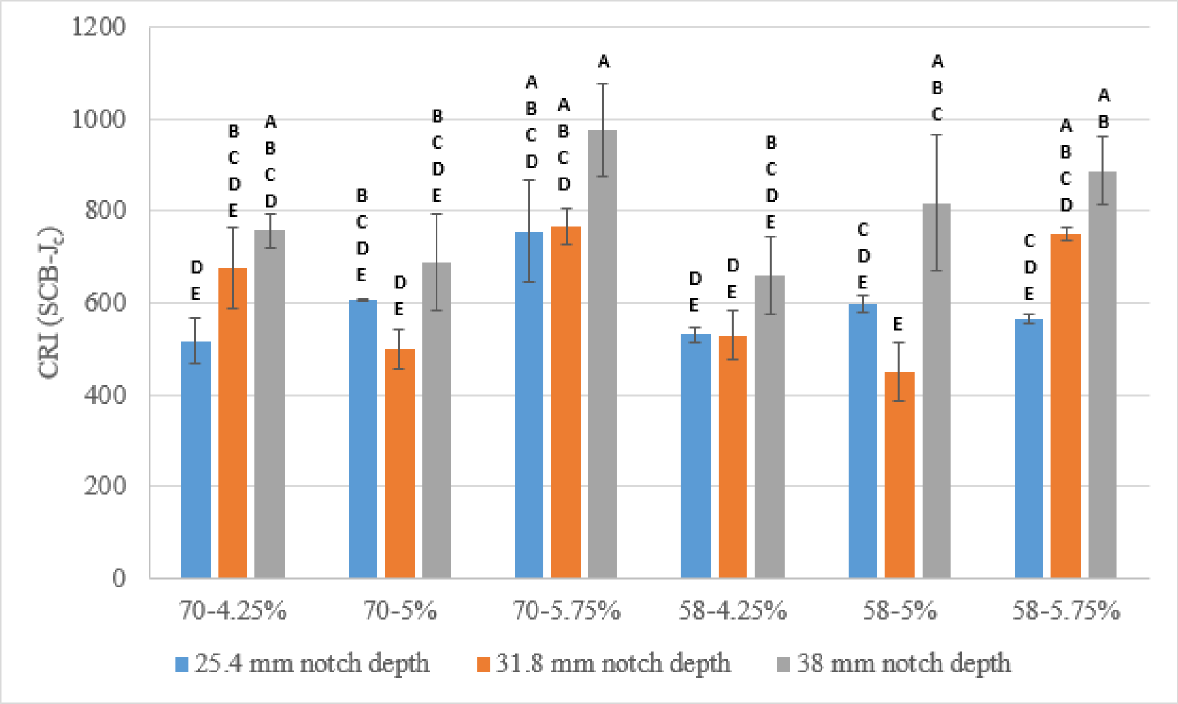

Figure 4.20. CRI for different notch depth for LMLC calculated from the SCB-J_c test

Figure 4.21 shows the variation of fracture energy for PMLC calculated from SCB-J_c test. D6L1 had higher fracture energy while D3L1 had the least fracture energy. The results are in agreement of those found from IDT and SCB-FI tests. D6L1 mixture has no RAP and softer binder, thus it is more flexible resulting in higher fracture energy. The general trend in the fracture energy is within the expectation for increasing notch depth as it shows a decreasing trend for most of the projects. The statistical analysis showed that there is a significant difference in the fracture energy results between D6L1 (highest fracture energy) and both D3L1 and D3L5 (both had lower fracture energy at the corresponding notch depths).

Figure 4.22 shows the variation in CRI values for different notch depths of the PMLC calculated from the SCB-J_c test. Overall, D6L1 and D1L1 had a higher CRI compared to other mixtures, while D3L1 showed the lowest CRI. There was no correlation between CRI and notch depth for all the mixtures. Since CRI is the ratio of fracture energy to peak load, it might be the case that the peak load value becomes comparatively smaller to achieve the high CRI. Consistent with the fracture energy (Figure 4.21), the result showed that there is a significant difference in the CRI results between D6L1 (highest fracture energy) and both D3L1 and D3L5 (both have lower fracture energy at the corresponding notch depths except

D3L5 at 31.8 mm). In addition, the project having a higher binder content of 5.4% (D6L1) showed significantly better cracking resistance index than the project having lesser binder content of 5.2% (D3L1).

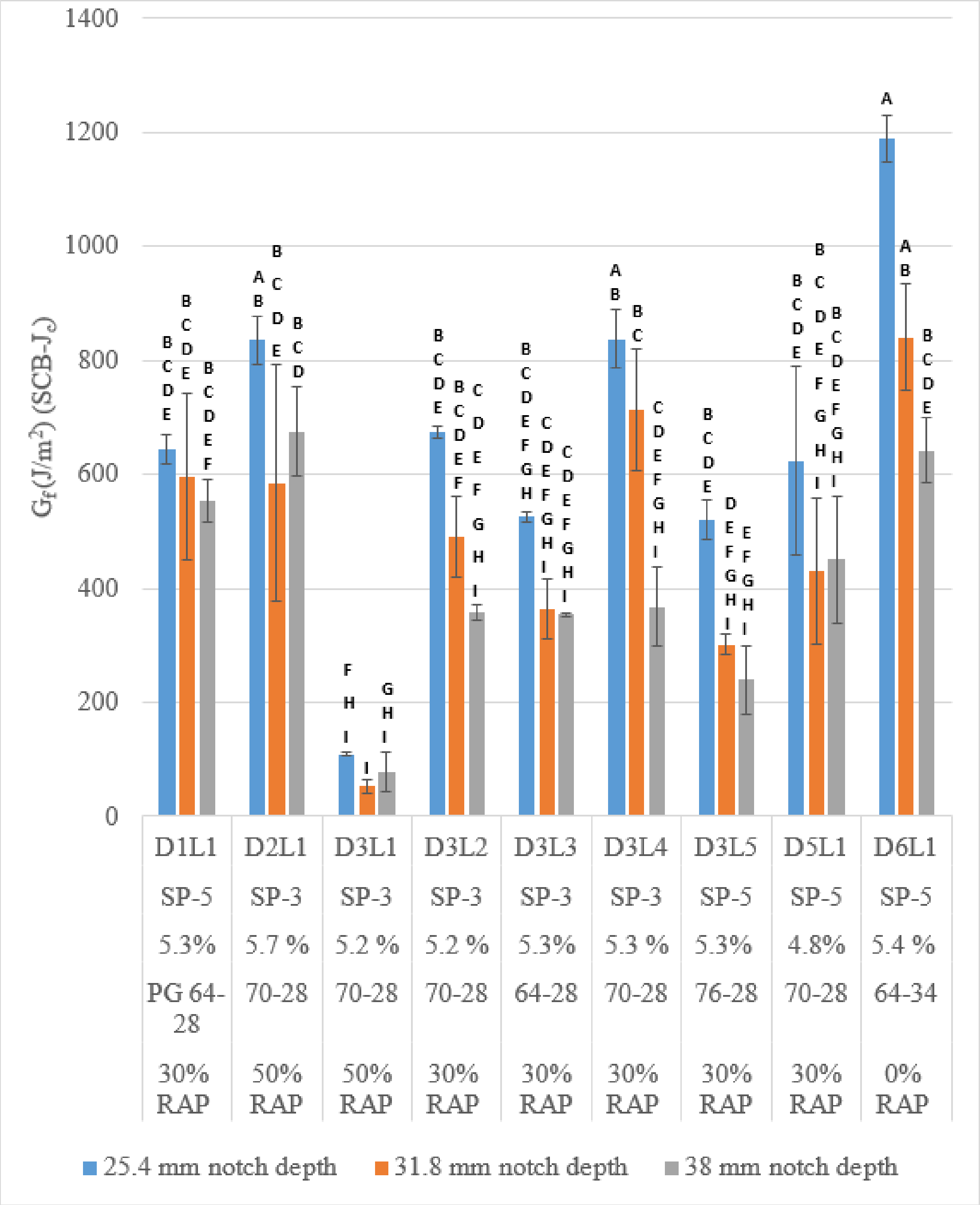

Figure 4.21. Fracture Energy for different notch depth for PMLC calculated from the SCB-Jc test

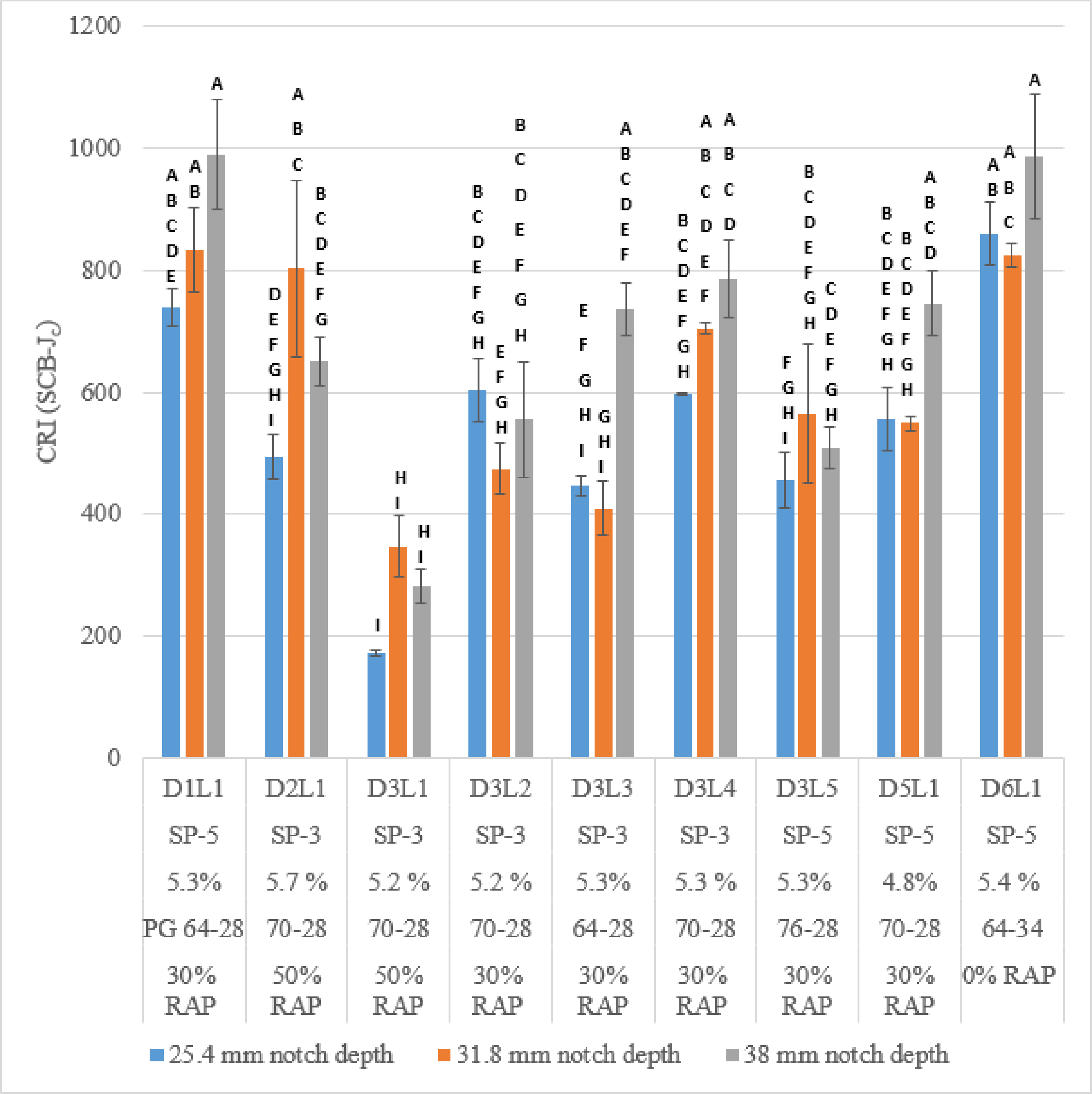

Figure 4.22. CRI for different notch depth for PMLC calculated from the SCB-J$_c$ test

Figure 4.23 shows the critical strain energy (J_c) for the LMLC mixtures. The critical strain energy (J_c) showed a decreasing values with binder content, which contradicts the expected trend. It is expected that test specimens get more flexible with increasing binder content resulting in higher J_c values (Bayomy and Abdo, 2006); however, this study showed the opposite trend for both binder grades (PG 70-28 and PG 58-34). Meanwhile, test specimens prepared with stiffer binder (PG 70-28) had higher J_c values compared to those prepared using softer binder (PG 58-34). This is consistent with previous findings by Cooper et al. (2016) where they proposed higher J_c of 0.6 kJ/m^2 for modified binder (PG 76 and higher).

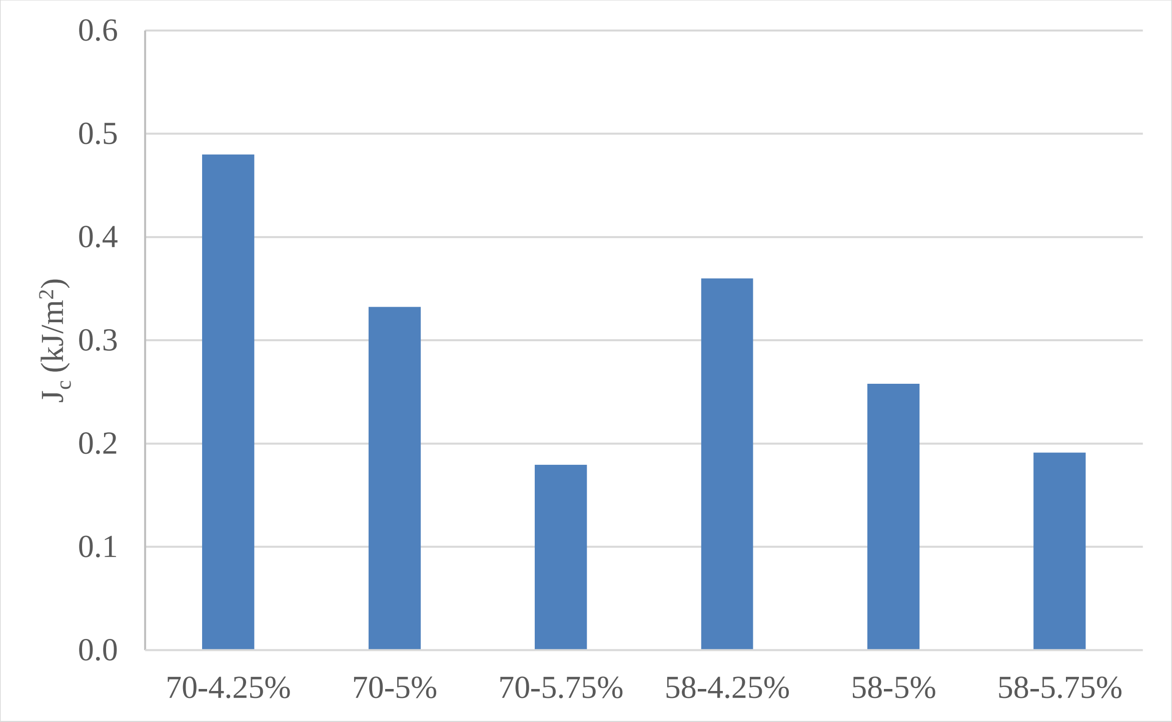

Figure 4.23 J_c Comparison for LMLC calculated from the SCB-J_c test

Figure 4.24 shows the variation of J_c for all nine PMLC projects. The results show that the D6L1 mixture has the highest value of J_c (0.976 kJ/m^2), while mixture D3L1 has the lowest (0.097 kJ/m^2). These results are in agreement with the test results of the fracture energy from the SCB-J_c test (Figure 4.21) and IDT and flexibility index from SCB-FI. According to the proposed J_c threshold by Cooper et al. (2016), samples with J_c of 0.5 kJ/m^2 (for binders having PG grade below 76-X) and J_c of 0.6 kJ/m^2 (for binders PG 76-X and higher) and lower will have poor resistance to fatigue cracking. Cooper et al. (2016) found that binder with high temperature grade (e.g., PG 76) to have higher J_c values and had higher resistance to cracking. Thus, it is expected that D6L1 and D3L2 would have better resistance to cracking compared to D3L1 and D3L3 as they have higher J_c values of 0.98 kJ/m^2 and 0.83 kJ/m^2, respectively.

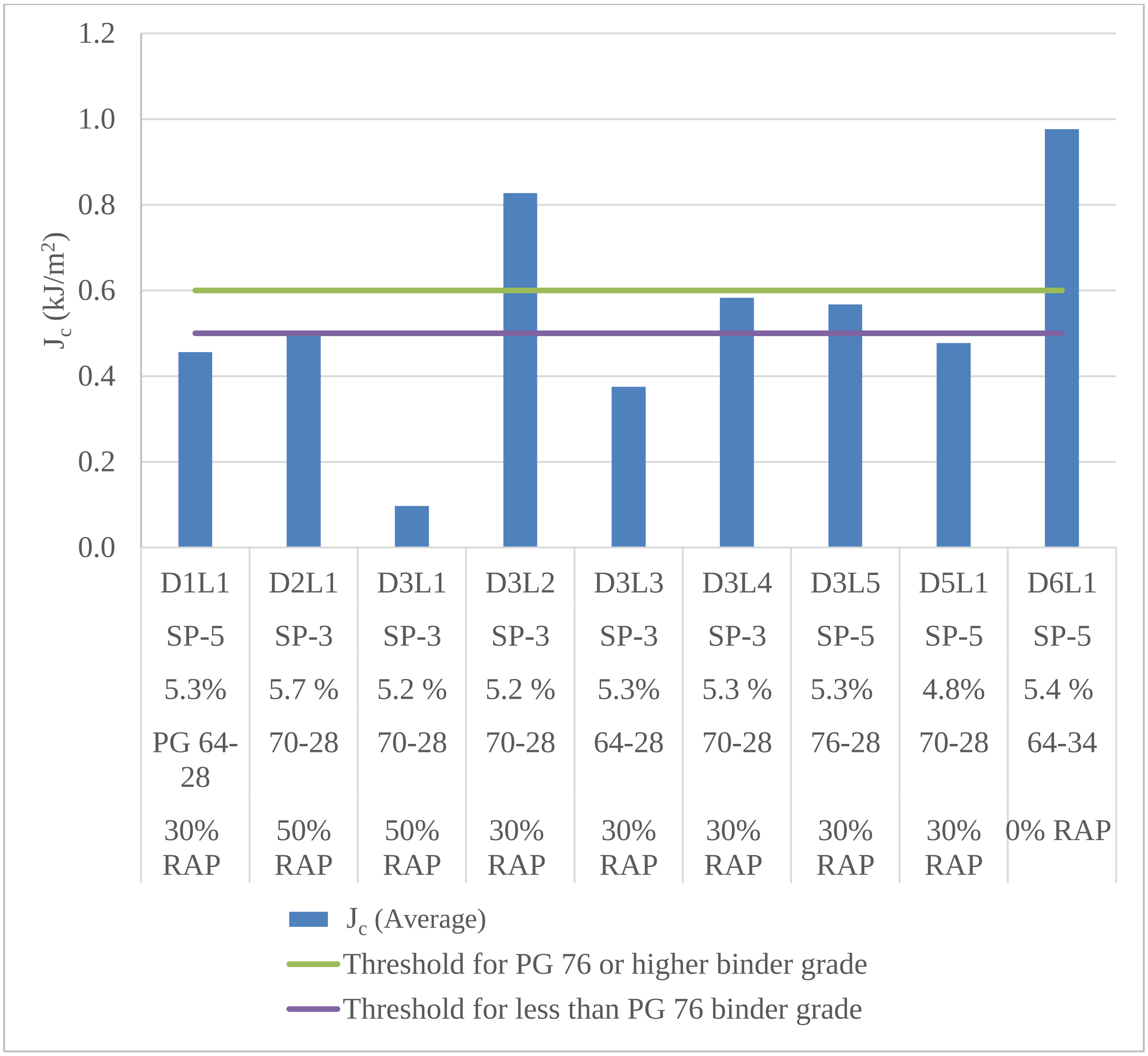

Figure 4.24 J_c Comparison for PMLC calculated from the SCB-J_c test

4.5. Variability of Cracking Resistance Parameters

Table 4.1 presents the IDT test performance indices, including fracture energy (G_f-IDT), flexibility index (FI- IDT), crack resistance index (CRI-IDT), and indirect tensile strength (IDT strength) along with the coefficients of variation for each index. The coefficient of variation (COV) is a simple measure of relative event dispersion, which measures variability in test results in relation to the mean values. It can be obtained by dividing the standard deviation of the population by the average of the population; therefore, the lower the COV, the lower variability of the test results. For G_f (IDT), mixture D3L1 showed the greatest variability (19%), while D3L4 showed the least variability (4%). The D1L1 mixture had the highest COV for FI (IDT) (43%), while D3L4 showed the lowest COV (3%). For CRI (IDT) and IDT strength, their variability was less than 20%. The average COV values were 11% for G_f (IDT), 20% for FI (IDT), 9% for CRI (IDT), and 8% for IDT strength.

Table 4.1. IDT Test performance indices for all projects

Project ID	**G_f (IDT) (J/m^2)**		**FI (IDT)**		**CRI Index (IDT)**		**IDT strength (kPa)**	
	Average	COV	Average	COV	Average	COV	Average	COV
D1L1	7277	14%	22	43%	579	10%	1024	4%
D2L1	9343	5%	21	1%	619	4%	1226	0%
D3L1	5672	19%	10	17%	436	14%	1066	6%
D3L2	7065	5%	25	11%	664	9%	882	8%
D3L3	7323	10%	17	23%	561	9%	1088	8%
D3L4	6352	4%	13	3%	515	4%	1040	2%
D3L5	5254	18%	12	25%	459	10%	931	19%
D5L1	6574	8%	27	19%	654	9%	835	4%
D6L1	10239	13%	31	37%	717	15%	1200	1%
70-4.25%	5684	9%	18	23%	574	11%	833	9%
70-5%	6946	11%	29	31%	726	17%	813	7%
70-5.75%	9133	9%	49	10%	886	3%	873	6%
58-4.25%	3557	16%	20	11%	569	6%	518	12%
58-5%	4872	12%	36	19%	827	13%	512	19%
58-5.75%	4893	13%	53	21%	929	6%	450	17%

Table 4.2 presents the values for all SCB-FI test performance indices, including G_f (15 mm), FI (15 mm), and CRI (15 mm) along with their coefficients of variation. For FI (15 mm), D2L1 showed higher variability (47%), while 70-5.75% LMLC had the least (19%). For CRI (15 mm), D5L1 exhibited the greatest variation (22%), while D3L3 and D3L5 had the least (5%). For fracture energy (G_f [IDT]), 70-4.5% LMLC had the greatest variability (32%), while 58-5.75% LMLC had the lowest (5%). The average COV values were 14% for G_f (15 mm), 26% for FI (15 mm), and 11% for CRI (15 mm).

Table 4.2. SCB-IFIT Test performance indices for all projects

Project ID	**G_f (15 mm) (J/m^2)**			**FI (15 mm)**		**CRI Index (15 mm)**
	Average	COV	Average	COV	Average	COV
D1L1	2030	11%	5	25%	571	6%
D2L1	2300	7%	2	47%	389	13%
D3L1	1405	9%	3	22%	391	8%
D3L2	2040	8%	6	28%	587	14%
D3L3	2005	6%	6	15%	587	5%
D3L4	2277	15%	4	22%	519	9%
D3L5	1594	15%	2	20%	384	5%
D5L1	2063	16%	7	44%	619	22%
D6L1	2706	8%	5	32%	602	13%
70-4.25%	1970	32%	4	21%	513	13%
70-5%	1587	20%	5	24%	563	12%
70-5.75%	1822	13%	13	19%	805	8%
58-4.25%	1090	28%	11	41%	642	24%
58-5%	1297	16%	12	24%	765	9%
58-5.75%	1578	5%	17	10%	972	8%

Table 4.3 presents SCB-J_c test performance indices, including G_f and CRI at various notch depths (25.4 mm, 31.8 mm, and 38.4 mm) and J_c along with coefficients of variation. For notch depth of 25.4 mm, 70-4.25% LMLC showed the most variability (38%) for fracture energy, while D3L2 showed the least (1%). For CRI, 40-5.75 % LMLC showed the most variability (15%), while D3L4 and 70-5% LMLC do not show any variability at all. For notch

depth of 31.8 mm, D2L1 had the most variability (35%) for fracture energy, while D3L5 had the least (6%). For CRI, 70-5% LMLC showed the most variability (30%), while D3L4 showed 1% variability. For notch depth of 38 mm, 70-5% showed the most variability (45%) for fracture energy, while 70-4.25% showed the least (5%). For CRI, 58-5% LMLC showed the most variability (18%), while 70-4.25% LMLC showed 5% variability. The R^2 for J_c was 1.00 for D1L1, while it was only 0.77 for D3L1. The average COV values were 13% for G_f (25.4mm), 6% for CRI (25.4mm), 19% for Gf (31.8 mm), 11% for CRI (31.8 mm), 19% G_f (38.4 mm), and 10% for CRI (38.4 mm).

Table 4.3. SCB-J_c Test performance indices for all projects

Project ID	**G_f (25.4 mm) (J/m2)**		**CRI Index (25.4 mm)**		**G_f (31.8 mm) (J/m2)**		**CRI Index (31.8 mm)**		**G_f (38.4 mm) (J/m2)**		**CRI Index (38.4 mm)**		**J_c**	**R^2**
	Avg.	COV	Avg.	COV	Avg.	COV	Avg.	COV	Avg.	COV	Avg.	COV		
D1L1	645	4%	739	4%	597	25%	834	8%	554	7%	989	9%	0.46	1.0
D2L1	835	5%	494	7%	585	35%	803	18%	675	12%	650	6%	0.50	0.83
D3L1	109	2%	172	2%	52	21%	348	14%	78	44%	281	10%	0.10	0.77
D3L2	673	1%	604	8%	490	14%	474	9%	358	4%	555	17%	0.83	0.96
D3L3	526	2%	447	3%	363	15%	409	11%	354	1%	735	6%	0.37	0.99
D3L4	838	6%	597	0%	713	15%	705	1%	368	19%	786	8%	0.58	0.85
D3L5	520	7%	456	10%	302	6%	565	20%	239	25%	509	7%	0.57	0.77
D5L1	623	27%	557	9%	430	30%	550	2%	450	25%	746	7%	0.48	0.73
D6L1	1189	3%	860	6%	841	11%	825	2%	642	9%	986	10%	0.98	1.0
70-4.25%	358	38%	518	9%	315	22%	677	13%	277	7%	758	5%	0.48	0.97
70-5%	299	8%	607	0%	269	15%	500	30%	159	45%	689	15%	0.33	0.99
70-5.75%	370	19%	756	15%	286	13%	767	5%	323	26%	976	10%	0.18	0.84
58-4.25%	289	16%	530	3%	133	26%	528	10%	127	20%	660	13%	0.36	0.86
58-5%	218	13%	598	3%	157	25%	451	14%	112	16%	818	18%	0.26	1.0
58-5.75%	227	36%	565	2%	200	11%	752	2%	190	31%	888	8%	0.19	1.0

Figure 4.25 shows a comparative analysis of the COV for the various cracking indices evaluated in this study. The results demonstrate that CRI (15 mm) has a lower COV compared to FI (15 mm) when both values are calculated from the SCB-FI test. The FI (15 mm) value

calculated from the SCB-FI test had the highest COV (26%) compared to all other indices, while the CRI index of the 25.4 mm notch depth calculated from the SCB-J_c test had the lowest COV (6%). The results demonstrate that the variability in FI values is significantly higher than the variability of the CRI values calculated from both the IDT and SCB FI tests. These findings are in agreement with a similar study by Kaseer et al (2018), where they found that CRI (15 mm) to have lower variability in the test results compared to FI (15 mm). In this study, both of these performance indices (FI and CRI) were able to show good potential to capture cracking behavior. However, CRI may be a better index due to the low variability in the test results.

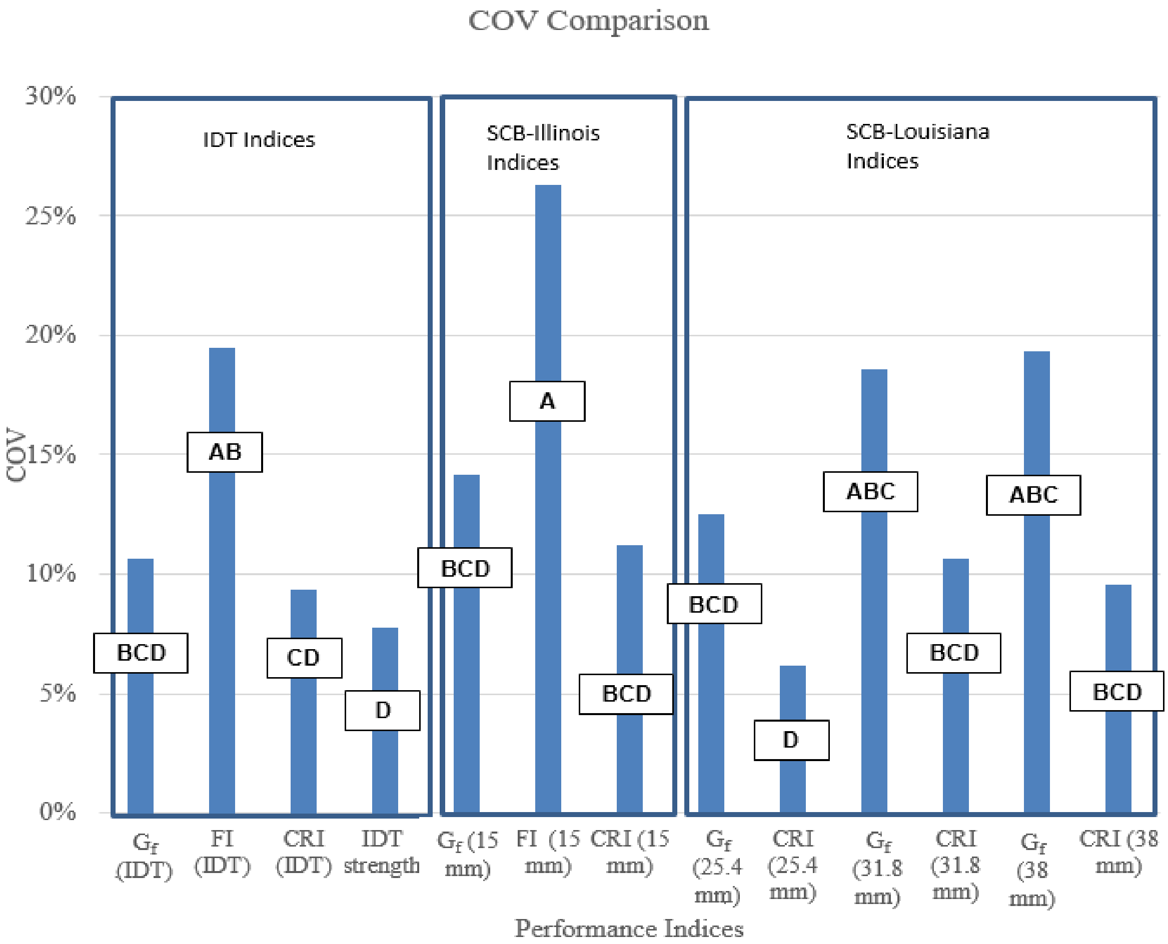

Figure 4.25 COV comparison of performance indices

4.6 Ranking of Mixtures using Various Cracking Parameters

The LMLC and PLMC mixtures were ranked from the best to the worst in terms of their resistance to cracking. Mixtures were ranked from 1 to 15 as presented in Table 4.4. The mixture ranked as 1 indicates the most cracking resistance, while mixture ranked 15 indicates the least resistance to cracking. Statistical analyses were performed to evaluate and assess the correlation between various cracking indices in terms of this ranking. The Pearson correlation coefficient (r) was calculated for each pair of indices. This tool measures the linear correlation between each pair of indices. The Pearson correlation coefficient (r) is represented mathematically in Equation 4.1 and ranges in value between -1 to +1. The sign relates to the type of relationship. A positive correlation coefficient indicates a direct (increasing) relationship, while a negative coefficient indicates an inverse (decreasing) relationship (Benesty et al., 2009). The coefficient magnitude expresses the relationship strength; the lower the magnitude, the weaker the relationship. The correlation tool in the Microsoft Excel software was used to obtain the Pearson correlation coefficients. The correlation coefficient matrix produced by the software is presented in Table 4.5.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2])}} \qquad 4.1$$

where

x and y are correlation variables (performance indices)

n is number of mixtures

Table 4.4 presents the mixture ranking from the best (rank 1) to worst (rank 15) in terms the resistance to cracking. It can be seen that LMLC project 58-34_5.75% is ranked higher in terms of CRI and FI calculated from both IDT and SCB-FI tests. Overall, PMLC project D6L1 ranked consistently better for all the indices, whereas D3L1 is consistently ranked the least for the majority of indices. This observation is in agreement with the previous test results from IDT, SCB-FI and SCB-J_c.

Table 4.4. The mixture ranking based on performance indices

Project ID	**G_f (25.4 mm)**	**CRI (25.4 mm)**	**G_f (31.8 mm)**	**CRI (31.8 mm)**	**G_f (38.4 mm)**	**CRI (38.4 mm)**	**J_c**	**G_f (IDT)**	**FI (IDT)**	**CRI Index (IDT)**	**IDT strength**	**G_f (15 mm)**	**FI (15 mm)**	**CRI (15 mm)**
D1L1	5	3	3	2	3	1	8	5	8	9	6	6	10	9
D2L1	3	12	4	4	1	12	5	2	9	8	1	2	14	14
D3L1	15	15	15	15	15	15	15	11	15	15	4	13	13	13
D3L2	4	5	5	12	6	13	2	6	7	6	8	5	7	7
D3L3	7	14	7	14	7	9	9	4	12	12	3	7	6	8
D3L4	2	7	2	7	5	6	3	9	13	13	5	3	11	11
D3L5	8	13	9	9	10	14	4	12	14	14	7	10	15	15
D5L1	6	9	6	10	4	8	7	8	6	7	10	4	5	5
D6L1	1	1	1	3	2	2	1	1	4	5	2	1	9	6
70-4.25%	10	11	8	8	9	7	6	10	11	10	11	8	12	12
70-5%	11	4	11	1	12	10	11	7	5	4	12	11	8	10
70-5.75%	9	2	10	5	8	3	14	3	2	2	9	9	2	2
58-4.25%	12	10	14	11	13	11	10	15	10	11	13	15	4	4
58-5%	14	6	13	13	14	5	12	14	3	3	14	14	3	3
58-5.75%	13	8	12	6	11	4	13	13	1	1	15	12	1	1

Rank: 1 (best) to 15 (worst)

Table 4.5 presents the correlation between each pair of test indices used in this study. Various transportation agencies use different indices to evaluate the cracking resistance as discussed in Chapter 2, and there is a need to examine the correlation between these indices. For example, there is a need to examine if FI and J_c rank the mixtures in a similar order from the best to worst in terms of cracking resistance. The following findings can be summarized from the results presented in Table 4.5.

- There is a moderately strong correlation between G_f (IDT) and IDT strength ($r = 0.69$) calculated from IDT test.

- There is a moderately strong correlation between G_f (IDT) calculated from IDT test and G_f (15 mm) calculated from SCB-FI test (r = 0.77).
- There is a poor correlation between G_f (IDT) calculated from IDT test and J_c (r = 0.36).
- There is a strong correlation (r = 0.99) between FI (IDT) and CRI (IDT) calculated from IDT test.
- There are fair correlations between FI (IDT) calculated from IDT test and FI (15 mm) and CRI (15 mm) calculated from SCB-FI test (r = 0.74 and 0.79, respectively).
- There are opposite correlations between IDT strength calculated from IDT test and FI (15 mm) and CRI (15 mm) calculated from SCB-FI test (r = -0.63 and -0.57, respectively).
- The fracture energy G_f (15 mm) calculated from the SCB-FI test had a fair correlation with J_c (r = 0.76).
- The FI (15 mm) and CRI (15 mm) calculated from SCB-FI test had a strong correlation (r = 0.97).
- The FI (15 mm) calculated from the SCB-FI test had a poor and opposite correlation with J_c (r =-0.48).
- The fracture energy at 31.8 mm notch depth, G_f (31.8 mm) calculated from the SCB-J_c test had fair correlation with J_c (r = 0.81).

Table 4.5 shows the correlation based on mixture ranking between various cracking parameters. The result showed that there is good correlations between some indices such as FI and CRI; however, other indices such as FI and J_c did not correlate. This observation is in agreement with a recent NCAT report (West et al. 2018), where a negative correlation of 0.64 between SCB-J_c and FI from the SCB test is reported. It is interesting to observe such acorrelation between FI and J_c since these indices are both proposed to evaluate the resistance of asphalt mixtures to cracking (Al Qadi et. al 2015, LDOTD TR – 330-14). Higher values for these indices indicate good resistance to cracking. Based on the results of this section, one should be careful when using such indices without field performance evaluation. It is important to monitor cracking performance in the field and correlate the results to various indices evaluated in Table 4.4 to identify the ones that provide good correlation with the field.

Table 4.5. Correlation between various cracking parameters

Perf. Indices	**G_f (25.4 mm)**	**CRI (25.4 mm)**	**G_f (31.8 mm)**	**CRI (31.8 mm)**	**G_f (38.4 mm)**	**CRI (38.4 mm)**	**J_c**	**G_f (IDT)**	**FI (IDT)**	**CRI (IDT)**	**IDT strength**	**G_f (15 mm)**	**FI (15 mm)**	**CRI (15 mm)**
G_f (25.4 mm)	1.00													
CRI (25.4 mm)	0.31	1.00												
G_f (31.8 mm)	0.97	0.35	1.00											
CRI (31.8 mm)	0.39	0.61	0.44	1.00										
G_f (38.4 mm)	0.93	0.29	0.94	0.47	1.00									
CRI (38.4 mm)	0.20	0.70	0.34	0.51	0.33	1.00								
J_c	0.84	0.13	0.81	0.19	0.69	-0.04	1.00							
G_f (IDT)	0.71	0.37	0.70	0.47	0.78	0.26	0.36	1.00						
FI (IDT)	-0.07	0.72	-0.04	0.41	0.07	0.61	-0.23	0.16	1.00					
CRI (IDT)	-0.09	0.69	-0.05	0.42	0.05	0.54	-0.23	0.18	0.99	1.00				
IDT Strength	0.66	-0.18	0.61	0.06	0.61	-0.15	0.46	0.69	-0.48	-0.48	1.00			
G_f (15 mm)	0.95	0.24	0.95	0.38	0.95	0.22	0.76	0.77	-0.03	-0.03	0.68	1.00		
FI (15 mm)	-0.33	0.40	-0.34	-0.10	-0.25	0.45	-0.48	-0.17	0.74	0.69	-0.63	-0.35	1.00	
CRI (15 mm)	-0.23	0.51	-0.23	-0.04	-0.14	0.56	-0.37	-0.12	0.79	0.72	-0.57	-0.25	0.97	1.00

4.7 Regression Model for CRI-IDT

The CRI, calculated from both IDT and SCB-FI, was found to have a good correlation with FI. In addition, the CRI was found to have lower variability in the test results compared to FI thus the CRI is recommended as a performance index to evaluate the resistance of asphalt mixtures to cracking over FI. A previous study conducted by Ling et al. (2017) found that aggregate source, binder type, and RAP content to have significant effect on FI. Therefore, they proposed a regression model for FI. Based on the data collected in this study, the author developed a similar regression model for CRI. All test mixtures were considered for the regression analysis as presented in Table 4.6. RAP content and percent binder were considered as numerical variables, while binder grade and mix gradation were considered as categorical variables. SP3 mixtures were assigned “0” as categorical value while SP5 mixtures were assigned “1”. Various binder grades were assigned different categorical values (i.e., PG 58-34 as “0”, PG 64-28 as “1”, PG 64-34 as “2”, PG 70-28 as “3” and PG 76-28 as “4”). Table 4.6 summarizes all project information along with the designated category.

A prediction model can be developed through regression analysis for CRI-IDT as presented in Equation 4.2.

$$\text{CRI-IDT} = -325 - 5.96\,\text{RAP} + 219.9\,\text{Binder Content} + 0.0\,\text{BG1\_0} - 143.6\,\text{BG1\_1} - 250.3\,\text{BG1\_2} - 44.9\,\text{BG1\_3} - 306.7\,\text{BG1\_4} + 0.0\,\text{MIX1\_0} + 104.3\,\text{MIX1\_1} \tag{4.2}$$

where,

BG1_0= PG 58-34

BG1_1= PG 64-28

BG1_2= PG 64-34

BG1_3= PG 70-28

BG1_4= PG 76-28

MIX1_0= SP3

MIX1_1= SP5

Table 4.7 presents the Analysis of Variance (ANOVA) outputs of the regression analysis. The results show that RAP content and percent binder to have significant effect on the CRI-IDT as they both have low p-value than 0.05. The effect of binder grade and mix type was found to be insignificant. Therefore the prediction model was modified as presented in Equation 4.3. The R^2 of the model is 0.72.

$$\text{CRI-IDT} = -180 - 6.16\ \text{RAP} + 182.4\ \text{Binder Content} \qquad 4.3$$

The CRI-IDT regression model shows that the CRI decreases with the increase of RAP content and increases with binder content. Increasing the RAP content causes the mixture to be less flexible resulting in lower resistance to cracking which is in good agreement with previous studies (Huang et al. 2010, Mogawer et al. 2012). On the other hand, increasing the binder content improves the resistance of asphalt mixtures to cracking as found by other researchers (Roque et al. 2005). The CRI-IDT model can be used during the mix design to ensure that a given asphalt mixture have adequate resistance to cracking (i.e., higher CRI). However, it is recommended to validate the model using additional data.

Table 4.6 Explanatory and categorical values for CRI-IDT

Projects	**Response Variable**	**Explanatory Variable**		**Categorical Variable**		**Categorical Values**	
	CRI (IDT)	RAP	Binder Content	Binder Grade	Mix Type	BG1	MIX1
D1L1	579	30.00	5.3	64-28	SP-5	1	1
D2L1	619	50.00	5.7	70-28	SP-3	3	0
D3L1	436	50.00	5.2	70-28	SP-3	3	0
D3L2	664	30.00	5.2	70-28	SP-3	3	0
D3L3	561	30.00	5.3	64-28	SP-3	1	0
D3L4	515	30.00	5.3	70-28	SP-3	3	0
D3L5	459	30.00	5.3	76-28	SP-5	4	1
D5L1	654	30.00	4.8	70-28	SP-5	3	1
D6L1	717	0.00	5.4	64-34	SP-5	2	1
70-28_4.25%	574	0.00	4.25	70-28	SP-3	3	0
70-28_5%	726	0.00	5	70-28	SP-3	3	0
70-28_5.75%	886	0.00	5.75	70-28	SP-3	3	0
58-34_4.25%	569	0.00	4.25	58-34	SP-3	0	0
58-34_5%	827	0.00	5	58-34	SP-3	0	0
58-34_5.75%	929	0.00	5.75	58-34	SP-3	0	0

Table 4.7 Analysis of Variance (ANOVA) from regression analysis

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	7	273626	39089	9.74	0.004
RAP	1	102637	102637	25.56	0.001
Binder Content	1	118406	118406	29.49	0.001
BG1	4	51795	12949	3.23	0.084
MIX1	1	14151	14151	3.52	0.103
Error	7	28106	4015		
Total	14	301731			

CHAPTER 5

RUTTING PERFORMANCE AND ANALYSIS

5.1 Introduction

Chapter 5 discusses the results of APA and Hamburg test results for both LMLC and PMLC mixtures. These tests are used to evaluate the resistance of asphalt mixtures to rutting. In addition the Hamburg test can be used to evaluate the resistance of asphalt mixtures to moisture damage. Statistical analysis was performed to observe how the mixture characteristics affect the rut depth.

5.2 Asphalt Pavement Analyzer

As described in Chapter 3, the APA Jr. was used to measure the rutting resistance of the LMLC and PMLC test specimens. In this study, the rutting depth was measured for each test specimen using both the APA and Hamburg tests. Figure 5.1 shows the rutting depth after 8,000 passes for the LMLC test specimens. If binder content is increased, the specimen becomes softer, thus it shows less resistance to permanent deformation or rutting. This trend was observed for specimens prepared by PG 70-28 and PG 58-34 binders. It should be noted that the test temperature for PG 70-28 specimens was 70°C, while it was 58°C for the PG 58-34 specimens as specified by AASHTO T 340. This explains the reason that soft binder (PG 58-34) has relatively less rutting compared to stiff binder (PG 70-28) at the corresponding binder content. The result showed that there is a significant difference in the rutting results between PG 70-28 and PG 58-34 at the corresponding binder content. Also, there was a significant difference between mixtures prepared with 5.75% binder content compared to mixtures prepared with 4.25% binder content for both binder grades (PG 70-28 and PG 58-34). The APA rut depths were well below the threshold criteria of 7 to 8 mm proposed by Choubane et al. (2000) and 5 mm set by ITD (ITD standard specifications 2017).

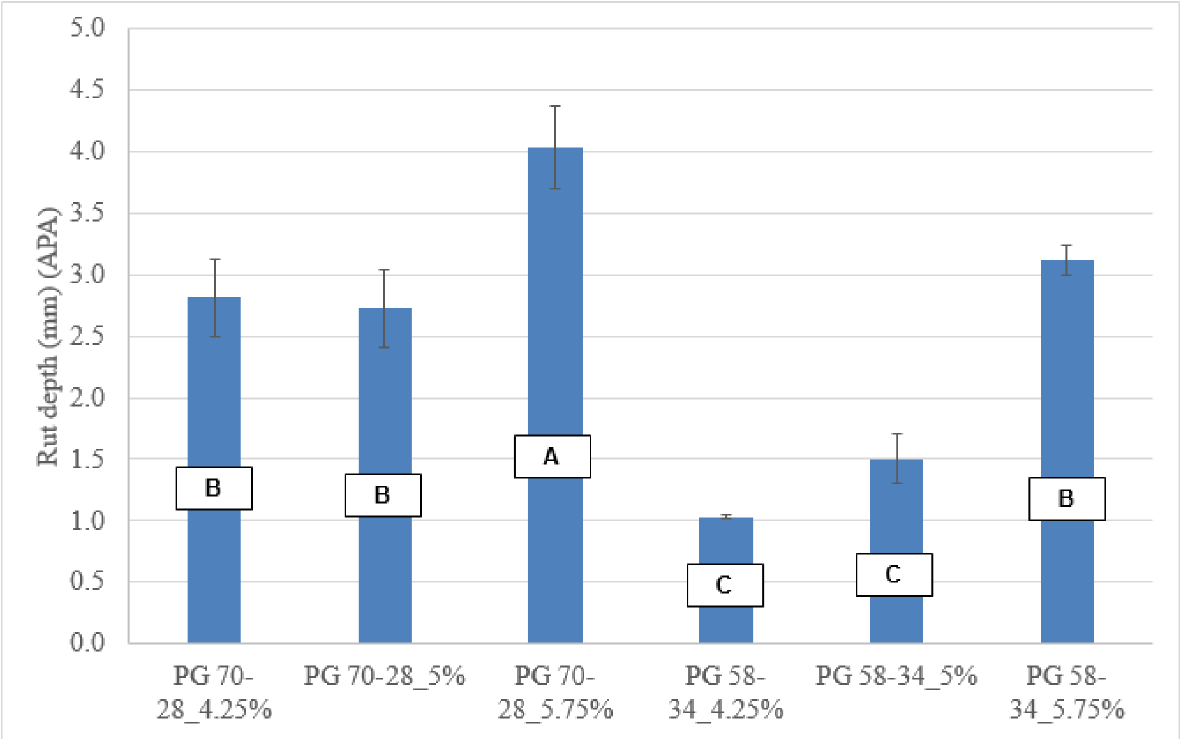

Figure 5.1 The rut depth for LMLC measured using APA Jr

Figure 5.2 shows the APA Jr rut depth after 8,000 passes for the PMLC test specimens. All the nine mixtures passed the failure criterion (5 mm after 8000 cycles). As discussed in Chapter 3 and shown in Figure 5.2, the mixtures PMLC are SP3 and SP5 that incorporate various percentages of RAP in almost all of them. The results in Figure 5.2 show that D1L1 and D3L5 mixtures had low rut depth (better resistance to rutting) while (D3L3) had a high rut depth (less resistance to rutting). Both of D1L1 and D3L5 are SP5 mixtures. The SP5 mixture is used where higher traffic is expected, which is why D1L1 and D3L5 exhibited lower rut depths. The result also showed that, D3L3 exhibited significantly more rut depth than D1L1 and D3L5. The rut depths for different PMLC also comply with the threshold criteria of 7 to 8 mm proposed by Choubane et al. (2000) and 5 mm of rut depth set by ITD (ITD standard specifications 2017). Also, different amounts of RAP proportions did not show significant differences in rut depth (i.e., D6L1 and D3L1), which also agrees with a previous study by Kim et al. (2009).

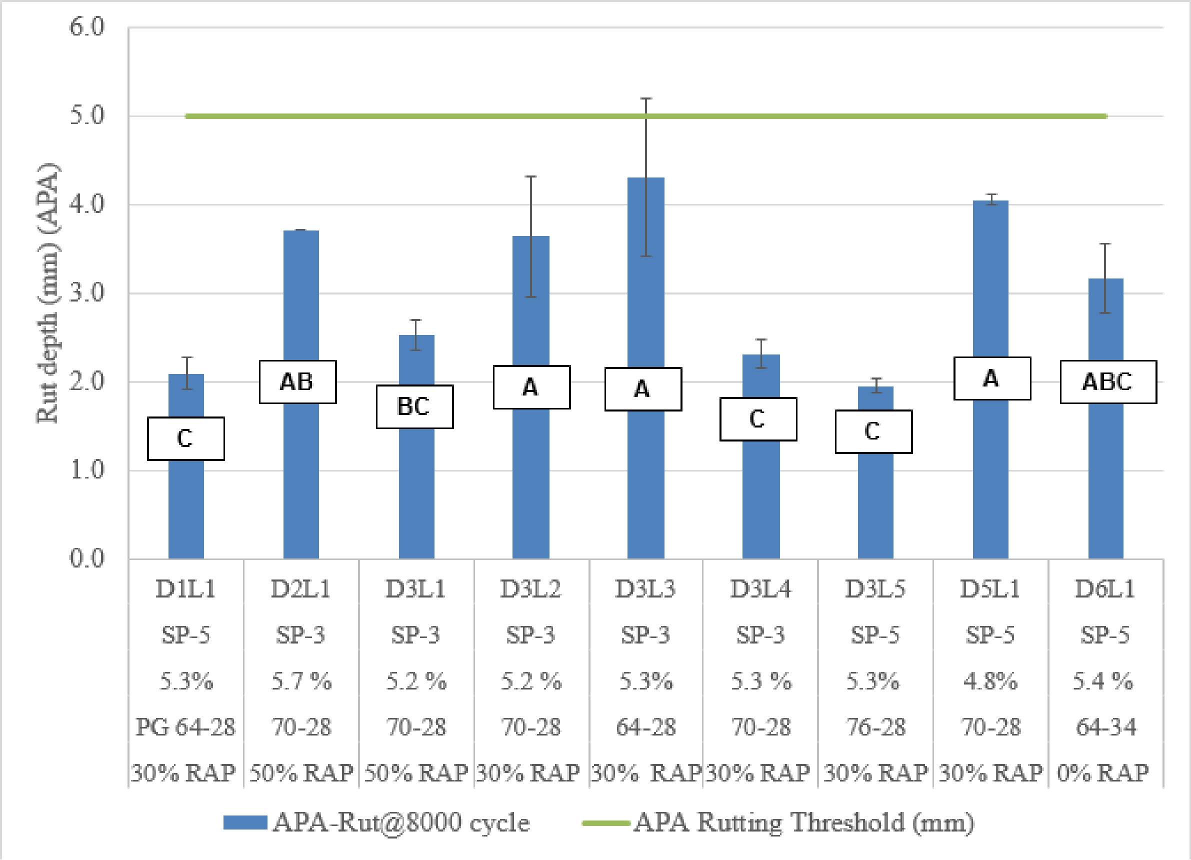

Figure 5.2 The rut depth for PMLC measured using APA Jr

5.3 Hamburg Wheel Tracking Test (HWTT)

In the Hamburg test, the rutting is measured at 20,000 cycles. Figure 5.3 shows the HWTT rut depth after 20,000 passes for the LMLC test specimens. The results are in agreement with the APA data. Figure 5.3 shows that the rutting resistance significantly decreases as the binder content increases from 4.25% to 5.75% for both binder types (PG 70-28 and PG 58-34). Since the test temperature is fixed in the HWTT test (55^{o}C), the PG 70- 28 test samples had less rutting compared to the test samples prepared using PG 58-34 binder at the corresponding binder content. The PG 70-28 binder is stiffer than the PG 58-34 binder, thus less rutting was expected and observed. The results showed that the binder grade has a significant effect at the 95% confidence interval on the rutting results at the corresponding binder content except at 4.25%. Also, the binder content had a significant effect on the rutting for PG 58-34 and PG 70-28 except at 5% binder content. As ITD does not have a threshold for rut depth from the Hamburg test, all the lab projects passed the threshold criteria of 12.5 mm set by TxDOT (2004), 10 mm set by LADOT (2016) and 13 mm set by MTDOT (2014).

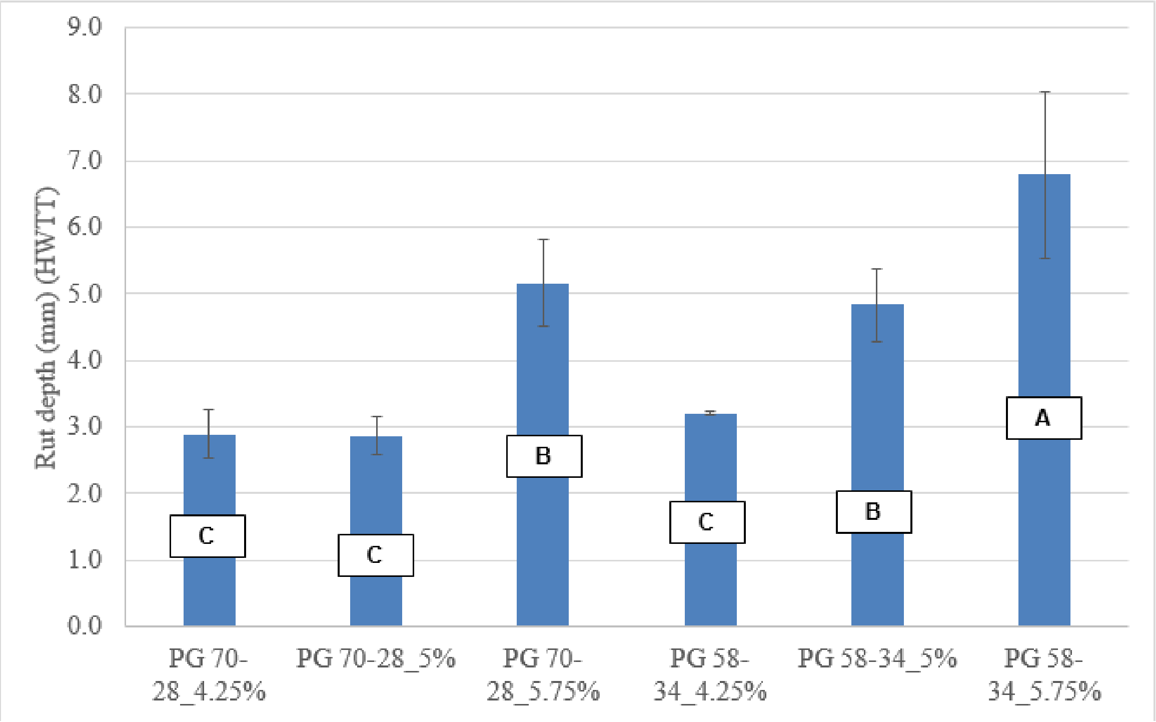

Figure 5.3 The rut depth for LMLC measured using HWTT

Figure 5.4 shows the HWTT rut depth after 20,000 passes for the PMLC test specimens. All the nine mixtures passed the failure criterion (12.5 mm after 20,000 cycles). Overall, the results demonstrate that these mixtures should not develop rutting in the field subject to proper field construction and compaction. The D2L1 mixture showed better resistance to rutting in terms of HWTT test results, whereas D3L3 mixture showed the least resistance, which is consistent with the APA test results. The D2L1 mixture had 50% RAP while, D3L3 had 30% RAP. In addition, the D2L1 mixture use stiffer binder compared to D3L3. The statistical analysis demonstrated that there is a significant difference in the rutting results. The rutting for both D2L1 and D3L3 is significantly different. The reason is explained due to the combined effect of RAP content and binder grade. For PMLC, all the projects passed the threshold criteria of 12.5 mm set by TxDOT (2004), 10 mm set by LADOT (2016) and 13 mm set by MTDOT (2014).

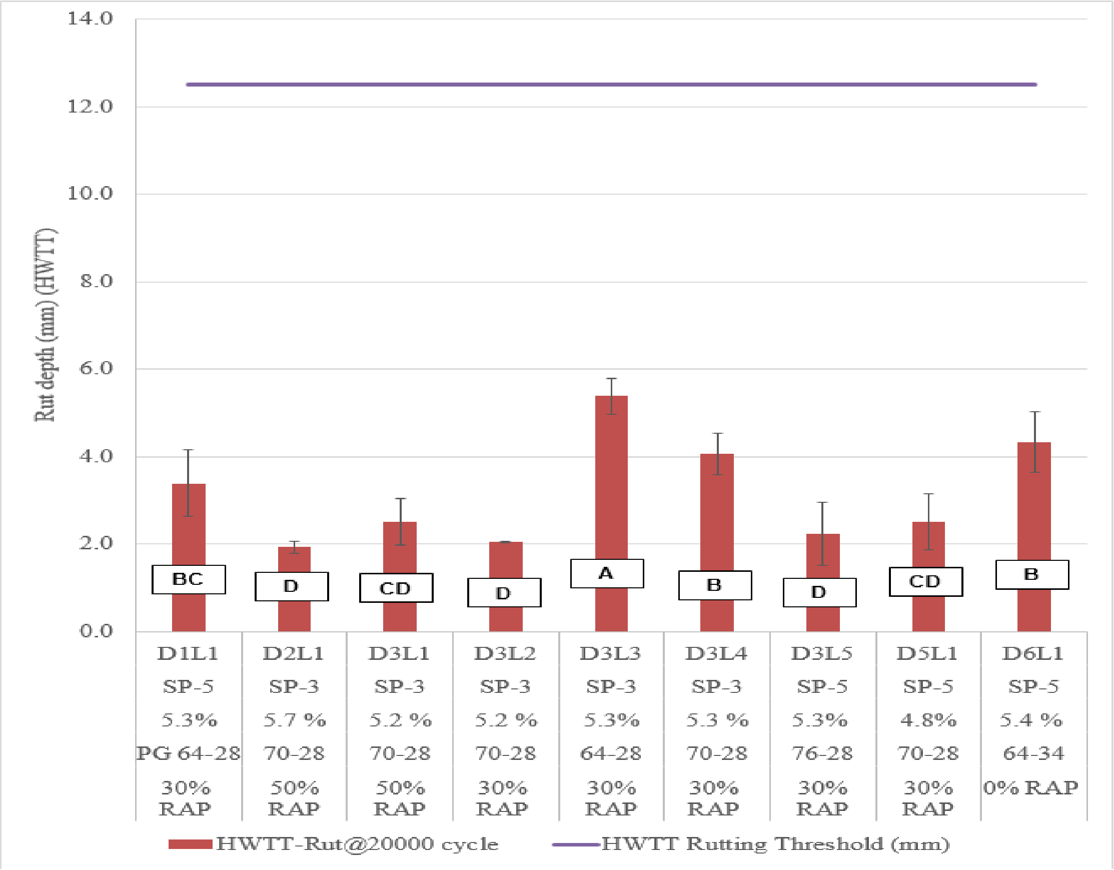

Figure 5.4 The rut depth for PMLC measured using HWTT

The following observations can be summarized from Figures 5.2 and 5.4.

- SP3 mixtures exhibit more rut depth compared to SP-5 (e.g., D1L1 and D3L3). These two mixtures (D1L1 and D3L3) have the same mix properties (binder grade, binder content, percent RAP content) while they have different gradations.
- A higher percentage of RAP tends to improve the resistance of asphalt mixtures to rutting (e.g., D6L1 compared to D1L1), but the difference is not significant. In some cases the RAP proportions showed significant changes in rut depth (D6L1 and D3L1). This observation is similar to the findings by Rahman and Hossain (2014), where they

experimented o observe the effect of RAP on superpave mixes and found that the effect of RAP is significant.

- Stiffer binder grade exhibited higher resistance to rutting compared to softer binders. For example, D3L5, prepared using PG 76-28, had less rutting compared to D1L1 which is prepared using PG 64-28. Yildrim et al. (2007) found similar results of having high resistance with stiffer binder grades when they evaluated the rutting performance for asphalt binders: PG 64-22, PG 70-22 and PG 76-22.

5.4 Moisture Damage Analysis

Moisture damage is the loss of adhesion between asphalt binder and aggregates in HMA. The adhesion between the asphalt and aggregate gets reduced due to water/moisture infiltration between asphalt binder and aggregates resulting in binder stripping from aggregates leading to mixture deterioration (Copeland, 2007). Many test methods such as boiling test, static immersion test, Lottman test, modified Lottman test, immersion compression test, Hamburg wheel-tracking device, are used to evaluate the moisture damage. The HWTT was used to evaluate the moisture susceptibility of test asphalt mixtures. Hamburg test results did not show any indication of moisture damage for the PMLC mixtures, which is in a good agreement with the immersion compression test conducted by Idaho Transportation Department (ITD) as shown in Figure 5.5. In the immersion compression test, the index of retained strength is used to assess the moisture damage and reflects the ratio of compressive strength of test specimens under dry and water-immerged conditions. The dry samples are stored at 25±1°C for 4 hours, while the wet specimens are immersed in water for 24 hours at 60±1°C and stored for 2 hours.

The index is calculated using Equation 5.1. Detailed test procedures are described in ASTM designation D1075 - 11 (ASTM 2001). A retained strength of 85% is selected as a pass criteria as per ITD standard specifications.

$$\text{Index of retained strength (\%)} = (S2/S1) \times 100 \qquad \text{Eq 5.1}$$

where,

S1 = compressive strength of dry specimens,

S2 = compressive strength of immersed specimens.

Figure 5.5 shows that all the nine PMLC mixtures passed the threshold criterion for an index of retained strength as well as HWTT. Project D3L4 marginally passed the threshold criterion (84%), whereas D3L3 showed the highest retained strength (98%). All of the rut values were well below the HWTT threshold of 12.5 mm. It should be noted that all the loose mixes provide by ITD has 0.5% antistrip agent as provided by ITD. The use of antistrip agents improves the resistance of asphalt mixtures to moisture damage as it enhances the adhesion between asphalt binder and aggregates making it difficult for the moisture to strip the binder away from the aggregates. Yin et al. (2014) has reported that the use of antistrip agents improves the resistance of asphalt mixtures to moisture susceptibility. Based on the results of this sudy, it is recommended that ITD continue to use antistrip agents in their asphalt mixtures.

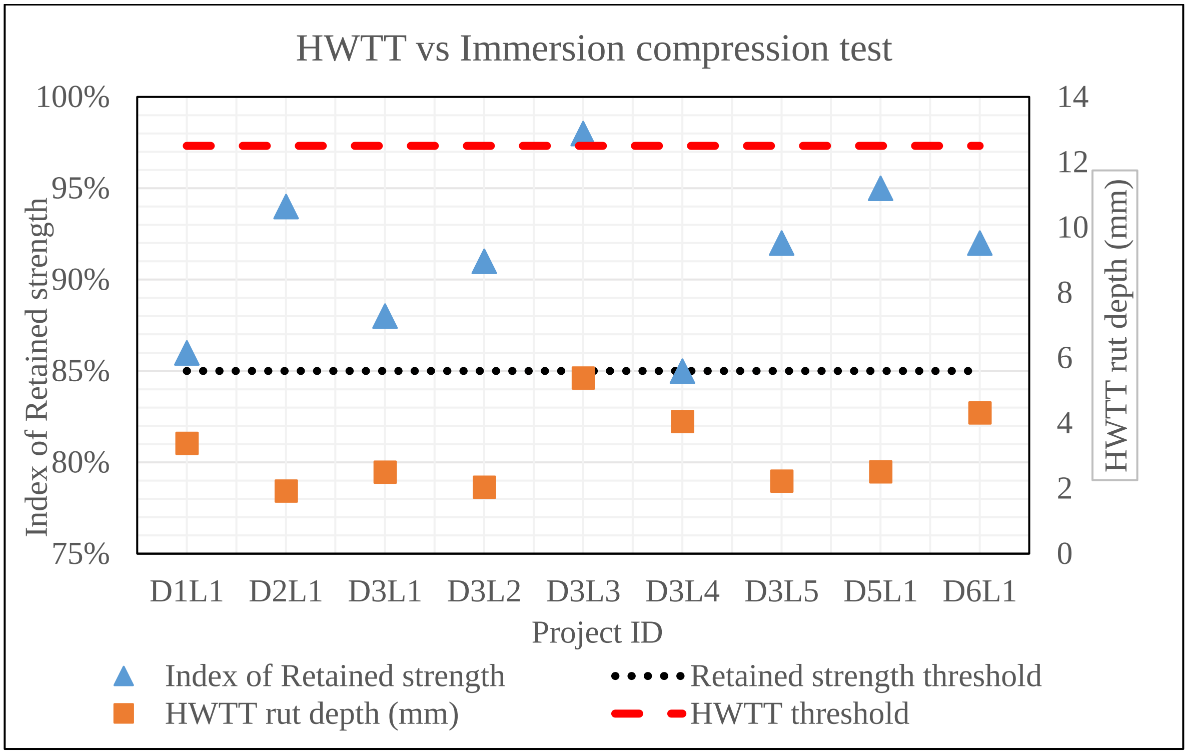

Figure 5.5 Comparison between HWTT Rut depth and Index Retained Streng

CHAPTER 6

CONCLUSIONS

This study conducted three monotonic tests to evaluate the resistance of asphalt mixtures to cracking: indirect tensile test (IDT), semicircular bending flexibility index test (SCB-FI), and semicircular bending critical strain energy test (SCB-J_c). Several parameters were calculated from these tests including FI, CRI, IDT strength, G_f, and J_c. All of the tests were conducted on laboratory-prepared asphalt mixtures as well as field cores. The IDT test was found to be simpler to conduct compared to the SCB-FI and SCB-J_c tests, since it does not require special sample preparation (e.g., cutting the test samples and creating a notch). Also, the SCB-FI was found to be faster compared to the SCB- J_c test since the former requires one notch depth while the latter requires three different notch depths.

For the LMLC test specimens, the binder grade was found to have a significant effect on the IDT strength while it did not show such an effect on CRI and FI. On the other hand, the effect of binder content on CRI (calculated from both IDT and SCB-FI tests) was found to be significant when the results of 5.75% are compared to 4.25% test samples. Similarly, the binder content was found to have a significant effect on FI (calculated from IDT) for both binders when the results of 5.75% are compared to 4.25% test samples; however, the binder content didn’t show a significant effect on FI (calculated from SCB-FI test) for both binder grades. These results indicate that CRI can capture the change in the flexibility of asphalt mixtures due to the change in mixture’s composition in more consistent way than FI. The J_c results indicated an opposite trend to FI and CRI with binder content. The J_c decreased with the increase in binder content. Both J_c and FI (calculated from SCB-FI test) are used by various transportation agencies to evaluate the resistance of asphalt mixtures to cracking. Based on the findings of this study, one should be careful when using these indices without laboratory and field correlations for asphalt mixtures.

For PMLC test specimens, and based on the published literature for both FI (calculated from SCB-FI test) and J_c, it is expected that some mixtures produced in Idaho may exhibit cracking in the field. Therefore, it is important to monitor field performance, especially cracking, to examine and establish correlations between various parameters calculated from different laboratory tests. This should be performed before any recommendations on performance thresholds can be made or proposed for asphalt mixtures produced in Idaho.

The CRI showed much lower variability in the test results compared to FI in both IDT and SCB-FI tests. The variation in the post-peak slope values contributed to the high variability in the FI. In addition, CRI had a strong correlation with FI when both used in ranking the test mixtures from the best to worst in terms of crack resistance. Based on the results of this study, CRI is recommended over FI to evaluate the cracking resistance of asphalt mixtures. The regression analysis of CRI-IDT showed that RAP content and percent binder to have significant effect on the CRI-IDT. The effect of binder grade and mix type was found to be insignificant. In addition, the J_c was not correlated with FI. Thus, and as mentioned earlier, there is a pressing need to monitor the cracking performance of asphalt mixtures in the field to select the proper laboratory tests and parameters that show good predictions or ranking compared to field performance.

This study used two methods (APA Jr. and Hamburg) to evaluate the resistance of asphalt mixtures to rutting. Both of these test methods indicated that the current produced asphalt mixtures in Idaho, evaluated in this study, and exhibited good resistance to rutting. The binder content and binder grade were found to have significant effects on rutting when the rutting results of 5.75% are compared to 4.25% test samples. Thus, for the balanced mix design, the effect of binder content on rutting should be performed and be part of the mix design. Furthermore, this study used the Hamburg test to evaluate the moisture susceptibility of the test asphalt mixtures. The results showed that the test mixtures had good resistance to moisture damage and these results are in good agreement with the results from the immersion compression test conducted by ITD. The current practice at ITD is to use anti-strip agents in asphalt mixtures and conduct the immersion compression test to ensure that the produced mixtures have good resistance to moisture damage. Based on the findings of the Hamburg test, it is recommended that ITD to continue their current practice.

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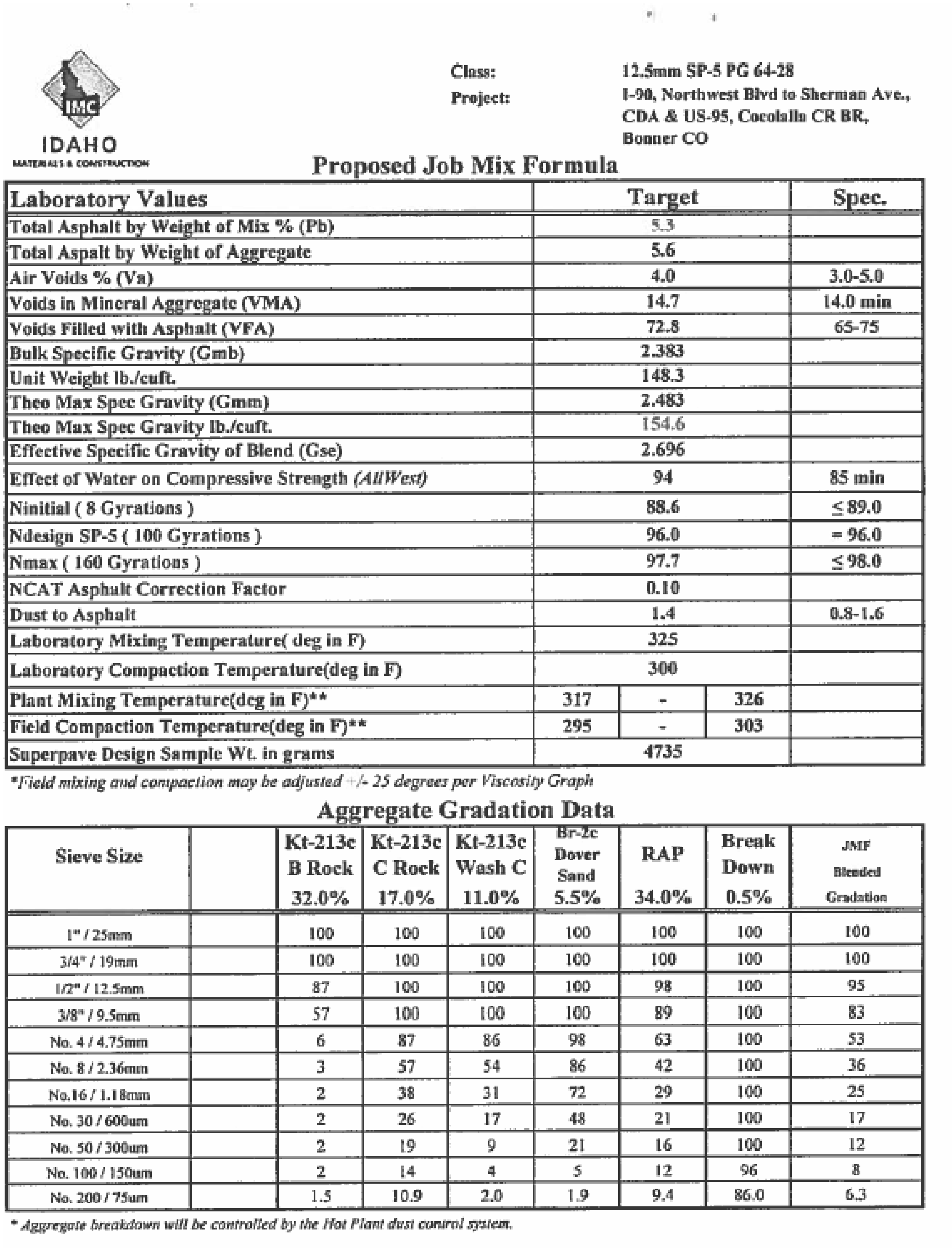
APPENDIX A: JOB MIX FORMULA FOR PMLC

Table A.1 Job mix formula for project D1L1



IDAHO
MATERIALS & CONSTRUCTION

Class: 12.5mm SP-5 PG 64-28
Project: I-90, Northwest Blvd to Sherman Ave., CDA & US-95, Cocolalla CR BR, Bonner CO

Proposed Job Mix Formula

Laboratory Values	Target			Spec.
Total Asphalt by Weight of Mix % (Pb)	5.3			
Total Aspalt by Weight of Aggregate	5.6			
Air Voids % (Va)	4.0			3.0-5.0
Voids in Mineral Aggregate (VMA)	14.7			14.0 min
Voids Filled with Asphalt (VFA)	72.8			65-75
Bulk Specific Gravity (Gmb)	2.383			
Unit Weight lb./cuft.	148.3			
Theo Max Spec Gravity (Gmm)	2.483			
Theo Max Spec Gravity lb./cuft.	154.6			
Effective Specific Gravity of Blend (Gse)	2.696			
Effect of Water on Compressive Strength *(AllWest)*	94			85 min
Ninitial (8 Gyrations)	88.6			≤ 89.0
Ndesign SP-5 (100 Gyrations)	96.0			= 96.0
Nmax (160 Gyrations)	97.7			≤ 98.0
NCAT Asphalt Correction Factor	0.10			
Dust to Asphalt	1.4			0.8-1.6
Laboratory Mixing Temperature(deg in F)	325			
Laboratory Compaction Temperature(deg in F)	300			
Plant Mixing Temperature(deg in F)**	317	-	326	
Field Compaction Temperature(deg in F)**	295	-	303	
Superpave Design Sample Wt. in grams	4735			

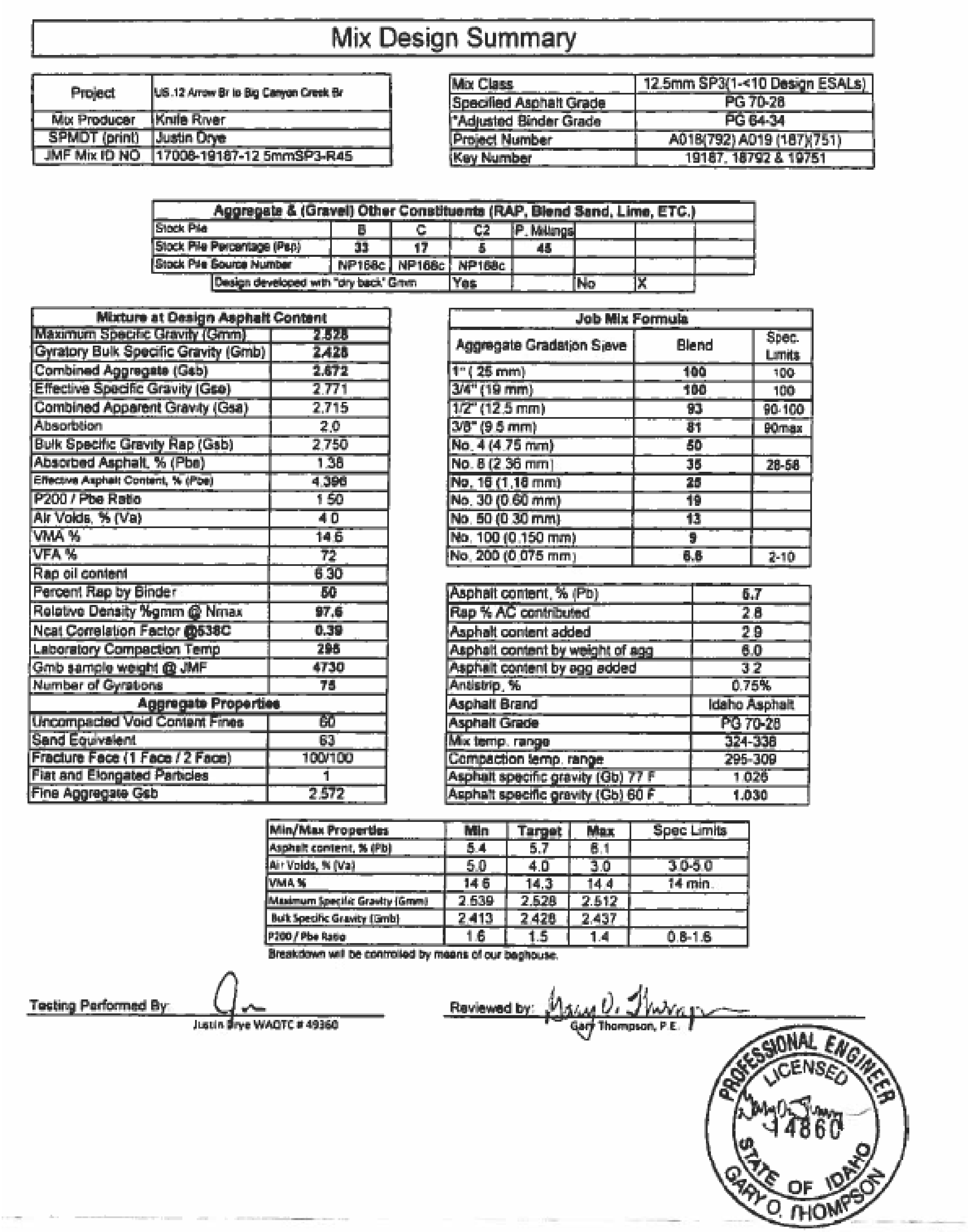
**Field mixing and compaction may be adjusted +/- 25 degrees per Viscosity Graph*

Aggregate Gradation Data

Sieve Size		Kt-213c B Rock 32.0%	Kt-213c C Rock 17.0%	Kt-213c Wash C 11.0%	Br-2c Dover Sand 5.5%	RAP 34.0%	Break Down 0.5%	JMF Blended Gradation
1" / 25mm		100	100	100	100	100	100	100
3/4" / 19mm		100	100	100	100	100	100	100
1/2" / 12.5mm		87	100	100	100	98	100	95
3/8" / 9.5mm		57	100	100	100	89	100	83
No. 4 / 4.75mm		6	87	86	98	63	100	53
No. 8 / 2.36mm		3	57	54	86	42	100	36
No.16 / 1.18mm		2	38	31	72	29	100	25
No. 30 / 600um		2	26	17	48	21	100	17
No. 50 / 300um		2	19	9	21	16	100	12
No. 100 / 150um		2	14	4	5	12	96	8
No. 200 / 75um		1.5	10.9	2.0	1.9	9.4	86.0	6.3

** Aggregate breakdown will be controlled by the Hot Plant dust control system.*

Table A.2. Job mix formula for project D2L1



Mix Design Summary

Project	US.12 Arrow Br to Big Canyon Creek Br
Mix Producer	Knife River
SPMDT (print)	Justin Drye
JMF Mix ID NO	17008-19187-12 5mmSP3-R45

Mix Class	12.5mm SP3(1-<10 Design ESALs)
Specified Asphalt Grade	PG 70-28
*Adjusted Binder Grade	PG 64-34
Project Number	A018(792) A019 (187)(751)
Key Number	19187, 18792 & 19751

Aggregate & (Gravel) Other Constituents (RAP, Blend Sand, Lime, ETC.)							
Stock Pile	B	C	C2	P. Millings			
Stock Pile Percentage (Psp)	33	17	5	45			
Stock Pile Source Number	NP168c	NP168c	NP168c				
Design developed with "dry back" Gmm		Yes		No	X		

Mixture at Design Asphalt Content	
Maximum Specific Gravity (Gmm)	2.528
Gyratory Bulk Specific Gravity (Gmb)	2.428
Combined Aggregate (Gsb)	2.672
Effective Specific Gravity (Gse)	2.771
Combined Apparent Gravity (Gsa)	2.715
Absorbtion	2.0
Bulk Specific Gravity Rap (Gsb)	2.750
Absorbed Asphalt, % (Pba)	1.38
Effective Asphalt Content, % (Pbe)	4.398
P200 / Pbe Ratio	1.50
Air Voids, % (Va)	4.0
VMA %	14.6
VFA %	72
Rap oil content	6.30
Percent Rap by Binder	50
Relative Density %gmm @ Nmax	97.6
Ncat Correlation Factor @538C	0.39
Laboratory Compaction Temp	298
Gmb sample weight @ JMF	4730
Number of Gyrations	75
Aggregate Properties	
Uncompacted Void Content Fines	60
Sand Equivalent	63
Fracture Face (1 Face / 2 Face)	100/100
Flat and Elongated Particles	1
Fine Aggregate Gsb	2.572

Job Mix Formula		
Aggregate Gradation Sieve	Blend	Spec. Limits
1" (25 mm)	100	100
3/4" (19 mm)	100	100
1/2" (12.5 mm)	93	90-100
3/8" (9.5 mm)	81	90max
No. 4 (4.75 mm)	50	
No. 8 (2.36 mm)	36	28-58
No. 16 (1.18 mm)	26	
No. 30 (0.60 mm)	19	
No. 50 (0.30 mm)	13	
No. 100 (0.150 mm)	9	
No. 200 (0.075 mm)	6.8	2-10

Asphalt content, % (Pb)	5.7
Rap % AC contributed	2.8
Asphalt content added	2.9
Asphalt content by weight of agg	6.0
Asphalt content by agg added	3.2
Antistrip, %	0.75%
Asphalt Brand	Idaho Asphalt
Asphalt Grade	PG 70-28
Mix temp. range	324-338
Compaction temp. range	295-309
Asphalt specific gravity (Gb) 77 F	1.026
Asphalt specific gravity (Gb) 60 F	1.030

Min/Max Properties	Min	Target	Max	Spec Limits
Asphalt content, % (Pb)	5.4	5.7	6.1	
Air Voids, % (Va)	5.0	4.0	3.0	3.0-5.0
VMA %	14.6	14.3	14.4	14 min.
Maximum Specific Gravity (Gmm)	2.539	2.528	2.512	
Bulk Specific Gravity (Gmb)	2.413	2.428	2.437	
P200 / Pbe Ratio	1.6	1.5	1.4	0.8-1.6

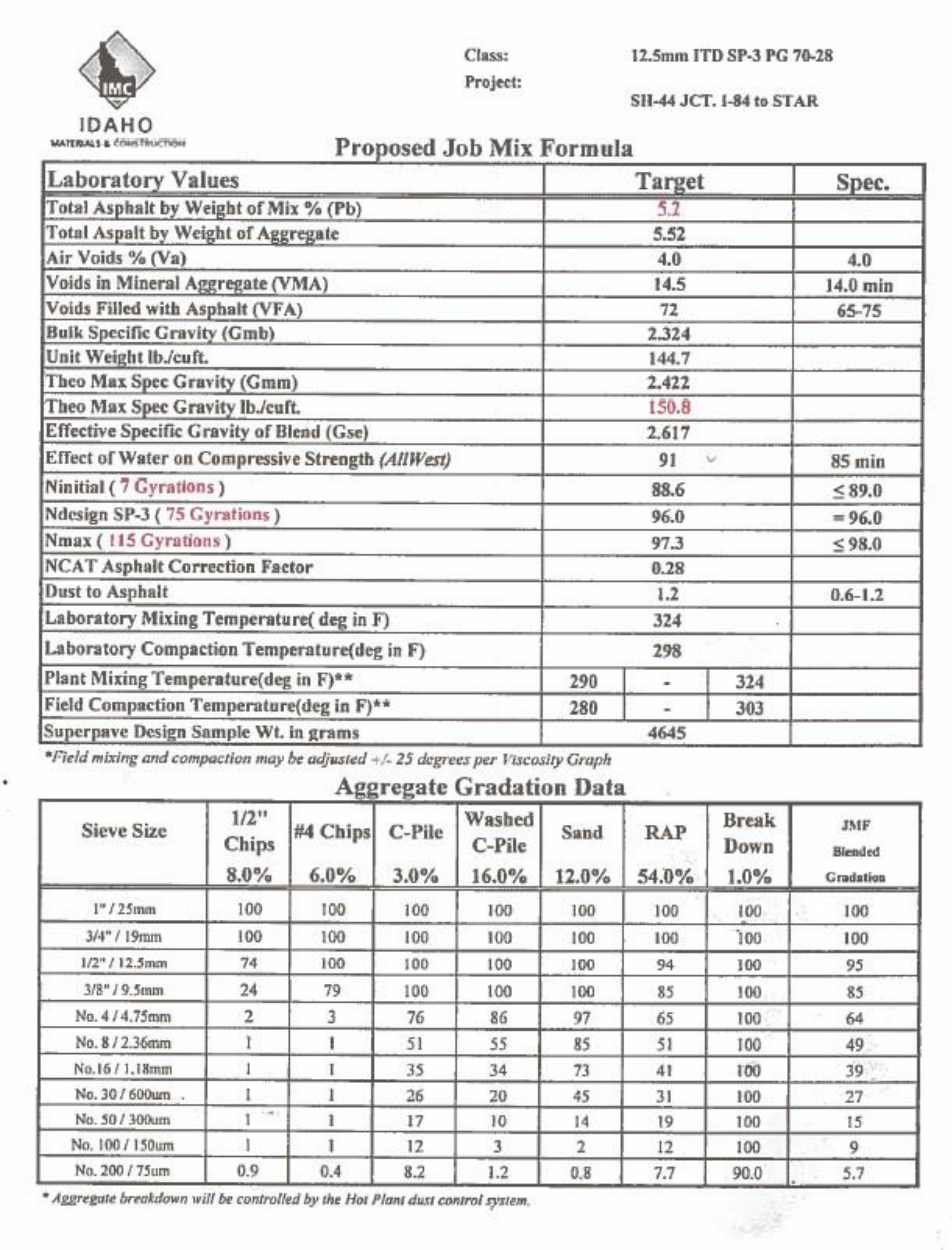
Breakdown will be controlled by means of our baghouse.

Testing Performed By:
Justin Drye WAQTC # 49360

Reviewed by: Gary O. Thompson
Gary Thompson, P.E.

14860
GARY O. THOMPSON

Table A.3. Job mix formula for project D2L1



IDAHO
MATERIALS & CONSTRUCTION

Class: 12.5mm ITD SP-3 PG 70-28
Project: SH-44 JCT. I-84 to STAR

Proposed Job Mix Formula

Laboratory Values	Target	Spec.
Total Asphalt by Weight of Mix % (Pb)	5.2	
Total Aspalt by Weight of Aggregate	5.52	
Air Voids % (Va)	4.0	4.0
Voids in Mineral Aggregate (VMA)	14.5	14.0 min
Voids Filled with Asphalt (VFA)	72	65-75
Bulk Specific Gravity (Gmb)	2.324	
Unit Weight lb./cuft.	144.7	
Theo Max Spec Gravity (Gmm)	2.422	
Theo Max Spec Gravity lb./cuft.	150.8	
Effective Specific Gravity of Blend (Gse)	2.617	
Effect of Water on Compressive Strength *(AllWest)*	91	85 min
Ninitial (7 Gyrations)	88.6	≤ 89.0
Ndesign SP-3 (75 Gyrations)	96.0	= 96.0
Nmax (115 Gyrations)	97.3	≤ 98.0
NCAT Asphalt Correction Factor	0.28	
Dust to Asphalt	1.2	0.6-1.2
Laboratory Mixing Temperature(deg in F)	324	
Laboratory Compaction Temperature(deg in F)	298	
Plant Mixing Temperature(deg in F)**	290 - 324	
Field Compaction Temperature(deg in F)**	280 - 303	
Superpave Design Sample Wt. in grams	4645	

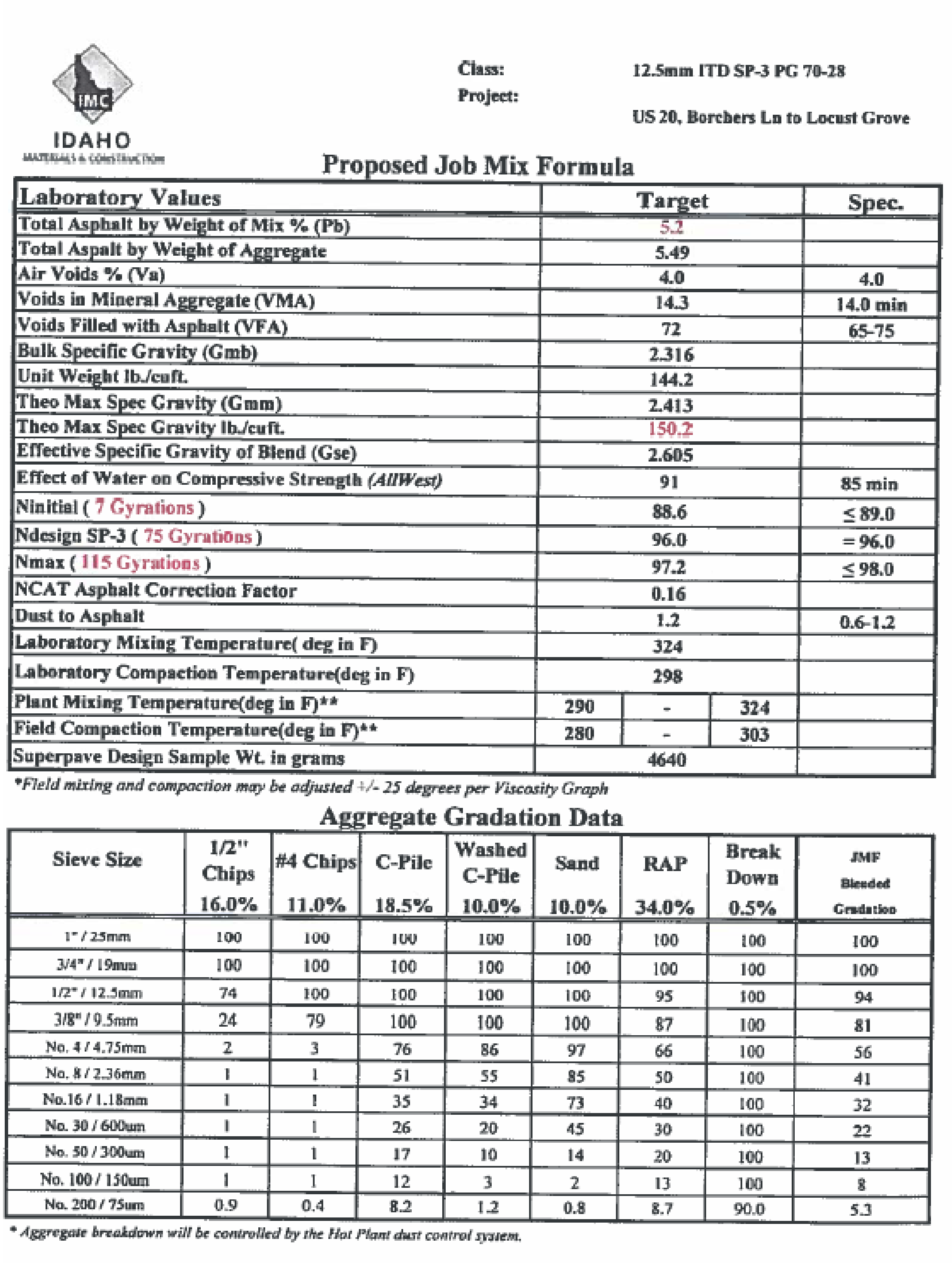
**Field mixing and compaction may be adjusted +/- 25 degrees per Viscosity Graph*

Aggregate Gradation Data

Sieve Size	1/2" Chips 8.0%	#4 Chips 6.0%	C-Pile 3.0%	Washed C-Pile 16.0%	Sand 12.0%	RAP 54.0%	Break Down 1.0%	JMF Blended Gradation
1" / 25mm	100	100	100	100	100	100	100	100
3/4" / 19mm	100	100	100	100	100	100	100	100
1/2" / 12.5mm	74	100	100	100	100	94	100	95
3/8" / 9.5mm	24	79	100	100	100	85	100	85
No. 4 / 4.75mm	2	3	76	86	97	65	100	64
No. 8 / 2.36mm	1	1	51	55	85	51	100	49
No.16 / 1.18mm	1	1	35	34	73	41	100	39
No. 30 / 600um	1	1	26	20	45	31	100	27
No. 50 / 300um	1	1	17	10	14	19	100	15
No. 100 / 150um	1	1	12	3	2	12	100	9
No. 200 / 75um	0.9	0.4	8.2	1.2	0.8	7.7	90.0	5.7

** Aggregate breakdown will be controlled by the Hot Plant dust control system.*

Table A.4. Job mix formula for project D3L2



IMC
IDAHO
MATERIALS & CONSTRUCTION

Class: 12.5mm ITD SP-3 PG 70-28
Project: US 20, Borchers Ln to Locust Grove

Proposed Job Mix Formula

Laboratory Values	Target	Spec.
Total Asphalt by Weight of Mix % (Pb)	5.2	
Total Aspalt by Weight of Aggregate	5.49	
Air Voids % (Va)	4.0	4.0
Voids in Mineral Aggregate (VMA)	14.3	14.0 min
Voids Filled with Asphalt (VFA)	72	65-75
Bulk Specific Gravity (Gmb)	2.316	
Unit Weight lb./cuft.	144.2	
Theo Max Spec Gravity (Gmm)	2.413	
Theo Max Spec Gravity lb./cuft.	150.2	
Effective Specific Gravity of Blend (Gse)	2.605	
Effect of Water on Compressive Strength *(AllWest)*	91	85 min
Ninitial (7 Gyrations)	88.6	≤ 89.0
Ndesign SP-3 (75 Gyrations)	96.0	= 96.0
Nmax (115 Gyrations)	97.2	≤ 98.0
NCAT Asphalt Correction Factor	0.16	
Dust to Asphalt	1.2	0.6-1.2
Laboratory Mixing Temperature(deg in F)	324	
Laboratory Compaction Temperature(deg in F)	298	
Plant Mixing Temperature(deg in F)**	290 - 324	
Field Compaction Temperature(deg in F)**	280 - 303	
Superpave Design Sample Wt. in grams	4640	

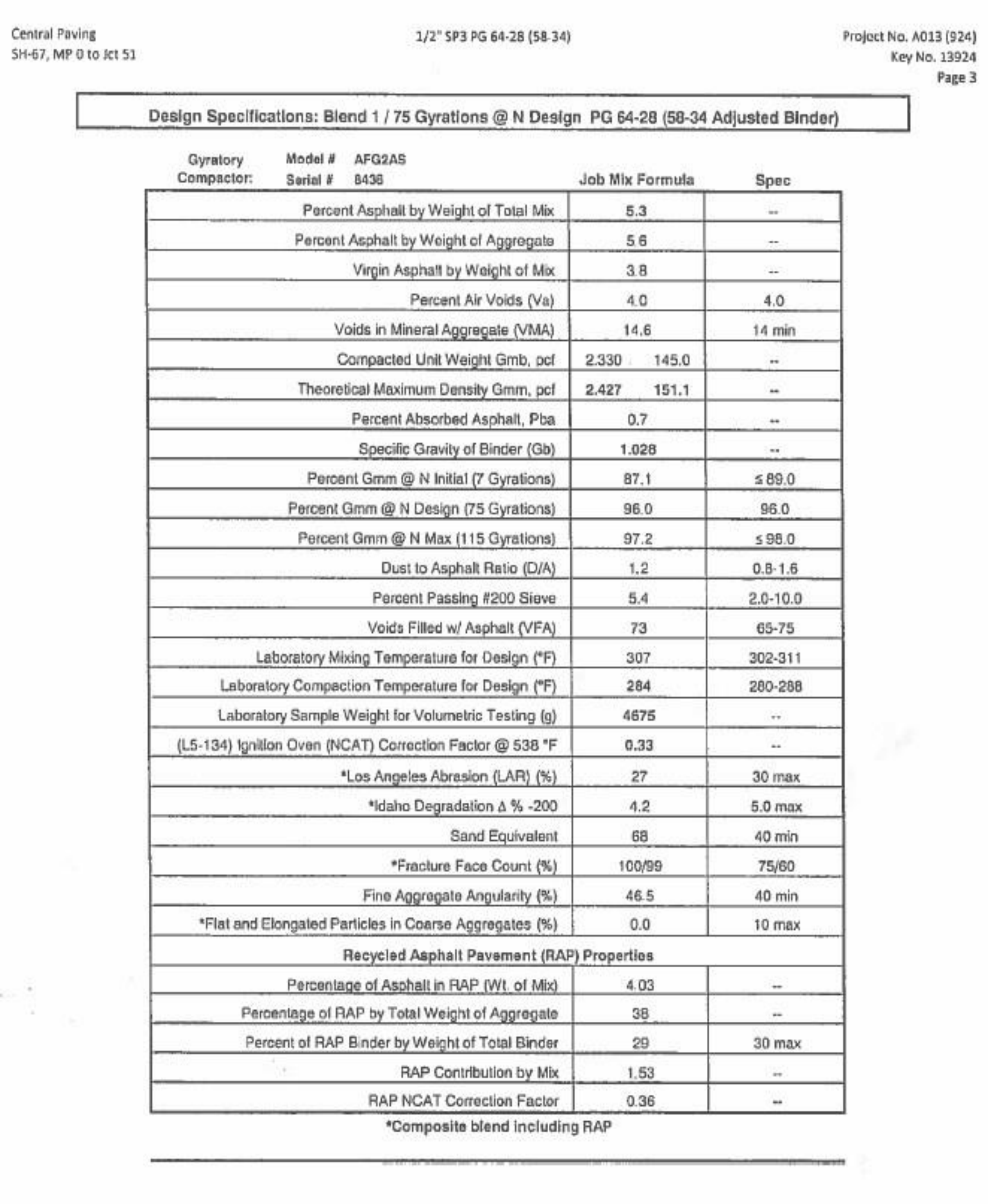
**Field mixing and compaction may be adjusted +/- 25 degrees per Viscosity Graph*

Aggregate Gradation Data

Sieve Size	1/2" Chips 16.0%	#4 Chips 11.0%	C-Pile 18.5%	Washed C-Pile 10.0%	Sand 10.0%	RAP 34.0%	Break Down 0.5%	JMF Blended Gradation
1" / 25mm	100	100	100	100	100	100	100	100
3/4" / 19mm	100	100	100	100	100	100	100	100
1/2" / 12.5mm	74	100	100	100	100	95	100	94
3/8" / 9.5mm	24	79	100	100	100	87	100	81
No. 4 / 4.75mm	2	3	76	86	97	66	100	56
No. 8 / 2.36mm	1	1	51	55	85	50	100	41
No.16 / 1.18mm	1	1	35	34	73	40	100	32
No. 30 / 600um	1	1	26	20	45	30	100	22
No. 50 / 300um	1	1	17	10	14	20	100	13
No. 100 / 150um	1	1	12	3	2	13	100	8
No. 200 / 75um	0.9	0.4	8.2	1.2	0.8	8.7	90.0	5.3

** Aggregate breakdown will be controlled by the Hot Plant dust control system.*

Table A.5. Job mix formula for project D3L3



Central Paving
SH-67, MP 0 to Jct 51

1/2" SP3 PG 64-28 (58-34)

Project No. A013 (924)
Key No. 13924
Page 3

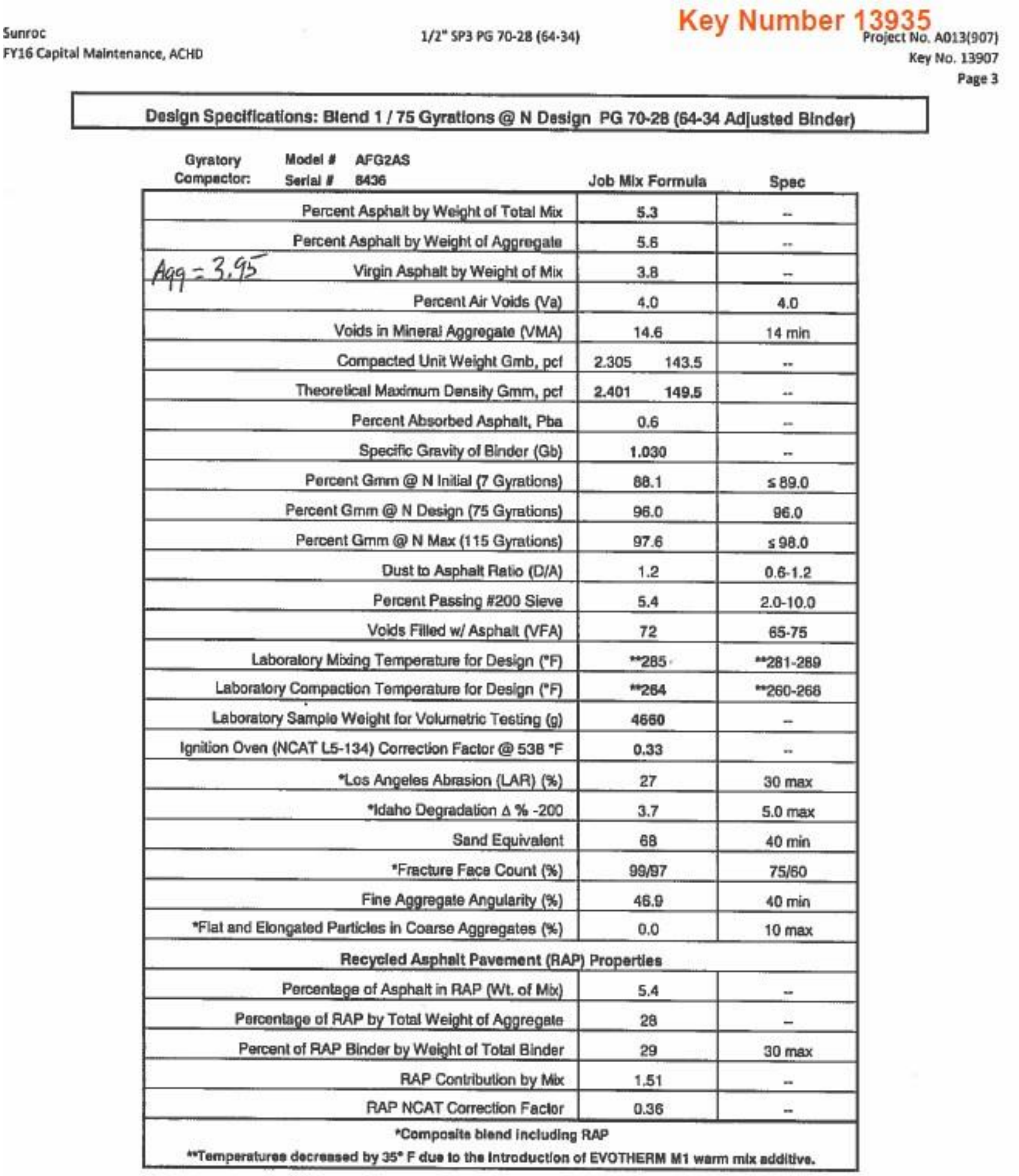
Design Specifications: Blend 1 / 75 Gyrations @ N Design PG 64-28 (58-34 Adjusted Binder)

Gyratory Compactor: Model # AFG2AS
Serial # 8436

	Job Mix Formula	Spec
Percent Asphalt by Weight of Total Mix	5.3	--
Percent Asphalt by Weight of Aggregate	5.6	--
Virgin Asphalt by Weight of Mix	3.8	--
Percent Air Voids (Va)	4.0	4.0
Voids in Mineral Aggregate (VMA)	14.6	14 min
Compacted Unit Weight Gmb, pcf	2.330 145.0	--
Theoretical Maximum Density Gmm, pcf	2.427 151.1	--
Percent Absorbed Asphalt, Pba	0.7	--
Specific Gravity of Binder (Gb)	1.028	--
Percent Gmm @ N Initial (7 Gyrations)	87.1	≤ 89.0
Percent Gmm @ N Design (75 Gyrations)	96.0	96.0
Percent Gmm @ N Max (115 Gyrations)	97.2	≤ 98.0
Dust to Asphalt Ratio (D/A)	1.2	0.8-1.6
Percent Passing #200 Sieve	5.4	2.0-10.0
Voids Filled w/ Asphalt (VFA)	73	65-75
Laboratory Mixing Temperature for Design (°F)	307	302-311
Laboratory Compaction Temperature for Design (°F)	284	280-288
Laboratory Sample Weight for Volumetric Testing (g)	4675	--
(L5-134) Ignition Oven (NCAT) Correction Factor @ 538 °F	0.33	--
*Los Angeles Abrasion (LAR) (%)	27	30 max
*Idaho Degradation Δ % -200	4.2	5.0 max
Sand Equivalent	68	40 min
*Fracture Face Count (%)	100/99	75/60
Fine Aggregate Angularity (%)	46.5	40 min
*Flat and Elongated Particles in Coarse Aggregates (%)	0.0	10 max
Recycled Asphalt Pavement (RAP) Properties		
Percentage of Asphalt in RAP (Wt. of Mix)	4.03	--
Percentage of RAP by Total Weight of Aggregate	38	--
Percent of RAP Binder by Weight of Total Binder	29	30 max
RAP Contribution by Mix	1.53	--
RAP NCAT Correction Factor	0.36	--

***Composite blend including RAP**

Table A.6. Job mix formula for project D3L4



Sunroc
FY16 Capital Maintenance, ACHD

1/2" SP3 PG 70-28 (64-34)

Key Number 13935

Project No. A013(907)
Key No. 13907
Page 3

Design Specifications: Blend 1 / 75 Gyrations @ N Design PG 70-28 (64-34 Adjusted Binder)

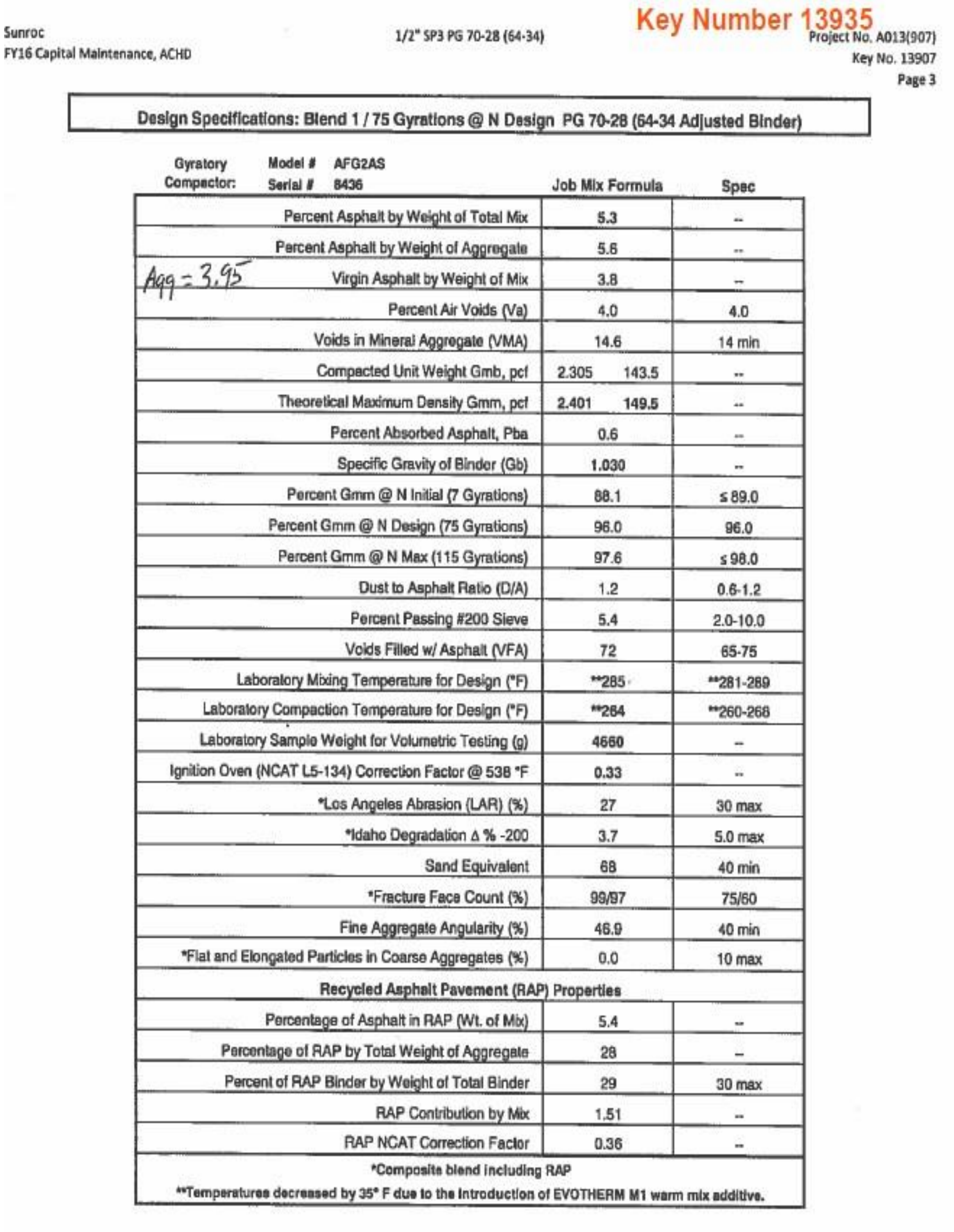
Gyratory Compactor: Model # AFG2AS
Serial # 8436

	Job Mix Formula	Spec
Percent Asphalt by Weight of Total Mix	5.3	--
Percent Asphalt by Weight of Aggregate	5.6	--
Agg = 3.95 Virgin Asphalt by Weight of Mix	3.8	--
Percent Air Voids (Va)	4.0	4.0
Voids in Mineral Aggregate (VMA)	14.6	14 min
Compacted Unit Weight Gmb, pcf	2.305 143.5	--
Theoretical Maximum Density Gmm, pcf	2.401 149.5	--
Percent Absorbed Asphalt, Pba	0.6	--
Specific Gravity of Binder (Gb)	1.030	--
Percent Gmm @ N Initial (7 Gyrations)	88.1	≤ 89.0
Percent Gmm @ N Design (75 Gyrations)	96.0	96.0
Percent Gmm @ N Max (115 Gyrations)	97.6	≤ 98.0
Dust to Asphalt Ratio (D/A)	1.2	0.6-1.2
Percent Passing #200 Sieve	5.4	2.0-10.0
Voids Filled w/ Asphalt (VFA)	72	65-75
Laboratory Mixing Temperature for Design (°F)	**285	**281-289
Laboratory Compaction Temperature for Design (°F)	**264	**260-268
Laboratory Sample Weight for Volumetric Testing (g)	4660	--
Ignition Oven (NCAT L5-134) Correction Factor @ 538 °F	0.33	--
*Los Angeles Abrasion (LAR) (%)	27	30 max
*Idaho Degradation Δ % -200	3.7	5.0 max
Sand Equivalent	68	40 min
*Fracture Face Count (%)	99/97	75/60
Fine Aggregate Angularity (%)	46.9	40 min
*Flat and Elongated Particles in Coarse Aggregates (%)	0.0	10 max
Recycled Asphalt Pavement (RAP) Properties		
Percentage of Asphalt in RAP (Wt. of Mix)	5.4	--
Percentage of RAP by Total Weight of Aggregate	28	--
Percent of RAP Binder by Weight of Total Binder	29	30 max
RAP Contribution by Mix	1.51	--
RAP NCAT Correction Factor	0.36	--

***Composite blend including RAP**

****Temperatures decreased by 35° F due to the introduction of EVOTHERM M1 warm mix additive.**

Table A.7. Job mix formula for project D3L5



Key Number 13935

Sunroc
FY16 Capital Maintenance, ACHD

1/2" SP3 PG 70-28 (64-34)

Project No. A013(907)
Key No. 13907
Page 3

Design Specifications: Blend 1 / 75 Gyrations @ N Design PG 70-28 (64-34 Adjusted Binder)

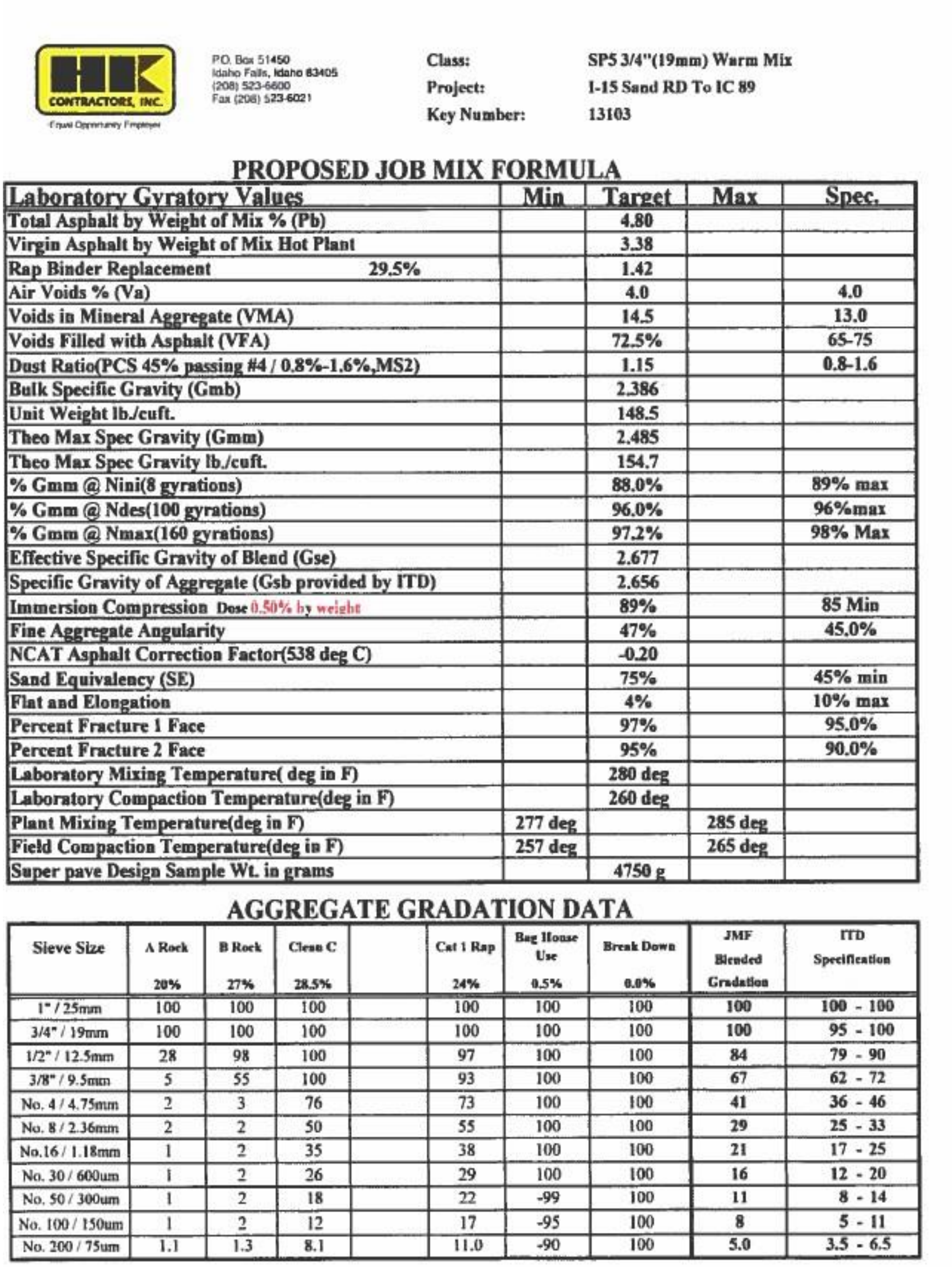
Gyratory Compactor: Model # AFG2AS, Serial # 8436

	Job Mix Formula	Spec
Percent Asphalt by Weight of Total Mix	5.3	--
Percent Asphalt by Weight of Aggregate	5.6	--
Agg = 3.95 Virgin Asphalt by Weight of Mix	3.8	--
Percent Air Voids (Va)	4.0	4.0
Voids in Mineral Aggregate (VMA)	14.6	14 min
Compacted Unit Weight Gmb, pcf	2.305 143.5	--
Theoretical Maximum Density Gmm, pcf	2.401 149.5	--
Percent Absorbed Asphalt, Pba	0.6	--
Specific Gravity of Binder (Gb)	1.030	--
Percent Gmm @ N Initial (7 Gyrations)	88.1	≤ 89.0
Percent Gmm @ N Design (75 Gyrations)	96.0	96.0
Percent Gmm @ N Max (115 Gyrations)	97.6	≤ 98.0
Dust to Asphalt Ratio (D/A)	1.2	0.6-1.2
Percent Passing #200 Sieve	5.4	2.0-10.0
Voids Filled w/ Asphalt (VFA)	72	65-75
Laboratory Mixing Temperature for Design (°F)	**285	**281-289
Laboratory Compaction Temperature for Design (°F)	**264	**260-268
Laboratory Sample Weight for Volumetric Testing (g)	4660	--
Ignition Oven (NCAT L5-134) Correction Factor @ 538 °F	0.33	--
*Los Angeles Abrasion (LAR) (%)	27	30 max
*Idaho Degradation Δ % -200	3.7	5.0 max
Sand Equivalent	68	40 min
*Fracture Face Count (%)	99/97	75/60
Fine Aggregate Angularity (%)	46.9	40 min
*Flat and Elongated Particles in Coarse Aggregates (%)	0.0	10 max
Recycled Asphalt Pavement (RAP) Properties		
Percentage of Asphalt in RAP (Wt. of Mix)	5.4	--
Percentage of RAP by Total Weight of Aggregate	28	--
Percent of RAP Binder by Weight of Total Binder	29	30 max
RAP Contribution by Mix	1.51	--
RAP NCAT Correction Factor	0.36	--

*Composite blend including RAP

**Temperatures decreased by 35° F due to the introduction of EVOTHERM M1 warm mix additive.

Table A.8. Job mix formula for project D5L1



CONTRACTORS, INC.

Equal Opportunity Employer

P.O. Box 51450
Idaho Falls, Idaho 83405
(208) 523-6600
Fax (208) 523-6021

Class: SP5 3/4"(19mm) Warm Mix
Project: I-15 Sand RD To IC 89
Key Number: 13103

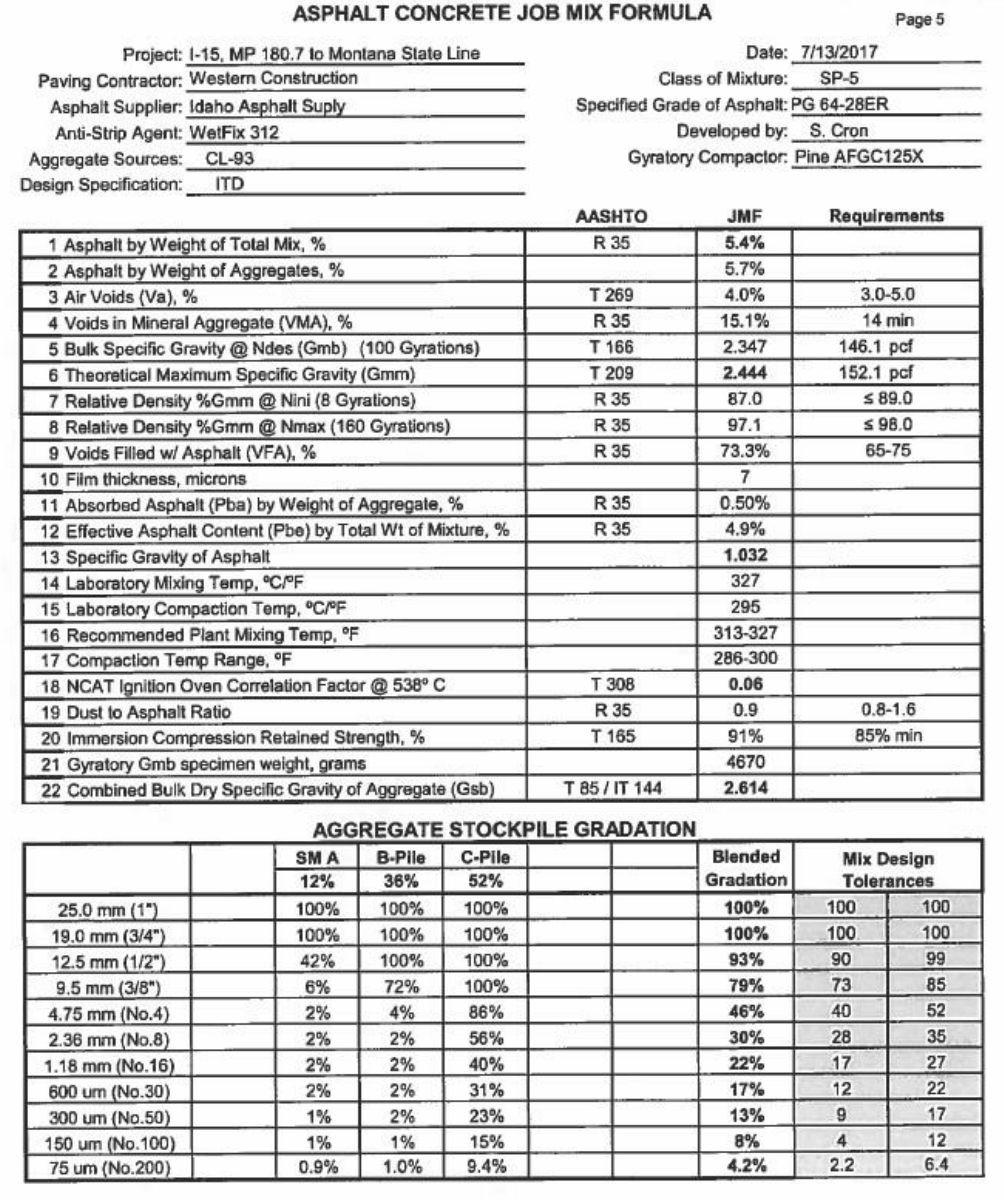
PROPOSED JOB MIX FORMULA

Laboratory Gyratory Values	Min	Target	Max	Spec.
Total Asphalt by Weight of Mix % (Pb)		4.80		
Virgin Asphalt by Weight of Mix Hot Plant		3.38		
Rap Binder Replacement 29.5%		1.42		
Air Voids % (Va)		4.0		4.0
Voids in Mineral Aggregate (VMA)		14.5		13.0
Voids Filled with Asphalt (VFA)		72.5%		65-75
Dust Ratio(PCS 45% passing #4 / 0.8%-1.6%,MS2)		1.15		0.8-1.6
Bulk Specific Gravity (Gmb)		2.386		
Unit Weight lb./cuft.		148.5		
Theo Max Spec Gravity (Gmm)		2.485		
Theo Max Spec Gravity lb./cuft.		154.7		
% Gmm @ Nini(8 gyrations)		88.0%		89% max
% Gmm @ Ndes(100 gyrations)		96.0%		96%max
% Gmm @ Nmax(160 gyrations)		97.2%		98% Max
Effective Specific Gravity of Blend (Gse)		2.677		
Specific Gravity of Aggregate (Gsb provided by ITD)		2.656		
Immersion Compression Dose 0.50% by weight		89%		85 Min
Fine Aggregate Angularity		47%		45.0%
NCAT Asphalt Correction Factor(538 deg C)		-0.20		
Sand Equivalency (SE)		75%		45% min
Flat and Elongation		4%		10% max
Percent Fracture 1 Face		97%		95.0%
Percent Fracture 2 Face		95%		90.0%
Laboratory Mixing Temperature(deg in F)		280 deg		
Laboratory Compaction Temperature(deg in F)		260 deg		
Plant Mixing Temperature(deg in F)	277 deg		285 deg	
Field Compaction Temperature(deg in F)	257 deg		265 deg	
Super pave Design Sample Wt. in grams		4750 g		

AGGREGATE GRADATION DATA

Sieve Size	A Rock 20%	B Rock 27%	Clean C 28.5%		Cat 1 Rap 24%	Bag House Use 0.5%	Break Down 0.0%	JMF Blended Gradation	ITD Specification
1" / 25mm	100	100	100		100	100	100	100	100 - 100
3/4" / 19mm	100	100	100		100	100	100	100	95 - 100
1/2" / 12.5mm	28	98	100		97	100	100	84	79 - 90
3/8" / 9.5mm	5	55	100		93	100	100	67	62 - 72
No. 4 / 4.75mm	2	3	76		73	100	100	41	36 - 46
No. 8 / 2.36mm	2	2	50		55	100	100	29	25 - 33
No.16 / 1.18mm	1	2	35		38	100	100	21	17 - 25
No. 30 / 600um	1	2	26		29	100	100	16	12 - 20
No. 50 / 300um	1	2	18		22	-99	100	11	8 - 14
No. 100 / 150um	1	2	12		17	-95	100	8	5 - 11
No. 200 / 75um	1.1	1.3	8.1		11.0	-90	100	5.0	3.5 - 6.5

Table A.9. Job mix formula for project D6L1



ASPHALT CONCRETE JOB MIX FORMULA

Page 5

Project: I-15, MP 180.7 to Montana State Line
Paving Contractor: Western Construction
Asphalt Supplier: Idaho Asphalt Suply
Anti-Strip Agent: WetFix 312
Aggregate Sources: CL-93
Design Specification: ITD

Date: 7/13/2017
Class of Mixture: SP-5
Specified Grade of Asphalt: PG 64-28ER
Developed by: S. Cron
Gyratory Compactor: Pine AFGC125X

	AASHTO	JMF	Requirements
1 Asphalt by Weight of Total Mix, %	R 35	**5.4%**	
2 Asphalt by Weight of Aggregates, %		5.7%	
3 Air Voids (Va), %	T 269	4.0%	3.0-5.0
4 Voids in Mineral Aggregate (VMA), %	R 35	15.1%	14 min
5 Bulk Specific Gravity @ Ndes (Gmb) (100 Gyrations)	T 166	2.347	146.1 pcf
6 Theoretical Maximum Specific Gravity (Gmm)	T 209	**2.444**	152.1 pcf
7 Relative Density %Gmm @ Nini (8 Gyrations)	R 35	87.0	≤ 89.0
8 Relative Density %Gmm @ Nmax (160 Gyrations)	R 35	97.1	≤ 98.0
9 Voids Filled w/ Asphalt (VFA), %	R 35	73.3%	65-75
10 Film thickness, microns		7	
11 Absorbed Asphalt (Pba) by Weight of Aggregate, %	R 35	0.50%	
12 Effective Asphalt Content (Pbe) by Total Wt of Mixture, %	R 35	4.9%	
13 Specific Gravity of Asphalt		**1.032**	
14 Laboratory Mixing Temp, °C/°F		327	
15 Laboratory Compaction Temp, °C/°F		295	
16 Recommended Plant Mixing Temp, °F		313-327	
17 Compaction Temp Range, °F		286-300	
18 NCAT Ignition Oven Correlation Factor @ 538° C	T 308	**0.06**	
19 Dust to Asphalt Ratio	R 35	0.9	0.8-1.6
20 Immersion Compression Retained Strength, %	T 165	91%	85% min
21 Gyratory Gmb specimen weight, grams		4670	
22 Combined Bulk Dry Specific Gravity of Aggregate (Gsb)	T 85 / IT 144	**2.614**	

AGGREGATE STOCKPILE GRADATION

		SM A	B-Pile	C-Pile			Blended Gradation	Mix Design Tolerances	
		12%	36%	52%					
25.0 mm (1")		100%	100%	100%			**100%**	100	100
19.0 mm (3/4")		100%	100%	100%			**100%**	100	100
12.5 mm (1/2")		42%	100%	100%			**93%**	90	99
9.5 mm (3/8")		6%	72%	100%			**79%**	73	85
4.75 mm (No.4)		2%	4%	86%			**46%**	40	52
2.36 mm (No.8)		2%	2%	56%			**30%**	28	35
1.18 mm (No.16)		2%	2%	40%			**22%**	17	27
600 um (No.30)		2%	2%	31%			**17%**	12	22
300 um (No.50)		1%	2%	23%			**13%**	9	17
150 um (No.100)		1%	1%	15%			**8%**	4	12
75 um (No.200)		0.9%	1.0%	9.4%			**4.2%**	2.2	6.4

APPENDIX B: STATISTICAL ANALYSIS

B.1. Statistical Analysis of Fracture Energy of LMLC computed from the IDT Test

One-way ANOVA: G_f (IDT) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

1) *Equal variances were assumed for the analysis.*

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	57408179	11481636	18.40	0.000
Error	12	7489598	624133		
Total	17	64897777			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
790.021	88.46%	83.65%	74.03%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	3	3557	694	(2563, 4551)
58-5%	3	4872	710	(3879, 5866)
58-5.75%	3	4893	792	(3899, 5887)
70-4.25%	3	5684	622	(4690, 6677)
70-5%	3	6946	894	(5952, 7940)
70-5.75%	3	9133	973	(8139, 10127)

2) *Pooled StDev = 790.021*

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping		
70-5.75%	3	9133	A		
70-5%	3	6946		B	
70-4.25%	3	5684		B	C
58-5.75%	3	4893		B	C
58-5%	3	4872		B	C
58-4.25%	3	3557			C

3) *Means that do not share a letter are significantly different.*

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	1315	645	(-851, 3482)	2.04	0.377
58-5.75% - 58-4.25%	1336	645	(-831, 3502)	2.07	0.362
70-4.25% - 58-4.25%	2126	645	(-40, 4293)	3.30	0.056
70-5% - 58-4.25%	3389	645	(1222, 5556)	5.25	0.002
70-5.75% - 58-4.25%	5576	645	(3409, 7742)	8.64	0.000
58-5.75% - 58-5%	20	645	(-2146, 2187)	0.03	1.000
70-4.25% - 58-5%	811	645	(-1355, 2978)	1.26	0.801
70-5% - 58-5%	2074	645	(-93, 4240)	3.21	0.064
70-5.75% - 58-5%	4261	645	(2094, 6427)	6.60	0.000
70-4.25% - 58-5.75%	791	645	(-1376, 2957)	1.23	0.817
70-5% - 58-5.75%	2053	645	(-113, 4220)	3.18	0.067
70-5.75% - 58-5.75%	4240	645	(2074, 6407)	6.57	0.000
70-5% - 70-4.25%	1263	645	(-904, 3429)	1.96	0.417
70-5.75% - 70-4.25%	3449	645	(1283, 5616)	5.35	0.002
70-5.75% - 70-5%	2187	645	(20, 4353)	3.39	0.047

4) *Individual confidence level = 99.43%*

B.2. Statistical Analysis of IDT Strength of LMLC computed from the IDT Test

One-way ANOVA: IDT Strength versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	553247	110649	14.35	0.000
Error	12	92531	7711		
Total	17	645778			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
87.8118	85.67%	79.70%	67.76%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	3	518.0	74.4	(407.5, 628.4)
58-5%	3	511.7	120.0	(401.2, 622.1)
58-5.75%	3	450.1	95.6	(339.7, 560.6)
70-4.25%	3	832.7	91.8	(722.2, 943.1)
70-5%	3	813.2	65.2	(702.7, 923.6)
70-5.75%	3	872.5	67.2	(762.1, 983.0)

Pooled StDev = 87.8118

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping	
70-5.75%	3	872.5	A	
70-4.25%	3	832.7	A	
70-5%	3	813.2	A	
58-4.25%	3	518.0		B
58-5%	3	511.7		B
58-5.75%	3	450.1		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	-6.3	71.7	(-247.1, 234.5)	-0.09	1.000
58-5.75% - 58-4.25%	-67.8	71.7	(-308.6, 173.0)	-0.95	0.926
70-4.25% - 58-4.25%	314.7	71.7	(73.9, 555.5)	4.39	0.009
70-5% - 58-4.25%	295.2	71.7	(54.4, 536.0)	4.12	0.014
70-5.75% - 58-4.25%	354.6	71.7	(113.8, 595.4)	4.95	0.004
58-5.75% - 58-5%	-61.5	71.7	(-302.3, 179.3)	-0.86	0.950
70-4.25% - 58-5%	321.0	71.7	(80.2, 561.8)	4.48	0.008
70-5% - 58-5%	301.5	71.7	(60.7, 542.3)	4.20	0.012
70-5.75% - 58-5%	360.9	71.7	(120.1, 601.7)	5.03	0.003
70-4.25% - 58-5.75%	382.5	71.7	(141.7, 623.3)	5.34	0.002
70-5% - 58-5.75%	363.0	71.7	(122.2, 603.8)	5.06	0.003
70-5.75% - 58-5.75%	422.4	71.7	(181.6, 663.2)	5.89	0.001
70-5% - 70-4.25%	-19.5	71.7	(-260.3, 221.3)	-0.27	1.000
70-5.75% - 70-4.25%	39.9	71.7	(-200.9, 280.7)	0.56	0.992
70-5.75% - 70-5%	59.4	71.7	(-181.4, 300.2)	0.83	0.956

Individual confidence level = 99.43

B.3. Statistical Analysis of Cracking Resistance Index (CRI) of LMLC computed from the IDT Test

One-way ANOVA: CRI (IDT) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	362777	72555	8.05	0.002
Error	12	108108	9009		
Total	17	470884			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
94.9156	77.04%	67.48%	48.34%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	3	568.8	43.4	(449.4, 688.2)
58-5%	3	826.6	129.2	(707.2, 946.0)
58-5.75%	3	928.8	69.2	(809.4, 1048.2)
70-4.25%	3	573.7	74.3	(454.3, 693.1)
70-5%	3	725.6	154.6	(606.2, 845.0)
70-5.75%	3	886.4	35.5	(767.0, 1005.8)

Pooled StDev = 94.9156

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping	
58-5.75%	3	928.8	A	
70-5.75%	3	886.4	A	
58-5%	3	826.6	A	B
70-5%	3	725.6	A	B
70-4.25%	3	573.7		B
58-4.25%	3	568.8		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	257.8	77.5	(-2.5, 518.1)	3.33	0.053
58-5.75% - 58-4.25%	360.0	77.5	(99.7, 620.3)	4.65	0.006
70-4.25% - 58-4.25%	4.9	77.5	(-255.3, 265.2)	0.06	1.000
70-5% - 58-4.25%	156.9	77.5	(-103.4, 417.2)	2.02	0.384
70-5.75% - 58-4.25%	317.6	77.5	(57.3, 577.9)	4.10	0.014
58-5.75% - 58-5%	102.2	77.5	(-158.1, 362.5)	1.32	0.770
70-4.25% - 58-5%	-252.9	77.5	(-513.2, 7.4)	-3.26	0.059
70-5% - 58-5%	-100.9	77.5	(-361.2, 159.4)	-1.30	0.779
70-5.75% - 58-5%	59.8	77.5	(-200.5, 320.1)	0.77	0.967
70-4.25% - 58-5.75%	-355.1	77.5	(-615.4, -94.8)	-4.58	0.006
70-5% - 58-5.75%	-203.2	77.5	(-463.5, 57.1)	-2.62	0.165
70-5.75% - 58-5.75%	-42.4	77.5	(-302.7, 217.9)	-0.55	0.993
70-5% - 70-4.25%	151.9	77.5	(-108.4, 412.2)	1.96	0.415
70-5.75% - 70-4.25%	312.7	77.5	(52.4, 573.0)	4.03	0.016
70-5.75% - 70-5%	160.7	77.5	(-99.6, 421.0)	2.07	0.360

Individual confidence level = 99.43%

B.4. Statistical Analysis of Flexibility Index (FI) of LMLC computed from the IDT Test

One-way ANOVA: FI (IDT) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	3192.7	638.55	8.28	0.001
Error	12	925.4	77.12		
Total	17	4118.2			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
8.78183	77.53%	68.16%	49.44%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	3	19.90	2.77	(8.85, 30.94)

58-5%	3	36.31	8.64	(25.27, 47.36)
58-5.75%	3	52.87	13.87	(41.82, 63.91)
70-4.25%	3	18.40	5.09	(7.36, 29.45)
70-5%	3	28.85	11.13	(17.80, 39.90)
70-5.75%	3	49.32	6.18	(38.27, 60.37)

Pooled StDev = 8.78183

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping	
58-5.75%	3	52.87	A	
70-5.75%	3	49.32	A	
58-5%	3	36.31	A	B
70-5%	3	28.85	A	B
58-4.25%	3	19.90		B
70-4.25%	3	18.40		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	16.42	7.17	(-7.66, 40.50)	2.29	0.269
58-5.75% - 58-4.25%	32.97	7.17	(8.89, 57.05)	4.60	0.006
70-4.25% - 58-4.25%	-1.49	7.17	(-25.57, 22.59)	-0.21	1.000

70-5% - 58-4.25%	8.96	7.17	(-15.13, 33.04)	1.25	0.805
70-5.75% - 58-4.25%	29.43	7.17	(5.34, 53.51)	4.10	0.014
58-5.75% - 58-5%	16.55	7.17	(-7.53, 40.64)	2.31	0.262
70-4.25% - 58-5%	-17.91	7.17	(-41.99, 6.17)	-2.50	0.199
70-5% - 58-5%	-7.46	7.17	(-31.55, 16.62)	-1.04	0.895
70-5.75% - 58-5%	13.01	7.17	(-11.08, 37.09)	1.81	0.492
70-4.25% - 58-5.75%	-34.46	7.17	(-58.55, -10.38)	-4.81	0.004
70-5% - 58-5.75%	-24.02	7.17	(-48.10, 0.07)	-3.35	0.051
70-5.75% - 58-5.75%	-3.55	7.17	(-27.63, 20.54)	-0.49	0.995
70-5% - 70-4.25%	10.45	7.17	(-13.64, 34.53)	1.46	0.695
70-5.75% - 70-4.25%	30.92	7.17	(6.83, 55.00)	4.31	0.010
70-5.75% - 70-5%	20.47	7.17	(-3.61, 44.55)	2.85	0.114

Individual confidence level = 99.43%

B.5. Statistical Analysis of Fracture Energy of PMLC computed from the IDT Test

One-way ANOVA: G_f (IDT) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	58648975	7331122	7.13	0.000
Error	17	17488097	1028712		
Total	25	76137072			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1014.25	77.03%	66.22%	47.48%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	3	7277	1238	(6042, 8513)

D2L1	2	9343	604	(7830, 10856)
D3L1	3	5672	1294	(4436, 6907)
D3L2	3	7065	472	(5830, 8301)
D3L3	3	7323	871	(6088, 8559)
D3L4	3	6352	285	(5117, 7588)
D3L5	3	5254	1136	(4019, 6489)
D5L1	3	6574	646	(5339, 7810)
D6L1	3	10239	1607	(9003, 11474)

Pooled StDev = 1014.25

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping		
D6L1	3	10239	A		
D2L1	2	9343	A	B	
D3L3	3	7323	A	B	C
D1L1	3	7277		B	C
D3L2	3	7065		B	C
D5L1	3	6574		B	C
D3L4	3	6352		B	C
D3L1	3	5672			C
D3L5	3	5254			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	2066	926	(-1201, 5333)	2.23	0.430
D3L1 - D1L1	-1606	828	(-4528, 1316)	-1.94	0.599
D3L2 - D1L1	-212	828	(-3134, 2710)	-0.26	1.000
D3L3 - D1L1	46	828	(-2876, 2968)	0.06	1.000
D3L4 - D1L1	-925	828	(-3847, 1997)	-1.12	0.963
D3L5 - D1L1	-2023	828	(-4945, 899)	-2.44	0.322
D5L1 - D1L1	-703	828	(-3625, 2219)	-0.85	0.993
D6L1 - D1L1	2961	828	(39, 5884)	3.58	0.046
D3L1 - D2L1	-3672	926	(-6939, -405)	-3.97	0.021
D3L2 - D2L1	-2278	926	(-5545, 989)	-2.46	0.315
D3L3 - D2L1	-2020	926	(-5287, 1247)	-2.18	0.457
D3L4 - D2L1	-2991	926	(-6258, 276)	-3.23	0.087
D3L5 - D2L1	-4089	926	(-7356, -822)	-4.42	0.009
D5L1 - D2L1	-2769	926	(-6036, 498)	-2.99	0.134
D6L1 - D2L1	896	926	(-2371, 4163)	0.97	0.984
D3L2 - D3L1	1394	828	(-1528, 4316)	1.68	0.749
D3L3 - D3L1	1652	828	(-1270, 4574)	1.99	0.566
D3L4 - D3L1	681	828	(-2241, 3603)	0.82	0.994
D3L5 - D3L1	-418	828	(-3340, 2504)	-0.50	1.000
D5L1 - D3L1	903	828	(-2019, 3825)	1.09	0.968
D6L1 - D3L1	4567	828	(1645, 7489)	5.52	0.001
D3L3 - D3L2	258	828	(-2664, 3180)	0.31	1.000
D3L4 - D3L2	-713	828	(-3635, 2209)	-0.86	0.992
D3L5 - D3L2	-1811	828	(-4733, 1111)	-2.19	0.454
D5L1 - D3L2	-491	828	(-3413, 2431)	-0.59	0.999
D6L1 - D3L2	3174	828	(252, 6096)	3.83	0.028

D3L4 - D3L3	-971	828	(-3893, 1951)	-1.17	0.952
D3L5 - D3L3	-2069	828	(-4991, 853)	-2.50	0.297
D5L1 - D3L3	-749	828	(-3671, 2173)	-0.90	0.990
D6L1 - D3L3	2915	828	(-7, 5837)	3.52	0.051
D3L5 - D3L4	-1098	828	(-4020, 1824)	-1.33	0.910
D5L1 - D3L4	222	828	(-2700, 3144)	0.27	1.000
D6L1 - D3L4	3886	828	(964, 6809)	4.69	0.005
D5L1 - D3L5	1320	828	(-1602, 4242)	1.59	0.796
D6L1 - D3L5	4985	828	(2063, 7907)	6.02	0.000
D6L1 - D5L1	3665	828	(743, 6587)	4.43	0.009

B.6. Statistical Analysis of IDT Strength of PMLC computed from the IDT Test

One-way ANOVA: IDT Strength versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	386174	48272	5.38	0.002
Error	17	152459	8968		
Total	25	538633			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
94.7003	71.70%	58.38%	36.30%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	3	1024.4	49.3	(909.1, 1139.8)
D2L1	2	1226.31	6.77	(1085.03, 1367.59)
D3L1	3	1065.6	83.6	(950.3, 1181.0)
D3L2	3	882.2	85.4	(766.8, 997.5)
D3L3	3	1087.6	107.5	(972.3, 1203.0)
D3L4	3	1040.1	20.4	(924.8, 1155.5)
D3L5	3	931	213	(816, 1047)
D5L1	3	834.9	43.2	(719.6, 950.3)
D6L1	3	1199.97	16.32	(1084.62, 1315.33)

Pooled StDev = 94.7003

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping	
D2L1	2	1226.31	A	
D6L1	3	1199.97	A	
D3L3	3	1087.6	A	B
D3L1	3	1065.6	A	B
D3L4	3	1040.1	A	B
D1L1	3	1024.4	A	B
D3L5	3	931	A	B
D3L2	3	882.2		B
D5L1	3	834.9		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	201.9	86.4	(-103.2, 506.9)	2.34	0.375
D3L1 - D1L1	41.2	77.3	(-231.7, 314.0)	0.53	1.000
D3L2 - D1L1	-142.3	77.3	(-415.1, 130.6)	-1.84	0.658
D3L3 - D1L1	63.2	77.3	(-209.7, 336.0)	0.82	0.995
D3L4 - D1L1	15.7	77.3	(-257.1, 288.5)	0.20	1.000
D3L5 - D1L1	-93.1	77.3	(-365.9, 179.7)	-1.20	0.945
D5L1 - D1L1	-189.5	77.3	(-462.3, 83.3)	-2.45	0.319
D6L1 - D1L1	175.5	77.3	(-97.3, 448.4)	2.27	0.409
D3L1 - D2L1	-160.7	86.4	(-465.7, 144.3)	-1.86	0.647
D3L2 - D2L1	-344.1	86.4	(-649.2, -39.1)	-3.98	0.021
D3L3 - D2L1	-138.7	86.4	(-443.7, 166.3)	-1.60	0.790
D3L4 - D2L1	-186.2	86.4	(-491.2, 118.9)	-2.15	0.473
D3L5 - D2L1	-295.0	86.4	(-600.0, 10.1)	-3.41	0.062
D5L1 - D2L1	-391.4	86.4	(-696.4, -86.3)	-4.53	0.007
D6L1 - D2L1	-26.3	86.4	(-331.4, 278.7)	-0.30	1.000
D3L2 - D3L1	-183.4	77.3	(-456.3, 89.4)	-2.37	0.356
D3L3 - D3L1	22.0	77.3	(-250.8, 294.8)	0.28	1.000
D3L4 - D3L1	-25.5	77.3	(-298.3, 247.4)	-0.33	1.000
D3L5 - D3L1	-134.3	77.3	(-407.1, 138.6)	-1.74	0.719
D5L1 - D3L1	-230.7	77.3	(-503.5, 42.2)	-2.98	0.136
D6L1 - D3L1	134.4	77.3	(-138.5, 407.2)	1.74	0.718
D3L3 - D3L2	205.4	77.3	(-67.4, 478.3)	2.66	0.234
D3L4 - D3L2	158.0	77.3	(-114.9, 430.8)	2.04	0.537
D3L5 - D3L2	49.2	77.3	(-223.7, 322.0)	0.64	0.999
D5L1 - D3L2	-47.2	77.3	(-320.1, 225.6)	-0.61	0.999
D6L1 - D3L2	317.8	77.3	(45.0, 590.6)	4.11	0.016

D3L4 - D3L3	-47.5	77.3	(-320.3, 225.4)	-0.61	0.999
D3L5 - D3L3	-156.3	77.3	(-429.1, 116.6)	-2.02	0.550
D5L1 - D3L3	-252.7	77.3	(-525.5, 20.2)	-3.27	0.082
D6L1 - D3L3	112.4	77.3	(-160.5, 385.2)	1.45	0.862
D3L5 - D3L4	-108.8	77.3	(-381.6, 164.0)	-1.41	0.880
D5L1 - D3L4	-205.2	77.3	(-478.0, 67.6)	-2.65	0.235
D6L1 - D3L4	159.8	77.3	(-113.0, 432.7)	2.07	0.523
D5L1 - D3L5	-96.4	77.3	(-369.2, 176.4)	-1.25	0.934
D6L1 - D3L5	268.6	77.3	(-4.2, 541.5)	3.47	0.056
D6L1 - D5L1	365.0	77.3	(92.2, 637.9)	4.72	0.005

Individual confidence level = 99.74%

B.7. Statistical Analysis of Cracking Resistance Index (CRI) of PMLC computed from the IDT Test

One-way ANOVA: CRI (IDT) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	216174	27022	4.99	0.003
Error	17	91989	5411		
Total	25	308163			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
73.5601	70.15%	56.10%	32.03%

Means

Projects (PMLC)	N	Mean	StDev	95% CI

D1L1	3	579.4	73.0	(489.8, 669.0)
D2L1	2	619.5	37.7	(509.7, 729.2)
D3L1	3	436.0	72.8	(346.4, 525.6)
D3L2	3	663.6	73.1	(574.0, 753.3)
D3L3	3	561.2	61.9	(471.6, 650.8)
D3L4	3	514.7	27.9	(425.1, 604.3)
D3L5	3	459.4	56.9	(369.8, 549.0)
D5L1	3	654.3	71.2	(564.7, 743.9)
D6L1	3	716.7	128.1	(627.1, 806.3)

Pooled StDev = 73.5601

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping		
D6L1	3	716.7	A		
D3L2	3	663.6	A	B	
D5L1	3	654.3	A	B	
D2L1	2	619.5	A	B	C
D1L1	3	579.4	A	B	C
D3L3	3	561.2	A	B	C
D3L4	3	514.7	A	B	C
D3L5	3	459.4		B	C
D3L1	3	436.0			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	40.1	67.2	(-196.9, 277.0)	0.60	0.999
D3L1 - D1L1	-143.4	60.1	(-355.3, 68.5)	-2.39	0.349
D3L2 - D1L1	84.3	60.1	(-127.7, 296.2)	1.40	0.882
D3L3 - D1L1	-18.2	60.1	(-230.1, 193.7)	-0.30	1.000
D3L4 - D1L1	-64.7	60.1	(-276.6, 147.2)	-1.08	0.970
D3L5 - D1L1	-120.0	60.1	(-331.9, 91.9)	-2.00	0.564
D5L1 - D1L1	74.9	60.1	(-137.0, 286.9)	1.25	0.934
D6L1 - D1L1	137.3	60.1	(-74.6, 349.2)	2.29	0.400
D3L1 - D2L1	-183.5	67.2	(-420.4, 53.5)	-2.73	0.207
D3L2 - D2L1	44.2	67.2	(-192.7, 281.1)	0.66	0.999
D3L3 - D2L1	-58.3	67.2	(-295.2, 178.7)	-0.87	0.992
D3L4 - D2L1	-104.8	67.2	(-341.7, 132.2)	-1.56	0.813
D3L5 - D2L1	-160.1	67.2	(-397.0, 76.9)	-2.38	0.351
D5L1 - D2L1	34.9	67.2	(-202.1, 271.8)	0.52	1.000
D6L1 - D2L1	97.2	67.2	(-139.7, 334.2)	1.45	0.864
D3L2 - D3L1	227.7	60.1	(15.8, 439.6)	3.79	0.030
D3L3 - D3L1	125.2	60.1	(-86.7, 337.1)	2.08	0.513
D3L4 - D3L1	78.7	60.1	(-133.2, 290.7)	1.31	0.915
D3L5 - D3L1	23.4	60.1	(-188.5, 235.3)	0.39	1.000
D5L1 - D3L1	218.3	60.1	(6.4, 430.3)	3.64	0.041
D6L1 - D3L1	280.7	60.1	(68.8, 492.6)	4.67	0.005
D3L3 - D3L2	-102.5	60.1	(-314.4, 109.5)	-1.71	0.736
D3L4 - D3L2	-148.9	60.1	(-360.9, 63.0)	-2.48	0.306
D3L5 - D3L2	-204.3	60.1	(-416.2, 7.7)	-3.40	0.064
D5L1 - D3L2	-9.3	60.1	(-221.3, 202.6)	-0.16	1.000
D6L1 - D3L2	53.0	60.1	(-158.9, 265.0)	0.88	0.991

D3L4 - D3L3	-46.5	60.1	(-258.4, 165.4)	-0.77	0.996
D3L5 - D3L3	-101.8	60.1	(-313.7, 110.1)	-1.69	0.742
D5L1 - D3L3	93.1	60.1	(-118.8, 305.1)	1.55	0.817
D6L1 - D3L3	155.5	60.1	(-56.4, 367.4)	2.59	0.260
D3L5 - D3L4	-55.3	60.1	(-267.3, 156.6)	-0.92	0.988
D5L1 - D3L4	139.6	60.1	(-72.3, 351.5)	2.32	0.380
D6L1 - D3L4	202.0	60.1	(-10.0, 413.9)	3.36	0.068
D5L1 - D3L5	194.9	60.1	(-17.0, 406.9)	3.25	0.085
D6L1 - D3L5	257.3	60.1	(45.4, 469.2)	4.28	0.011
D6L1 - D5L1	62.4	60.1	(-149.6, 274.3)	1.04	0.976

Individual confidence level = 99.74%

B.8. Statistical Analysis of Flexibility Index (FI) of PMLC computed from the IDT Test

One-way ANOVA: FI (IDT) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	1262.2	157.77	3.12	0.023
Error	17	859.0	50.53		
Total	25	2121.2			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7.10858	59.50%	40.44%	8.87%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	3	21.84	11.47	(13.18, 30.50)

D2L1	2	21.259	0.303	(10.654, 31.865)
D3L1	3	10.06	2.15	(1.40, 18.72)
D3L2	3	25.00	3.42	(16.35, 33.66)
D3L3	3	16.92	4.80	(8.26, 25.58)
D3L4	3	13.387	0.533	(4.728, 22.046)
D3L5	3	12.26	3.73	(3.60, 20.92)
D5L1	3	27.48	6.42	(18.82, 36.14)
D6L1	3	31.11	14.25	(22.45, 39.77)

Pooled StDev = 7.10858

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping	
D6L1	3	31.11	A	
D5L1	3	27.48	A	B
D3L2	3	25.00	A	B
D1L1	3	21.84	A	B
D2L1	2	21.259	A	B
D3L3	3	16.92	A	B
D3L4	3	13.387	A	B
D3L5	3	12.26	A	B
D3L1	3	10.06		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	-0.58	6.49	(-23.48, 22.32)	-0.09	1.000
D3L1 - D1L1	-11.78	5.80	(-32.26, 8.70)	-2.03	0.545
D3L2 - D1L1	3.16	5.80	(-17.32, 23.64)	0.54	1.000
D3L3 - D1L1	-4.92	5.80	(-25.40, 15.56)	-0.85	0.993
D3L4 - D1L1	-8.45	5.80	(-28.93, 12.03)	-1.46	0.860
D3L5 - D1L1	-9.58	5.80	(-30.06, 10.90)	-1.65	0.766
D5L1 - D1L1	5.64	5.80	(-14.84, 26.12)	0.97	0.984
D6L1 - D1L1	9.27	5.80	(-11.21, 29.75)	1.60	0.794
D3L1 - D2L1	-11.20	6.49	(-34.09, 11.70)	-1.73	0.725
D3L2 - D2L1	3.74	6.49	(-19.15, 26.64)	0.58	1.000
D3L3 - D2L1	-4.34	6.49	(-27.23, 18.56)	-0.67	0.999
D3L4 - D2L1	-7.87	6.49	(-30.77, 15.02)	-1.21	0.943
D3L5 - D2L1	-9.00	6.49	(-31.90, 13.89)	-1.39	0.888
D5L1 - D2L1	6.22	6.49	(-16.67, 29.12)	0.96	0.985
D6L1 - D2L1	9.85	6.49	(-13.04, 32.75)	1.52	0.833
D3L2 - D3L1	14.94	5.80	(-5.54, 35.42)	2.57	0.266
D3L3 - D3L1	6.86	5.80	(-13.62, 27.34)	1.18	0.950
D3L4 - D3L1	3.33	5.80	(-17.15, 23.81)	0.57	1.000
D3L5 - D3L1	2.20	5.80	(-18.28, 22.68)	0.38	1.000
D5L1 - D3L1	17.42	5.80	(-3.06, 37.90)	3.00	0.132
D6L1 - D3L1	21.05	5.80	(0.57, 41.53)	3.63	0.041
D3L3 - D3L2	-8.08	5.80	(-28.56, 12.40)	-1.39	0.886
D3L4 - D3L2	-11.62	5.80	(-32.10, 8.86)	-2.00	0.562
D3L5 - D3L2	-12.75	5.80	(-33.23, 7.73)	-2.20	0.449
D5L1 - D3L2	2.48	5.80	(-18.00, 22.96)	0.43	1.000
D6L1 - D3L2	6.11	5.80	(-14.37, 26.59)	1.05	0.974

D3L4 - D3L3	-3.54	5.80	(-24.02, 16.94)	-0.61	0.999
D3L5 - D3L3	-4.67	5.80	(-25.15, 15.81)	-0.80	0.995
D5L1 - D3L3	10.56	5.80	(-9.92, 31.04)	1.82	0.671
D6L1 - D3L3	14.19	5.80	(-6.29, 34.67)	2.44	0.322
D3L5 - D3L4	-1.13	5.80	(-21.61, 19.35)	-0.19	1.000
D5L1 - D3L4	14.10	5.80	(-6.38, 34.57)	2.43	0.329
D6L1 - D3L4	17.72	5.80	(-2.76, 38.20)	3.05	0.120
D5L1 - D3L5	15.22	5.80	(-5.25, 35.70)	2.62	0.246
D6L1 - D3L5	18.85	5.80	(-1.63, 39.33)	3.25	0.085
D6L1 - D5L1	3.63	5.80	(-16.85, 24.11)	0.63	0.999

Individual confidence level = 99.74%

B.9. Statistical Analysis of Fracture Energy of LMLC computed from the SCB-IFIT Test

One-way ANOVA: G_f (15 mm) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	2113571	422714	2.74	0.052
Error	18	2777461	154303		
Total	23	4891032			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
392.815	43.21%	27.44%	0.00%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	4	1090	347	(677, 1502)

58-5%	4	1297	245	(884, 1709)
58-5.75%	4	1577.7	88.0	(1165.1, 1990.3)
70-4.25%	4	1970	724	(1558, 2383)
70-5%	4	1587	364	(1174, 2000)
70-5.75%	4	1822	283	(1409, 2234)

Pooled StDev = 392.815

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping
70-4.25%	4	1970	A
70-5.75%	4	1822	A
70-5%	4	1587	A
58-5.75%	4	1577.7	A
58-5%	4	1297	A
58-4.25%	4	1090	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	207	278	(-675, 1089)	0.75	0.973
58-5.75% - 58-4.25%	488	278	(-394, 1370)	1.76	0.515
70-4.25% - 58-4.25%	881	278	(-1, 1763)	3.17	0.051
70-5% - 58-4.25%	497	278	(-384, 1379)	1.79	0.495
70-5.75% - 58-4.25%	732	278	(-150, 1614)	2.64	0.139
58-5.75% - 58-5%	281	278	(-601, 1163)	1.01	0.908
70-4.25% - 58-5%	674	278	(-208, 1555)	2.42	0.199
70-5% - 58-5%	290	278	(-592, 1172)	1.05	0.896
70-5.75% - 58-5%	525	278	(-357, 1407)	1.89	0.439
70-4.25% - 58-5.75%	393	278	(-489, 1274)	1.41	0.719
70-5% - 58-5.75%	9	278	(-872, 891)	0.03	1.000
70-5.75% - 58-5.75%	244	278	(-638, 1126)	0.88	0.947
70-5% - 70-4.25%	-383	278	(-1265, 499)	-1.38	0.738
70-5.75% - 70-4.25%	-149	278	(-1030, 733)	-0.53	0.994
70-5.75% - 70-5%	235	278	(-647, 1117)	0.84	0.955

Individual confidence level = 99.48%

B.10. Statistical Analysis of Flexibility Index (FI) of LMLC computed from the SCB-IFIT Test

One-way ANOVA: FI (15 mm) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	490.3	98.058	10.88	0.000
Error	18	162.2	9.013		
Total	23	652.5			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
3.00223	75.14%	68.23%	55.80%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	4	10.90	5.22	(7.75, 14.05)
58-5%	4	12.30	3.48	(9.15, 15.45)
58-5.75%	4	17.196	1.951	(14.042, 20.350)
70-4.25%	4	3.829	0.943	(0.675, 6.983)
70-5%	4	5.449	1.532	(2.295, 8.602)
70-5.75%	4	12.60	2.78	(9.45, 15.75)

Pooled StDev = 3.00223

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping		
58-5.75%	4	17.196	A		
70-5.75%	4	12.60	A		
58-5%	4	12.30	A		
58-4.25%	4	10.90	A	B	
70-5%	4	5.449		B	C
70-4.25%	4	3.829			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	1.40	2.12	(-5.34, 8.14)	0.66	0.984
58-5.75% - 58-4.25%	6.30	2.12	(-0.44, 13.04)	2.97	0.076
70-4.25% - 58-4.25%	-7.07	2.12	(-13.81, -0.33)	-3.33	0.037
70-5% - 58-4.25%	-5.45	2.12	(-12.19, 1.29)	-2.57	0.156
70-5.75% - 58-4.25%	1.70	2.12	(-5.04, 8.44)	0.80	0.964
58-5.75% - 58-5%	4.90	2.12	(-1.84, 11.64)	2.31	0.242
70-4.25% - 58-5%	-8.47	2.12	(-15.21, -1.73)	-3.99	0.009
70-5% - 58-5%	-6.85	2.12	(-13.59, -0.11)	-3.23	0.045
70-5.75% - 58-5%	0.30	2.12	(-6.44, 7.04)	0.14	1.000
70-4.25% - 58-5.75%	-13.37	2.12	(-20.11, -6.63)	-6.30	0.000
70-5% - 58-5.75%	-11.75	2.12	(-18.49, -5.01)	-5.53	0.000
70-5.75% - 58-5.75%	-4.60	2.12	(-11.34, 2.14)	-2.17	0.300
70-5% - 70-4.25%	1.62	2.12	(-5.12, 8.36)	0.76	0.970
70-5.75% - 70-4.25%	8.77	2.12	(2.03, 15.51)	4.13	0.007
70-5.75% - 70-5%	7.15	2.12	(0.41, 13.89)	3.37	0.034

Individual confidence level = 99.48%

B.11. Statistical Analysis of Cracking Resistance Index (CRI) of LMLC computed from the SCB-IFIT Test

One-way ANOVA: CRI (15 mm) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	583568	116714	11.07	0.000
Error	18	189784	10544		
Total	23	773353			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
102.682	75.46%	68.64%	56.37%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	4	642.4	175.7	(534.5, 750.2)
58-5%	4	764.9	77.0	(657.0, 872.7)
58-5.75%	4	972.4	92.1	(864.6, 1080.3)
70-4.25%	4	512.5	78.6	(404.7, 620.4)
70-5%	4	563.3	75.6	(455.5, 671.2)
70-5.75%	4	804.5	78.1	(696.7, 912.4)

Pooled StDev = 102.682

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping			
58-5.75%	4	972.4	A			
70-5.75%	4	804.5	A	B		
58-5%	4	764.9	A	B	C	
58-4.25%	4	642.4		B	C	D
70-5%	4	563.3			C	D
70-4.25%	4	512.5				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	122.5	72.6	(-108.0, 353.0)	1.69	0.557
58-5.75% - 58-4.25%	330.0	72.6	(99.5, 560.6)	4.55	0.003
70-4.25% - 58-4.25%	-129.8	72.6	(-360.4, 100.7)	-1.79	0.497
70-5% - 58-4.25%	-79.0	72.6	(-309.6, 151.5)	-1.09	0.880
70-5.75% - 58-4.25%	162.2	72.6	(-68.4, 392.7)	2.23	0.271
58-5.75% - 58-5%	207.6	72.6	(-23.0, 438.1)	2.86	0.093
70-4.25% - 58-5%	-252.3	72.6	(-482.9, -21.8)	-3.48	0.027
70-5% - 58-5%	-201.5	72.6	(-432.0, 29.0)	-2.78	0.108
70-5.75% - 58-5%	39.7	72.6	(-190.8, 270.2)	0.55	0.993
70-4.25% - 58-5.75%	-459.9	72.6	(-690.4, -229.4)	-6.33	0.000
70-5% - 58-5.75%	-409.1	72.6	(-639.6, -178.6)	-5.63	0.000
70-5.75% - 58-5.75%	-167.9	72.6	(-398.4, 62.6)	-2.31	0.239
70-5% - 70-4.25%	50.8	72.6	(-179.7, 281.3)	0.70	0.980
70-5.75% - 70-4.25%	292.0	72.6	(61.5, 522.5)	4.02	0.009
70-5.75% - 70-5%	241.2	72.6	(10.7, 471.7)	3.32	0.038

Individual confidence level = 99.48%

B.12. Statistical Analysis of Fracture Energy of PMLC computed from the SCB-IFIT Test

One-way ANOVA: G_f (15 mm) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	5411143	676393	6.97	0.000
Error	25	2425083	97003		
Total	33	7836227			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
311.454	69.05%	59.15%	42.77%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	4	2030	246	(1709, 2350)
D2L1	4	2550	524	(2229, 2870)
D3L1	4	1404.6	148.2	(1083.9, 1725.3)
D3L2	4	2040.3	187.9	(1719.6, 2361.0)
D3L3	3	2004.9	148.0	(1634.6, 2375.2)
D3L4	4	2277	400	(1956, 2597)
D3L5	4	1594	277	(1273, 1914)
D5L1	3	2063	402	(1693, 2434)
D6L1	4	2706	237	(2386, 3027)

Pooled StDev = 311.454

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping		
D6L1	4	2706	A		
D2L1	4	2550	A		
D3L4	4	2277	A	B	
D5L1	3	2063	A	B	C
D3L2	4	2040.3	A	B	C
D1L1	4	2030	A	B	C
D3L3	3	2004.9	A	B	C
D3L5	4	1594		B	C

D3L1	4	1404.6			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	520	220	(-226, 1266)	2.36	0.346
D3L1 - D1L1	-625	220	(-1371, 121)	-2.84	0.154
D3L2 - D1L1	11	220	(-735, 756)	0.05	1.000
D3L3 - D1L1	-25	238	(-831, 781)	-0.10	1.000
D3L4 - D1L1	247	220	(-499, 993)	1.12	0.965
D3L5 - D1L1	-436	220	(-1182, 310)	-1.98	0.570
D5L1 - D1L1	34	238	(-772, 839)	0.14	1.000
D6L1 - D1L1	677	220	(-69, 1423)	3.07	0.097
D3L1 - D2L1	-1145	220	(-1891, -399)	-5.20	0.001
D3L2 - D2L1	-509	220	(-1255, 237)	-2.31	0.372
D3L3 - D2L1	-545	238	(-1350, 261)	-2.29	0.384
D3L4 - D2L1	-273	220	(-1019, 473)	-1.24	0.939
D3L5 - D2L1	-956	220	(-1702, -210)	-4.34	0.005
D5L1 - D2L1	-486	238	(-1292, 319)	-2.05	0.529
D6L1 - D2L1	157	220	(-589, 903)	0.71	0.998
D3L2 - D3L1	636	220	(-110, 1382)	2.89	0.140
D3L3 - D3L1	600	238	(-205, 1406)	2.52	0.268
D3L4 - D3L1	872	220	(126, 1618)	3.96	0.014
D3L5 - D3L1	189	220	(-557, 935)	0.86	0.993
D5L1 - D3L1	659	238	(-147, 1464)	2.77	0.175
D6L1 - D3L1	1302	220	(556, 2048)	5.91	0.000
D3L3 - D3L2	-35	238	(-841, 770)	-0.15	1.000
D3L4 - D3L2	236	220	(-510, 982)	1.07	0.973

D3L5 - D3L2	-447	220	(-1193, 299)	-2.03	0.540
D5L1 - D3L2	23	238	(-783, 829)	0.10	1.000
D6L1 - D3L2	666	220	(-80, 1412)	3.02	0.107
D3L4 - D3L3	272	238	(-534, 1077)	1.14	0.961
D3L5 - D3L3	-411	238	(-1217, 394)	-1.73	0.724
D5L1 - D3L3	58	254	(-803, 920)	0.23	1.000
D6L1 - D3L3	701	238	(-104, 1507)	2.95	0.124
D3L5 - D3L4	-683	220	(-1429, 63)	-3.10	0.092
D5L1 - D3L4	-213	238	(-1019, 592)	-0.90	0.991
D6L1 - D3L4	430	220	(-316, 1176)	1.95	0.588
D5L1 - D3L5	470	238	(-336, 1275)	1.97	0.573
D6L1 - D3L5	1113	220	(367, 1859)	5.05	0.001
D6L1 - D5L1	643	238	(-163, 1449)	2.70	0.197

Individual confidence level = 99.77%

B.13. Statistical Analysis of Flexibility Index (FI) of PMLC computed from the SCB-IFIT Test

One-way ANOVA: FI (15 mm) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	94.28	11.786	4.16	0.003
Error	25	70.85	2.834		
Total	33	165.13			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.68343	57.10%	43.37%	14.78%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	4	4.657	1.346	(2.923, 6.390)
D2L1	4	2.619	1.297	(0.886, 4.353)
D3L1	4	2.772	0.691	(1.039, 4.506)
D3L2	4	6.245	1.995	(4.511, 7.978)
D3L3	3	6.431	1.160	(4.430, 8.433)
D3L4	4	4.371	1.135	(2.637, 6.104)
D3L5	4	2.055	0.464	(0.321, 3.789)
D5L1	3	6.96	3.78	(4.96, 8.97)
D6L1	4	5.298	1.931	(3.564, 7.032)

Pooled StDev = 1.68343

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping	
D5L1	3	6.96	A	
D3L3	3	6.431	A	
D3L2	4	6.245	A	
D6L1	4	5.298	A	B
D1L1	4	4.657	A	B
D3L4	4	4.371	A	B
D3L1	4	2.772	A	B
D2L1	4	2.619	A	B

D3L5	4	2.055		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	-2.04	1.19	(-6.07, 1.99)	-1.71	0.734
D3L1 - D1L1	-1.88	1.19	(-5.92, 2.15)	-1.58	0.805
D3L2 - D1L1	1.59	1.19	(-2.44, 5.62)	1.33	0.911
D3L3 - D1L1	1.77	1.29	(-2.58, 6.13)	1.38	0.895
D3L4 - D1L1	-0.29	1.19	(-4.32, 3.75)	-0.24	1.000
D3L5 - D1L1	-2.60	1.19	(-6.63, 1.43)	-2.19	0.444
D5L1 - D1L1	2.31	1.29	(-2.05, 6.66)	1.80	0.685
D6L1 - D1L1	0.64	1.19	(-3.39, 4.67)	0.54	1.000
D3L1 - D2L1	0.15	1.19	(-3.88, 4.18)	0.13	1.000
D3L2 - D2L1	3.63	1.19	(-0.41, 7.66)	3.05	0.102
D3L3 - D2L1	3.81	1.29	(-0.54, 8.17)	2.96	0.120
D3L4 - D2L1	1.75	1.19	(-2.28, 5.78)	1.47	0.858
D3L5 - D2L1	-0.56	1.19	(-4.60, 3.47)	-0.47	1.000
D5L1 - D2L1	4.35	1.29	(-0.01, 8.70)	3.38	0.051
D6L1 - D2L1	2.68	1.19	(-1.35, 6.71)	2.25	0.406
D3L2 - D3L1	3.47	1.19	(-0.56, 7.50)	2.92	0.132
D3L3 - D3L1	3.66	1.29	(-0.70, 8.01)	2.85	0.151
D3L4 - D3L1	1.60	1.19	(-2.43, 5.63)	1.34	0.908
D3L5 - D3L1	-0.72	1.19	(-4.75, 3.31)	-0.60	0.999
D5L1 - D3L1	4.19	1.29	(-0.16, 8.55)	3.26	0.066
D6L1 - D3L1	2.53	1.19	(-1.51, 6.56)	2.12	0.482
D3L3 - D3L2	0.19	1.29	(-4.17, 4.54)	0.14	1.000
D3L4 - D3L2	-1.87	1.19	(-5.91, 2.16)	-1.57	0.809

D3L5 - D3L2	-4.19	1.19	(-8.22, -0.16)	-3.52	0.037
D5L1 - D3L2	0.72	1.29	(-3.64, 5.07)	0.56	1.000
D6L1 - D3L2	-0.95	1.19	(-4.98, 3.08)	-0.80	0.996
D3L4 - D3L3	-2.06	1.29	(-6.42, 2.29)	-1.60	0.795
D3L5 - D3L3	-4.38	1.29	(-8.73, -0.02)	-3.40	0.048
D5L1 - D3L3	0.53	1.37	(-4.12, 5.19)	0.39	1.000
D6L1 - D3L3	-1.13	1.29	(-5.49, 3.22)	-0.88	0.992
D3L5 - D3L4	-2.32	1.19	(-6.35, 1.72)	-1.95	0.591
D5L1 - D3L4	2.59	1.29	(-1.76, 6.95)	2.02	0.546
D6L1 - D3L4	0.93	1.19	(-3.10, 4.96)	0.78	0.997
D5L1 - D3L5	4.91	1.29	(0.55, 9.26)	3.82	0.019
D6L1 - D3L5	3.24	1.19	(-0.79, 7.27)	2.72	0.190
D6L1 - D5L1	-1.67	1.29	(-6.02, 2.69)	-1.30	0.923

Individual confidence level = 99.77%

B.14. Statistical Analysis of Cracking Resistance Index (CRI) of PMLC computed from the SCB-IFIT Test

One-way ANOVA: CRI (15 mm) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	276154	34519	5.85	0.000
Error	25	147499	5900		
Total	33	423653			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
76.8112	65.18%	54.04%	31.52%

Means

Projects (PMLC)	N	Mean	StDev	95% CI

D1L1	4	571.1	41.0	(492.0, 650.2)
D2L1	4	420.9	82.6	(341.8, 500.0)
D3L1	4	391.3	34.0	(312.2, 470.4)
D3L2	4	587.2	92.6	(508.2, 666.3)
D3L3	3	586.7	38.1	(495.3, 678.0)
D3L4	4	518.5	51.0	(439.4, 597.6)
D3L5	4	384.2	22.2	(305.1, 463.3)
D5L1	3	618.6	167.6	(527.3, 710.0)
D6L1	4	601.5	90.3	(522.4, 680.6)

Pooled StDev = 76.8112

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping		
D5L1	3	618.6	A		
D6L1	4	601.5	A		
D3L2	4	587.2	A		
D3L3	3	586.7	A	B	
D1L1	4	571.1	A	B	
D3L4	4	518.5	A	B	C
D2L1	4	420.9	A	B	C
D3L1	4	391.3		B	C
D3L5	4	384.2			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	-150.2	54.3	(-334.1, 33.8)	-2.77	0.176
D3L1 - D1L1	-179.8	54.3	(-363.8, 4.1)	-3.31	0.059
D3L2 - D1L1	16.1	54.3	(-167.8, 200.1)	0.30	1.000
D3L3 - D1L1	15.5	58.7	(-183.2, 214.2)	0.26	1.000
D3L4 - D1L1	-52.6	54.3	(-236.6, 131.4)	-0.97	0.986
D3L5 - D1L1	-186.9	54.3	(-370.9, -3.0)	-3.44	0.044
D5L1 - D1L1	47.5	58.7	(-151.2, 246.2)	0.81	0.995
D6L1 - D1L1	30.4	54.3	(-153.6, 214.4)	0.56	1.000
D3L1 - D2L1	-29.7	54.3	(-213.6, 154.3)	-0.55	1.000
D3L2 - D2L1	166.3	54.3	(-17.7, 350.3)	3.06	0.099
D3L3 - D2L1	165.7	58.7	(-33.0, 364.4)	2.82	0.158
D3L4 - D2L1	97.6	54.3	(-86.4, 281.5)	1.80	0.684
D3L5 - D2L1	-36.8	54.3	(-220.7, 147.2)	-0.68	0.999
D5L1 - D2L1	197.7	58.7	(-1.0, 396.4)	3.37	0.052
D6L1 - D2L1	180.6	54.3	(-3.4, 364.5)	3.32	0.057
D3L2 - D3L1	196.0	54.3	(12.0, 379.9)	3.61	0.031
D3L3 - D3L1	195.4	58.7	(-3.3, 394.1)	3.33	0.057
D3L4 - D3L1	127.2	54.3	(-56.7, 311.2)	2.34	0.356
D3L5 - D3L1	-7.1	54.3	(-191.1, 176.9)	-0.13	1.000
D5L1 - D3L1	227.3	58.7	(28.6, 426.0)	3.88	0.016
D6L1 - D3L1	210.3	54.3	(26.3, 394.2)	3.87	0.017
D3L3 - D3L2	-0.6	58.7	(-199.3, 198.1)	-0.01	1.000
D3L4 - D3L2	-68.7	54.3	(-252.7, 115.2)	-1.27	0.932
D3L5 - D3L2	-203.1	54.3	(-387.0, -19.1)	-3.74	0.023
D5L1 - D3L2	31.4	58.7	(-167.3, 230.1)	0.53	1.000
D6L1 - D3L2	14.3	54.3	(-169.7, 198.2)	0.26	1.000

D3L4 - D3L3	-68.1	58.7	(-266.8, 130.6)	-1.16	0.958
D3L5 - D3L3	-202.5	58.7	(-401.2, -3.8)	-3.45	0.043
D5L1 - D3L3	32.0	62.7	(-180.5, 244.4)	0.51	1.000
D6L1 - D3L3	14.9	58.7	(-183.8, 213.6)	0.25	1.000
D3L5 - D3L4	-134.3	54.3	(-318.3, 49.6)	-2.47	0.291
D5L1 - D3L4	100.1	58.7	(-98.6, 298.8)	1.71	0.737
D6L1 - D3L4	83.0	54.3	(-101.0, 267.0)	1.53	0.832
D5L1 - D3L5	234.4	58.7	(35.7, 433.1)	4.00	0.012
D6L1 - D3L5	217.3	54.3	(33.4, 401.3)	4.00	0.012
D6L1 - D5L1	-17.1	58.7	(-215.8, 181.6)	-0.29	1.000

B.15. Statistical Analysis of Fracture Energy of LMLC computed from the SCB-J_c Test

One-way ANOVA: G_f (SCB-J_c) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	18	58-4.25% (25.4 mm), 58-4.25% (31.8 mm), 58-4.25% (38 mm), 58-5% (25.4 mm), 58-5% (31.8 mm), 58-5% (38 mm), 58-5.75% (25.4 mm), 58-5.75% (31.8 mm), 58-5.75% (38 mm), 70-4.25% (25.4 mm), 70-4.25% (31.8 mm), 70-4.25% (38 mm), 70-5% (25.4 mm), 70-5%

		(31.8 mm), 70-5% (38 mm), 70-5.75% (25.4 mm), 70-5.75% (31.8 mm), 70-5.75% (38 mm)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	17	333474	19616	3.36	0.001
Error	34	198573	5840		
Total	51	532047			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
76.4224	62.68%	44.02%	10.38%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25% (25.4 mm)	3	289.2	57.5	(199.6, 378.9)
58-4.25% (31.8 mm)	3	132.6	42.5	(43.0, 222.3)
58-4.25% (38 mm)	3	126.6	30.4	(36.9, 216.3)
58-5% (25.4 mm)	3	217.9	34.1	(128.3, 307.6)
58-5% (31.8 mm)	3	157.0	48.9	(67.3, 246.6)
58-5% (38 mm)	3	111.7	21.5	(22.0, 201.3)
58-5.75% (25.4 mm)	3	227.0	99.7	(137.3, 316.7)
58-5.75% (31.8 mm)	3	199.9	27.7	(110.2, 289.5)
58-5.75% (38 mm)	3	189.8	72.0	(100.1, 279.4)
70-4.25% (25.4 mm)	3	357.9	168.0	(268.2, 447.6)
70-4.25% (31.8 mm)	3	315.0	85.1	(225.3, 404.6)
70-4.25% (38 mm)	3	276.8	25.3	(187.2, 366.5)
70-5% (25.4 mm)	2	298.7	32.8	(188.9, 408.6)
70-5% (31.8 mm)	2	269.2	126.8	(159.4, 379.0)

70-5% (38 mm)	3	158.6	87.9	(69.0, 248.3)
70-5.75% (25.4 mm)	3	370.1	88.2	(280.4, 459.8)
70-5.75% (31.8 mm)	3	286.4	47.2	(196.7, 376.0)
70-5.75% (38 mm)	3	322.8	104.6	(233.1, 412.5)

Pooled StDev = 76.4224

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping		
70-5.75% (25.4 mm)	3	370.1	A		
70-4.25% (25.4 mm)	3	357.9	A	B	
70-5.75% (38 mm)	3	322.8	A	B	C
70-4.25% (31.8 mm)	3	315.0	A	B	C
70-5% (25.4 mm)	2	298.7	A	B	C
58-4.25% (25.4 mm)	3	289.2	A	B	C
70-5.75% (31.8 mm)	3	286.4	A	B	C
70-4.25% (38 mm)	3	276.8	A	B	C
70-5% (31.8 mm)	2	269.2	A	B	C
58-5.75% (25.4 mm)	3	227.0	A	B	C
58-5% (25.4 mm)	3	217.9	A	B	C
58-5.75% (31.8 mm)	3	199.9	A	B	C
58-5.75% (38 mm)	3	189.8	A	B	C
70-5% (38 mm)	3	158.6	A	B	C
58-5% (31.8 mm)	3	157.0	A	B	C
58-4.25% (31.8 mm)	3	132.6		B	C
58-4.25% (38 mm)	3	126.6		B	C
58-5% (38 mm)	3	111.7			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-4.25% (31 - 58-4.25% (25	-156.6	62.4	(-391.8, 78.6)	-2.51	0.539
58-4.25% (38 - 58-4.25% (25	-162.6	62.4	(-397.8, 72.6)	-2.61	0.476
58-5% (25.4 - 58-4.25% (25	-71.3	62.4	(-306.5, 163.9)	-1.14	0.999
58-5% (31.8 - 58-4.25% (25	-132.3	62.4	(-367.4, 102.9)	-2.12	0.788
58-5% (38 mm - 58-4.25% (25	-177.6	62.4	(-412.7, 57.6)	-2.85	0.332
58-5.75% (25 - 58-4.25% (25	-62.2	62.4	(-297.4, 172.9)	-1.00	1.000
58-5.75% (31 - 58-4.25% (25	-89.4	62.4	(-324.5, 145.8)	-1.43	0.990
58-5.75% (38 - 58-4.25% (25	-99.4	62.4	(-334.6, 135.7)	-1.59	0.973
70-4.25% (25 - 58-4.25% (25	68.7	62.4	(-166.5, 303.9)	1.10	0.999
70-4.25% (31 - 58-4.25% (25	25.8	62.4	(-209.4, 260.9)	0.41	1.000
70-4.25% (38 - 58-4.25% (25	-12.4	62.4	(-247.6, 222.8)	-0.20	1.000
70-5% (25.4 - 58-4.25% (25	9.5	69.8	(-253.4, 272.5)	0.14	1.000
70-5% (31.8 - 58-4.25% (25	-20.0	69.8	(-282.9, 242.9)	-0.29	1.000

70-5% (38 mm - 58-4.25% (25	-130.6	62.4	(-365.8, 104.6)	-2.09	0.802
70-5.75% (25 - 58-4.25% (25	80.9	62.4	(-154.3, 316.0)	1.30	0.997
70-5.75% (31 - 58-4.25% (25	-2.9	62.4	(-238.0, 232.3)	-0.05	1.000
70-5.75% (38 - 58-4.25% (25	33.6	62.4	(-201.6, 268.7)	0.54	1.000
58-4.25% (38 - 58-4.25% (31	-6.0	62.4	(-241.2, 229.2)	-0.10	1.000
58-5% (25.4 - 58-4.25% (31	85.3	62.4	(-149.9, 320.5)	1.37	0.994
58-5% (31.8 - 58-4.25% (31	24.3	62.4	(-210.8, 259.5)	0.39	1.000
58-5% (38 mm - 58-4.25% (31	-21.0	62.4	(-256.1, 214.2)	-0.34	1.000
58-5.75% (25 - 58-4.25% (31	94.4	62.4	(-140.8, 329.5)	1.51	0.983
58-5.75% (31 - 58-4.25% (31	67.2	62.4	(-167.9, 302.4)	1.08	1.000
58-5.75% (38 - 58-4.25% (31	57.1	62.4	(-178.0, 292.3)	0.92	1.000
70-4.25% (25 - 58-4.25% (31	225.3	62.4	(-9.9, 460.5)	3.61	0.072
70-4.25% (31 - 58-4.25% (31	182.3	62.4	(-52.8, 417.5)	2.92	0.292
70-4.25% (38 - 58-4.25% (31	144.2	62.4	(-91.0, 379.4)	2.31	0.671
70-5% (25.4 - 58-4.25% (31	166.1	69.8	(-96.8, 429.1)	2.38	0.625

70-5% (31.8 - 58-4.25% (31	136.6	69.8	(-126.3, 399.5)	1.96	0.869
70-5% (38 mm - 58-4.25% (31	26.0	62.4	(-209.2, 261.2)	0.42	1.000
70-5.75% (25 - 58-4.25% (31	237.5	62.4	(2.3, 472.6)	3.81	0.046
70-5.75% (31 - 58-4.25% (31	153.7	62.4	(-81.4, 388.9)	2.46	0.570
70-5.75% (38 - 58-4.25% (31	190.2	62.4	(-45.0, 425.3)	3.05	0.234
58-5% (25.4 - 58-4.25% (38	91.3	62.4	(-143.8, 326.5)	1.46	0.988
58-5% (31.8 - 58-4.25% (38	30.4	62.4	(-204.8, 265.5)	0.49	1.000
58-5% (38 mm - 58-4.25% (38	-14.9	62.4	(-250.1, 220.2)	-0.24	1.000
58-5.75% (25 - 58-4.25% (38	100.4	62.4	(-134.8, 335.6)	1.61	0.971
58-5.75% (31 - 58-4.25% (38	73.3	62.4	(-161.9, 308.4)	1.17	0.999
58-5.75% (38 - 58-4.25% (38	63.2	62.4	(-172.0, 298.3)	1.01	1.000
70-4.25% (25 - 58-4.25% (38	231.3	62.4	(-3.9, 466.5)	3.71	0.058
70-4.25% (31 - 58-4.25% (38	188.4	62.4	(-46.8, 423.5)	3.02	0.246
70-4.25% (38 - 58-4.25% (38	150.2	62.4	(-85.0, 385.4)	2.41	0.607
70-5% (25.4 - 58-4.25% (38	172.1	69.8	(-90.8, 435.1)	2.47	0.567

70-5% (31.8 - 58-4.25% (38	142.6	69.8	(-120.3, 405.5)	2.04	0.828
70-5% (38 mm - 58-4.25% (38	32.0	62.4	(-203.1, 267.2)	0.51	1.000
70-5.75% (25 - 58-4.25% (38	243.5	62.4	(8.3, 478.7)	3.90	0.036
70-5.75% (31 - 58-4.25% (38	159.8	62.4	(-75.4, 394.9)	2.56	0.506
70-5.75% (38 - 58-4.25% (38	196.2	62.4	(-39.0, 431.4)	3.14	0.195
58-5% (31.8 - 58-5% (25.4	-61.0	62.4	(-296.1, 174.2)	-0.98	1.000
58-5% (38 mm - 58-5% (25.4	-106.3	62.4	(-341.4, 128.9)	-1.70	0.953
58-5.75% (25 - 58-5% (25.4	9.1	62.4	(-226.1, 244.2)	0.15	1.000
58-5.75% (31 - 58-5% (25.4	-18.1	62.4	(-253.2, 217.1)	-0.29	1.000
58-5.75% (38 - 58-5% (25.4	-28.2	62.4	(-263.3, 207.0)	-0.45	1.000
70-4.25% (25 - 58-5% (25.4	140.0	62.4	(-95.2, 375.2)	2.24	0.714
70-4.25% (31 - 58-5% (25.4	97.0	62.4	(-138.1, 332.2)	1.56	0.979
70-4.25% (38 - 58-5% (25.4	58.9	62.4	(-176.3, 294.1)	0.94	1.000
70-5% (25.4 - 58-5% (25.4	80.8	69.8	(-182.1, 343.7)	1.16	0.999
70-5% (31.8 - 58-5% (25.4	51.3	69.8	(-211.6, 314.2)	0.74	1.000

70-5% (38 mm - 58-5% (25.4	-59.3	62.4	(-294.5, 175.9)	-0.95	1.000
70-5.75% (25 - 58-5% (25.4	152.2	62.4	(-83.0, 387.3)	2.44	0.586
70-5.75% (31 - 58-5% (25.4	68.4	62.4	(-166.7, 303.6)	1.10	1.000
70-5.75% (38 - 58-5% (25.4	104.9	62.4	(-130.3, 340.0)	1.68	0.958
58-5% (38 mm - 58-5% (31.8	-45.3	62.4	(-280.5, 189.9)	-0.73	1.000
58-5.75% (25 - 58-5% (31.8	70.0	62.4	(-165.1, 305.2)	1.12	0.999
58-5.75% (31 - 58-5% (31.8	42.9	62.4	(-192.3, 278.1)	0.69	1.000
58-5.75% (38 - 58-5% (31.8	32.8	62.4	(-202.4, 268.0)	0.53	1.000
70-4.25% (25 - 58-5% (31.8	200.9	62.4	(-34.2, 436.1)	3.22	0.167
70-4.25% (31 - 58-5% (31.8	158.0	62.4	(-77.2, 393.2)	2.53	0.524
70-4.25% (38 - 58-5% (31.8	119.9	62.4	(-115.3, 355.0)	1.92	0.884
70-5% (25.4 - 58-5% (31.8	141.8	69.8	(-121.2, 404.7)	2.03	0.834
70-5% (31.8 - 58-5% (31.8	112.3	69.8	(-150.7, 375.2)	1.61	0.971
70-5% (38 mm - 58-5% (31.8	1.7	62.4	(-233.5, 236.9)	0.03	1.000
70-5.75% (25 - 58-5% (31.8	213.1	62.4	(-22.1, 448.3)	3.42	0.111

70-5.75% (31 - 58-5% (31.8	129.4	62.4	(-105.8, 364.6)	2.07	0.812
70-5.75% (38 - 58-5% (31.8	165.8	62.4	(-69.3, 401.0)	2.66	0.443
58-5.75% (25 - 58-5% (38 mm	115.3	62.4	(-119.9, 350.5)	1.85	0.912
58-5.75% (31 - 58-5% (38 mm	88.2	62.4	(-147.0, 323.4)	1.41	0.991
58-5.75% (38 - 58-5% (38 mm	78.1	62.4	(-157.1, 313.3)	1.25	0.998
70-4.25% (25 - 58-5% (38 mm	246.2	62.4	(11.1, 481.4)	3.95	0.032
70-4.25% (31 - 58-5% (38 mm	203.3	62.4	(-31.9, 438.5)	3.26	0.155
70-4.25% (38 - 58-5% (38 mm	165.2	62.4	(-70.0, 400.3)	2.65	0.450
70-5% (25.4 - 58-5% (38 mm	187.1	69.8	(-75.9, 450.0)	2.68	0.428
70-5% (31.8 - 58-5% (38 mm	157.6	69.8	(-105.4, 420.5)	2.26	0.704
70-5% (38 mm - 58-5% (38 mm	47.0	62.4	(-188.2, 282.1)	0.75	1.000
70-5.75% (25 - 58-5% (38 mm	258.4	62.4	(23.2, 493.6)	4.14	0.020
70-5.75% (31 - 58-5% (38 mm	174.7	62.4	(-60.5, 409.9)	2.80	0.358
70-5.75% (38 - 58-5% (38 mm	211.1	62.4	(-24.0, 446.3)	3.38	0.119
58-5.75% (31 - 58-5.75% (25	-27.1	62.4	(-262.3, 208.1)	-0.43	1.000

58-5.75% (38 - 58-5.75% (25	-37.2	62.4	(-272.4, 198.0)	-0.60	1.000
70-4.25% (25 - 58-5.75% (25	130.9	62.4	(-104.2, 366.1)	2.10	0.799
70-4.25% (31 - 58-5.75% (25	88.0	62.4	(-147.2, 323.2)	1.41	0.992
70-4.25% (38 - 58-5.75% (25	49.8	62.4	(-185.3, 285.0)	0.80	1.000
70-5% (25.4 - 58-5.75% (25	71.8	69.8	(-191.2, 334.7)	1.03	1.000
70-5% (31.8 - 58-5.75% (25	42.2	69.8	(-220.7, 305.2)	0.61	1.000
70-5% (38 mm - 58-5.75% (25	-68.3	62.4	(-303.5, 166.8)	-1.10	1.000
70-5.75% (25 - 58-5.75% (25	143.1	62.4	(-92.1, 378.3)	2.29	0.682
70-5.75% (31 - 58-5.75% (25	59.4	62.4	(-175.8, 294.6)	0.95	1.000
70-5.75% (38 - 58-5.75% (25	95.8	62.4	(-139.4, 331.0)	1.54	0.981
58-5.75% (38 - 58-5.75% (31	-10.1	62.4	(-245.3, 225.1)	-0.16	1.000
70-4.25% (25 - 58-5.75% (31	158.0	62.4	(-77.1, 393.2)	2.53	0.524
70-4.25% (31 - 58-5.75% (31	115.1	62.4	(-120.1, 350.3)	1.84	0.913
70-4.25% (38 - 58-5.75% (31	77.0	62.4	(-158.2, 312.1)	1.23	0.998
70-5% (25.4 - 58-5.75% (31	98.9	69.8	(-164.1, 361.8)	1.42	0.991

70-5% (31.8 - 58-5.75% (31	69.3	69.8	(-193.6, 332.3)	0.99	1.000
70-5% (38 mm - 58-5.75% (31	-41.2	62.4	(-276.4, 193.9)	-0.66	1.000
70-5.75% (25 - 58-5.75% (31	170.2	62.4	(-65.0, 405.4)	2.73	0.400
70-5.75% (31 - 58-5.75% (31	86.5	62.4	(-148.7, 321.7)	1.39	0.993
70-5.75% (38 - 58-5.75% (31	122.9	62.4	(-112.2, 358.1)	1.97	0.863
70-4.25% (25 - 58-5.75% (38	168.1	62.4	(-67.0, 403.3)	2.69	0.420
70-4.25% (31 - 58-5.75% (38	125.2	62.4	(-110.0, 360.4)	2.01	0.846
70-4.25% (38 - 58-5.75% (38	87.0	62.4	(-148.1, 322.2)	1.40	0.993
70-5% (25.4 - 58-5.75% (38	109.0	69.8	(-154.0, 371.9)	1.56	0.978
70-5% (31.8 - 58-5.75% (38	79.4	69.8	(-183.5, 342.4)	1.14	0.999
70-5% (38 mm - 58-5.75% (38	-31.1	62.4	(-266.3, 204.0)	-0.50	1.000
70-5.75% (25 - 58-5.75% (38	180.3	62.4	(-54.9, 415.5)	2.89	0.309
70-5.75% (31 - 58-5.75% (38	96.6	62.4	(-138.6, 331.8)	1.55	0.979
70-5.75% (38 - 58-5.75% (38	133.0	62.4	(-102.2, 368.2)	2.13	0.781
70-4.25% (31 - 70-4.25% (25	-42.9	62.4	(-278.1, 192.2)	-0.69	1.000

70-4.25% (38 - 70-4.25% (25	-81.1	62.4	(-316.3, 154.1)	-1.30	0.996
70-5% (25.4 - 70-4.25% (25	-59.2	69.8	(-322.1, 203.8)	-0.85	1.000
70-5% (31.8 - 70-4.25% (25	-88.7	69.8	(-351.6, 174.2)	-1.27	0.997
70-5% (38 mm - 70-4.25% (25	-199.3	62.4	(-434.4, 35.9)	-3.19	0.177
70-5.75% (25 - 70-4.25% (25	12.2	62.4	(-223.0, 247.3)	0.20	1.000
70-5.75% (31 - 70-4.25% (25	-71.5	62.4	(-306.7, 163.6)	-1.15	0.999
70-5.75% (38 - 70-4.25% (25	-35.1	62.4	(-270.3, 200.1)	-0.56	1.000
70-4.25% (38 - 70-4.25% (31	-38.2	62.4	(-273.3, 197.0)	-0.61	1.000
70-5% (25.4 - 70-4.25% (31	-16.2	69.8	(-279.2, 246.7)	-0.23	1.000
70-5% (31.8 - 70-4.25% (31	-45.8	69.8	(-308.7, 217.2)	-0.66	1.000
70-5% (38 mm - 70-4.25% (31	-156.3	62.4	(-391.5, 78.8)	-2.51	0.542
70-5.75% (25 - 70-4.25% (31	55.1	62.4	(-180.1, 290.3)	0.88	1.000
70-5.75% (31 - 70-4.25% (31	-28.6	62.4	(-263.8, 206.6)	-0.46	1.000
70-5.75% (38 - 70-4.25% (31	7.8	62.4	(-227.4, 243.0)	0.13	1.000
70-5% (25.4 - 70-4.25% (38	21.9	69.8	(-241.0, 284.9)	0.31	1.000

70-5% (31.8 - 70-4.25% (38	-7.6	69.8	(-270.5, 255.3)	-0.11	1.000
70-5% (38 mm - 70-4.25% (38	-118.2	62.4	(-353.4, 117.0)	-1.89	0.895
70-5.75% (25 - 70-4.25% (38	93.3	62.4	(-141.9, 328.4)	1.49	0.985
70-5.75% (31 - 70-4.25% (38	9.5	62.4	(-225.6, 244.7)	0.15	1.000
70-5.75% (38 - 70-4.25% (38	46.0	62.4	(-189.2, 281.1)	0.74	1.000
70-5% (31.8 - 70-5% (25.4	-29.5	76.4	(-317.6, 258.5)	-0.39	1.000
70-5% (38 mm - 70-5% (25.4	-140.1	69.8	(-403.0, 122.8)	-2.01	0.845
70-5.75% (25 - 70-5% (25.4	71.3	69.8	(-191.6, 334.3)	1.02	1.000
70-5.75% (31 - 70-5% (25.4	-12.4	69.8	(-275.3, 250.6)	-0.18	1.000
70-5.75% (38 - 70-5% (25.4	24.0	69.8	(-238.9, 287.0)	0.34	1.000
70-5% (38 mm - 70-5% (31.8	-110.6	69.8	(-373.5, 152.4)	-1.59	0.975
70-5.75% (25 - 70-5% (31.8	100.9	69.8	(-162.1, 363.8)	1.45	0.989
70-5.75% (31 - 70-5% (31.8	17.2	69.8	(-245.8, 280.1)	0.25	1.000
70-5.75% (38 - 70-5% (31.8	53.6	69.8	(-209.4, 316.5)	0.77	1.000
70-5.75% (25 - 70-5% (38 mm	211.4	62.4	(-23.7, 446.6)	3.39	0.118

70-5.75% (31 - 70-5% (38 mm	127.7	62.4	(-107.4, 362.9)	2.05	0.826
70-5.75% (38 - 70-5% (38 mm	164.2	62.4	(-71.0, 399.3)	2.63	0.460
70-5.75% (31 - 70-5.75% (25	-83.7	62.4	(-318.9, 151.5)	-1.34	0.995
70-5.75% (38 - 70-5.75% (25	-47.3	62.4	(-282.5, 187.9)	-0.76	1.000
70-5.75% (38 - 70-5.75% (31	36.4	62.4	(-198.7, 271.6)	0.58	1.000

Individual confidence level = 99.94%

B.16. Statistical Analysis of Cracking Resistance Index (CRI) of LMLC computed from the SCB-J_c Test

One-way ANOVA: CRI (SCB-J_c) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	18	58-4.25% (25.4 mm), 58-4.25% (31.8 mm), 58-4.25% (38 mm), 58-5% (25.4 mm), 58-5% (31.8 mm), 58-5% (38 mm), 58-5.75% (25.4 mm), 58-5.75% (31.8 mm), 58-5.75% (38 mm), 70-4.25% (25.4 mm), 70-4.25% (31.8 mm), 70-4.25% (38 mm), 70-5% (25.4 mm), 70-5% (31.8 mm), 70-5% (38 mm), 70-5.75% (25.4 mm), 70-5.75% (31.8 mm), 70-5.75% (38 mm)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	17	1030936	60643	7.58	0.000
Error	34	271964	7999		
Total	51	1302900			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
89.4367	79.13%	68.69%	52.31%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25% (25.4 mm)	3	530.4	20.5	(425.5, 635.3)
58-4.25% (31.8 mm)	3	528.3	65.5	(423.4, 633.3)
58-4.25% (38 mm)	3	659.9	103.5	(555.0, 764.9)
58-5% (25.4 mm)	3	598.4	22.1	(493.5, 703.4)
58-5% (31.8 mm)	3	451.0	77.9	(346.1, 555.9)
58-5% (38 mm)	3	818	183	(713, 923)
58-5.75% (25.4 mm)	3	564.93	11.35	(459.99, 669.86)
58-5.75% (31.8 mm)	3	751.6	17.7	(646.7, 856.6)
58-5.75% (38 mm)	3	888.1	90.9	(783.2, 993.0)
70-4.25% (25.4 mm)	3	517.5	58.7	(412.6, 622.4)
70-4.25% (31.8 mm)	3	676.7	108.1	(571.8, 781.6)
70-4.25% (38 mm)	3	757.7	44.3	(652.8, 862.7)
70-5% (25.4 mm)	2	606.775	1.130	(478.253, 735.296)
70-5% (31.8 mm)	2	500.3	73.6	(371.8, 628.8)

70-5% (38 mm)	3	688.9	128.0	(584.0, 793.8)
70-5.75% (25.4 mm)	3	756.0	135.8	(651.1, 860.9)
70-5.75% (31.8 mm)	3	767.4	48.2	(662.4, 872.3)
70-5.75% (38 mm)	3	976.3	121.9	(871.3, 1081.2)

Pooled StDev = 89.4367

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping				
70-5.75% (38 mm)	3	976.3	A				
58-5.75% (38 mm)	3	888.1	A	B			
58-5% (38 mm)	3	818	A	B	C		
70-5.75% (31.8 mm)	3	767.4	A	B	C	D	
70-4.25% (38 mm)	3	757.7	A	B	C	D	
70-5.75% (25.4 mm)	3	756.0	A	B	C	D	
58-5.75% (31.8 mm)	3	751.6	A	B	C	D	
70-5% (38 mm)	3	688.9		B	C	D	E
70-4.25% (31.8 mm)	3	676.7		B	C	D	E
58-4.25% (38 mm)	3	659.9		B	C	D	E
70-5% (25.4 mm)	2	606.775		B	C	D	E
58-5% (25.4 mm)	3	598.4			C	D	E
58-5.75% (25.4 mm)	3	564.93			C	D	E
58-4.25% (25.4 mm)	3	530.4				D	E
58-4.25% (31.8 mm)	3	528.3				D	E
70-4.25% (25.4 mm)	3	517.5				D	E
70-5% (31.8 mm)	2	500.3				D	E

58-5% (31.8 mm)	3	451.0					E

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-4.25% (31 - 58-4.25% (25	-2.0	73.0	(-277.3, 273.2)	-0.03	1.000
58-4.25% (38 - 58-4.25% (25	129.6	73.0	(-145.7, 404.8)	1.77	0.935
58-5% (25.4 - 58-4.25% (25	68.0	73.0	(-207.2, 343.3)	0.93	1.000
58-5% (31.8 - 58-4.25% (25	-79.4	73.0	(-354.6, 195.8)	-1.09	1.000
58-5% (38 mm - 58-4.25% (25	287.7	73.0	(12.4, 562.9)	3.94	0.033
58-5.75% (25 - 58-4.25% (25	34.5	73.0	(-240.7, 309.8)	0.47	1.000
58-5.75% (31 - 58-4.25% (25	221.2	73.0	(-54.0, 496.5)	3.03	0.242
58-5.75% (38 - 58-4.25% (25	357.7	73.0	(82.5, 632.9)	4.90	0.003
70-4.25% (25 - 58-4.25% (25	-12.9	73.0	(-288.1, 262.3)	-0.18	1.000
70-4.25% (31 - 58-4.25% (25	146.3	73.0	(-128.9, 421.5)	2.00	0.848
70-4.25% (38 - 58-4.25% (25	227.3	73.0	(-47.9, 502.6)	3.11	0.207

70-5% (25.4 - 58-4.25% (25	76.4	81.6	(-231.3, 384.1)	0.94	1.000
70-5% (31.8 - 58-4.25% (25	-30.1	81.6	(-337.8, 277.6)	-0.37	1.000
70-5% (38 mm - 58-4.25% (25	158.5	73.0	(-116.7, 433.7)	2.17	0.758
70-5.75% (25 - 58-4.25% (25	225.6	73.0	(-49.6, 500.8)	3.09	0.216
70-5.75% (31 - 58-4.25% (25	237.0	73.0	(-38.2, 512.2)	3.25	0.159
70-5.75% (38 - 58-4.25% (25	445.9	73.0	(170.7, 721.1)	6.11	0.000
58-4.25% (38 - 58-4.25% (31	131.6	73.0	(-143.6, 406.8)	1.80	0.927
58-5% (25.4 - 58-4.25% (31	70.1	73.0	(-205.1, 345.3)	0.96	1.000
58-5% (31.8 - 58-4.25% (31	-77.3	73.0	(-352.6, 197.9)	-1.06	1.000
58-5% (38 mm - 58-4.25% (31	289.7	73.0	(14.5, 564.9)	3.97	0.031
58-5.75% (25 - 58-4.25% (31	36.6	73.0	(-238.6, 311.8)	0.50	1.000
58-5.75% (31 - 58-4.25% (31	223.3	73.0	(-51.9, 498.5)	3.06	0.229
58-5.75% (38 - 58-4.25% (31	359.8	73.0	(84.5, 635.0)	4.93	0.002
70-4.25% (25 - 58-4.25% (31	-10.8	73.0	(-286.1, 264.4)	-0.15	1.000
70-4.25% (31 - 58-4.25% (31	148.3	73.0	(-126.9, 423.6)	2.03	0.834

70-4.25% (38 - 58-4.25% (31	229.4	73.0	(-45.8, 504.6)	3.14	0.196
70-5% (25.4 - 58-4.25% (31	78.4	81.6	(-229.3, 386.1)	0.96	1.000
70-5% (31.8 - 58-4.25% (31	-28.1	81.6	(-335.8, 279.6)	-0.34	1.000
70-5% (38 mm - 58-4.25% (31	160.6	73.0	(-114.7, 435.8)	2.20	0.741
70-5.75% (25 - 58-4.25% (31	227.7	73.0	(-47.6, 502.9)	3.12	0.205
70-5.75% (31 - 58-4.25% (31	239.0	73.0	(-36.2, 514.3)	3.27	0.150
70-5.75% (38 - 58-4.25% (31	447.9	73.0	(172.7, 723.1)	6.13	0.000
58-5% (25.4 - 58-4.25% (38	-61.5	73.0	(-336.7, 213.7)	-0.84	1.000
58-5% (31.8 - 58-4.25% (38	-208.9	73.0	(-484.2, 66.3)	-2.86	0.324
58-5% (38 mm - 58-4.25% (38	158.1	73.0	(-117.1, 433.3)	2.17	0.761
58-5.75% (25 - 58-4.25% (38	-95.0	73.0	(-370.2, 180.2)	-1.30	0.996
58-5.75% (31 - 58-4.25% (38	91.7	73.0	(-183.5, 366.9)	1.26	0.998
58-5.75% (38 - 58-4.25% (38	228.2	73.0	(-47.1, 503.4)	3.12	0.202
70-4.25% (25 - 58-4.25% (38	-142.4	73.0	(-417.7, 132.8)	-1.95	0.872
70-4.25% (31 - 58-4.25% (38	16.7	73.0	(-258.5, 292.0)	0.23	1.000

70-4.25% (38 - 58-4.25% (38	97.8	73.0	(-177.4, 373.0)	1.34	0.995
70-5% (25.4 - 58-4.25% (38	-53.2	81.6	(-360.9, 254.5)	-0.65	1.000
70-5% (31.8 - 58-4.25% (38	-159.7	81.6	(-467.4, 148.0)	-1.96	0.870
70-5% (38 mm - 58-4.25% (38	29.0	73.0	(-246.3, 304.2)	0.40	1.000
70-5.75% (25 - 58-4.25% (38	96.1	73.0	(-179.2, 371.3)	1.32	0.996
70-5.75% (31 - 58-4.25% (38	107.4	73.0	(-167.8, 382.6)	1.47	0.987
70-5.75% (38 - 58-4.25% (38	316.3	73.0	(41.1, 591.5)	4.33	0.012
58-5% (31.8 - 58-5% (25.4	-147.4	73.0	(-422.6, 127.8)	-2.02	0.840
58-5% (38 mm - 58-5% (25.4	219.6	73.0	(-55.6, 494.8)	3.01	0.252
58-5.75% (25 - 58-5% (25.4	-33.5	73.0	(-308.7, 241.7)	-0.46	1.000
58-5.75% (31 - 58-5% (25.4	153.2	73.0	(-122.0, 428.4)	2.10	0.800
58-5.75% (38 - 58-5% (25.4	289.7	73.0	(14.4, 564.9)	3.97	0.031
70-4.25% (25 - 58-5% (25.4	-80.9	73.0	(-356.2, 194.3)	-1.11	0.999
70-4.25% (31 - 58-5% (25.4	78.3	73.0	(-197.0, 353.5)	1.07	1.000
70-4.25% (38 - 58-5% (25.4	159.3	73.0	(-115.9, 434.5)	2.18	0.752

70-5% (25.4 - 58-5% (25.4	8.3	81.6	(-299.4, 316.0)	0.10	1.000
70-5% (31.8 - 58-5% (25.4	-98.2	81.6	(-405.9, 209.6)	-1.20	0.999
70-5% (38 mm - 58-5% (25.4	90.5	73.0	(-184.8, 365.7)	1.24	0.998
70-5.75% (25 - 58-5% (25.4	157.6	73.0	(-117.7, 432.8)	2.16	0.766
70-5.75% (31 - 58-5% (25.4	168.9	73.0	(-106.3, 444.2)	2.31	0.669
70-5.75% (38 - 58-5% (25.4	377.8	73.0	(102.6, 653.1)	5.17	0.001
58-5% (38 mm - 58-5% (31.8	367.0	73.0	(91.8, 642.3)	5.03	0.002
58-5.75% (25 - 58-5% (31.8	113.9	73.0	(-161.3, 389.1)	1.56	0.978
58-5.75% (31 - 58-5% (31.8	300.6	73.0	(25.4, 575.8)	4.12	0.021
58-5.75% (38 - 58-5% (31.8	437.1	73.0	(161.9, 712.3)	5.99	0.000
70-4.25% (25 - 58-5% (31.8	66.5	73.0	(-208.7, 341.7)	0.91	1.000
70-4.25% (31 - 58-5% (31.8	225.7	73.0	(-49.5, 500.9)	3.09	0.216
70-4.25% (38 - 58-5% (31.8	306.7	73.0	(31.5, 581.9)	4.20	0.017
70-5% (25.4 - 58-5% (31.8	155.8	81.6	(-151.9, 463.5)	1.91	0.889
70-5% (31.8 - 58-5% (31.8	49.3	81.6	(-258.4, 357.0)	0.60	1.000
70-5% (38 mm - 58-5% (31.8	237.9	73.0	(-37.3, 513.1)	3.26	0.155

70-5.75% (25 - 58-5% (31.8	305.0	73.0	(29.8, 580.2)	4.18	0.018
70-5.75% (31 - 58-5% (31.8	316.4	73.0	(41.1, 591.6)	4.33	0.012
70-5.75% (38 - 58-5% (31.8	525.3	73.0	(250.0, 800.5)	7.19	0.000
58-5.75% (25 - 58-5% (38 mm	-253.1	73.0	(-528.3, 22.1)	-3.47	0.100
58-5.75% (31 - 58-5% (38 mm	-66.4	73.0	(-341.6, 208.8)	-0.91	1.000
58-5.75% (38 - 58-5% (38 mm	70.1	73.0	(-205.2, 345.3)	0.96	1.000
70-4.25% (25 - 58-5% (38 mm	-300.5	73.0	(-575.8, -25.3)	-4.12	0.021
70-4.25% (31 - 58-5% (38 mm	-141.4	73.0	(-416.6, 133.9)	-1.94	0.878
70-4.25% (38 - 58-5% (38 mm	-60.3	73.0	(-335.5, 214.9)	-0.83	1.000
70-5% (25.4 - 58-5% (38 mm	-211.3	81.6	(-519.0, 96.4)	-2.59	0.488
70-5% (31.8 - 58-5% (38 mm	-317.8	81.6	(-625.5, -10.1)	-3.89	0.037
70-5% (38 mm - 58-5% (38 mm	-129.1	73.0	(-404.4, 146.1)	-1.77	0.936
70-5.75% (25 - 58-5% (38 mm	-62.0	73.0	(-337.3, 213.2)	-0.85	1.000
70-5.75% (31 - 58-5% (38 mm	-50.7	73.0	(-325.9, 224.5)	-0.69	1.000
70-5.75% (38 - 58-5% (38 mm	158.2	73.0	(-117.0, 433.4)	2.17	0.761
58-5.75% (31 - 58-5.75% (25	186.7	73.0	(-88.5, 461.9)	2.56	0.508

58-5.75% (38 - 58-5.75% (25	323.2	73.0	(48.0, 598.4)	4.43	0.009
70-4.25% (25 - 58-5.75% (25	-47.4	73.0	(-322.6, 227.8)	-0.65	1.000
70-4.25% (31 - 58-5.75% (25	111.8	73.0	(-163.5, 387.0)	1.53	0.982
70-4.25% (38 - 58-5.75% (25	192.8	73.0	(-82.4, 468.0)	2.64	0.454
70-5% (25.4 - 58-5.75% (25	41.8	81.6	(-265.9, 349.6)	0.51	1.000
70-5% (31.8 - 58-5.75% (25	-64.6	81.6	(-372.4, 243.1)	-0.79	1.000
70-5% (38 mm - 58-5.75% (25	124.0	73.0	(-151.2, 399.2)	1.70	0.954
70-5.75% (25 - 58-5.75% (25	191.1	73.0	(-84.1, 466.3)	2.62	0.469
70-5.75% (31 - 58-5.75% (25	202.4	73.0	(-72.8, 477.7)	2.77	0.374
70-5.75% (38 - 58-5.75% (25	411.3	73.0	(136.1, 686.6)	5.63	0.000
58-5.75% (38 - 58-5.75% (31	136.5	73.0	(-138.8, 411.7)	1.87	0.904
70-4.25% (25 - 58-5.75% (31	-234.1	73.0	(-509.4, 41.1)	-3.21	0.172
70-4.25% (31 - 58-5.75% (31	-74.9	73.0	(-350.2, 200.3)	-1.03	1.000
70-4.25% (38 - 58-5.75% (31	6.1	73.0	(-269.1, 281.3)	0.08	1.000
70-5% (25.4 - 58-5.75% (31	-144.9	81.6	(-452.6, 162.9)	-1.77	0.935

70-5% (31.8 - 58-5.75% (31	-251.3	81.6	(-559.1, 56.4)	-3.08	0.221
70-5% (38 mm - 58-5.75% (31	-62.7	73.0	(-338.0, 212.5)	-0.86	1.000
70-5.75% (25 - 58-5.75% (31	4.4	73.0	(-270.8, 279.6)	0.06	1.000
70-5.75% (31 - 58-5.75% (31	15.7	73.0	(-259.5, 291.0)	0.22	1.000
70-5.75% (38 - 58-5.75% (31	224.6	73.0	(-50.6, 499.9)	3.08	0.222
70-4.25% (25 - 58-5.75% (38	-370.6	73.0	(-645.8, -95.4)	-5.07	0.002
70-4.25% (31 - 58-5.75% (38	-211.4	73.0	(-486.6, 63.8)	-2.90	0.306
70-4.25% (38 - 58-5.75% (38	-130.4	73.0	(-405.6, 144.8)	-1.79	0.932
70-5% (25.4 - 58-5.75% (38	-281.3	81.6	(-589.0, 26.4)	-3.45	0.104
70-5% (31.8 - 58-5.75% (38	-387.8	81.6	(-695.5, -80.1)	-4.75	0.004
70-5% (38 mm - 58-5.75% (38	-199.2	73.0	(-474.4, 76.0)	-2.73	0.400
70-5.75% (25 - 58-5.75% (38	-132.1	73.0	(-407.3, 143.1)	-1.81	0.924
70-5.75% (31 - 58-5.75% (38	-120.7	73.0	(-395.9, 154.5)	-1.65	0.963
70-5.75% (38 - 58-5.75% (38	88.2	73.0	(-187.1, 363.4)	1.21	0.998
70-4.25% (31 - 70-4.25% (25	159.2	73.0	(-116.0, 434.4)	2.18	0.753

70-4.25% (38 - 70-4.25% (25	240.2	73.0	(-35.0, 515.4)	3.29	0.145
70-5% (25.4 - 70-4.25% (25	89.3	81.6	(-218.4, 397.0)	1.09	1.000
70-5% (31.8 - 70-4.25% (25	-17.2	81.6	(-324.9, 290.5)	-0.21	1.000
70-5% (38 mm - 70-4.25% (25	171.4	73.0	(-103.8, 446.6)	2.35	0.647
70-5.75% (25 - 70-4.25% (25	238.5	73.0	(-36.7, 513.7)	3.27	0.153
70-5.75% (31 - 70-4.25% (25	249.9	73.0	(-25.3, 525.1)	3.42	0.110
70-5.75% (38 - 70-4.25% (25	458.8	73.0	(183.5, 734.0)	6.28	0.000
70-4.25% (38 - 70-4.25% (31	81.0	73.0	(-194.2, 356.3)	1.11	0.999
70-5% (25.4 - 70-4.25% (31	-69.9	81.6	(-377.6, 237.8)	-0.86	1.000
70-5% (31.8 - 70-4.25% (31	-176.4	81.6	(-484.1, 131.3)	-2.16	0.764
70-5% (38 mm - 70-4.25% (31	12.2	73.0	(-263.0, 287.4)	0.17	1.000
70-5.75% (25 - 70-4.25% (31	79.3	73.0	(-195.9, 354.5)	1.09	1.000
70-5.75% (31 - 70-4.25% (31	90.7	73.0	(-184.5, 365.9)	1.24	0.998
70-5.75% (38 - 70-4.25% (31	299.6	73.0	(24.4, 574.8)	4.10	0.022
70-5% (25.4 - 70-4.25% (38	-151.0	81.6	(-458.7, 156.8)	-1.85	0.911

70-5% (31.8 - 70-4.25% (38	-257.4	81.6	(-565.2, 50.3)	-3.15	0.191
70-5% (38 mm - 70-4.25% (38	-68.8	73.0	(-344.1, 206.4)	-0.94	1.000
70-5.75% (25 - 70-4.25% (38	-1.7	73.0	(-276.9, 273.5)	-0.02	1.000
70-5.75% (31 - 70-4.25% (38	9.6	73.0	(-265.6, 284.9)	0.13	1.000
70-5.75% (38 - 70-4.25% (38	218.5	73.0	(-56.7, 493.8)	2.99	0.258
70-5% (31.8 - 70-5% (25.4	-106.5	89.4	(-443.6, 230.6)	-1.19	0.999
70-5% (38 mm - 70-5% (25.4	82.1	81.6	(-225.6, 389.8)	1.01	1.000
70-5.75% (25 - 70-5% (25.4	149.2	81.6	(-158.5, 456.9)	1.83	0.918
70-5.75% (31 - 70-5% (25.4	160.6	81.6	(-147.1, 468.3)	1.97	0.865
70-5.75% (38 - 70-5% (25.4	369.5	81.6	(61.8, 677.2)	4.53	0.007
70-5% (38 mm - 70-5% (31.8	188.6	81.6	(-119.1, 496.3)	2.31	0.671
70-5.75% (25 - 70-5% (31.8	255.7	81.6	(-52.0, 563.4)	3.13	0.199
70-5.75% (31 - 70-5% (31.8	267.1	81.6	(-40.6, 574.8)	3.27	0.151
70-5.75% (38 - 70-5% (31.8	476.0	81.6	(168.3, 783.7)	5.83	0.000
70-5.75% (25 - 70-5% (38 mm	67.1	73.0	(-208.1, 342.3)	0.92	1.000

70-5.75% (31 - 70-5% (38 mm	78.5	73.0	(-196.7, 353.7)	1.07	1.000
70-5.75% (38 - 70-5% (38 mm	287.4	73.0	(12.1, 562.6)	3.94	0.033
70-5.75% (31 - 70-5.75% (25	11.4	73.0	(-263.9, 286.6)	0.16	1.000
70-5.75% (38 - 70-5.75% (25	220.3	73.0	(-55.0, 495.5)	3.02	0.247
70-5.75% (38 - 70-5.75% (31	208.9	73.0	(-66.3, 484.1)	2.86	0.324

Individual confidence level = 99.94%

B.17. Statistical Analysis of Fracture Energy of PMLC computed from the SCB-J_c Test

One-way ANOVA: G_f (SCB-J_c) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	27	D1L1 (25.4 mm), D1L1 (31.8 mm), D1L1 (38 mm), D2L1 (25.4 mm), D2L1 (31.8 mm), D2L1 (38 mm), D3L1 (25.4 mm), D3L1 (31.8 mm), D3L1 (38 mm), D3L2 (25.4 mm), D3L2 (31.8 mm), D3L2 (38 mm), D3L3 (25.4 mm), D3L3 (31.8 mm), D3L3 (38 mm), D3L4 (25.4 mm), D3L4 (31.8 mm), D3L4 (38 mm), D3L5 (25.4 mm), D3L5 (31.8 mm), D3L5 (38 mm), D5L1 (25.4 mm), D5L1 (31.8 mm), D5L1 (38 mm), D6L1 (25.4 mm), D6L1 (31.8 mm), D6L1 (38 mm)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	26	3563531	137059	10.91	0.000
Error	36	452446	12568		
Total	62	4015977			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
112.107	88.73%	80.60%	68.52%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1 (25.4 mm)	3	644.5	31.5	(513.2, 775.8)
D1L1 (31.8 mm)	3	597	179	(466, 728)
D1L1 (38 mm)	2	553.6	53.5	(392.8, 714.4)
D2L1 (25.4 mm)	2	835.3	60.4	(674.5, 996.0)
D2L1 (31.8 mm)	3	585	253	(454, 716)
D2L1 (38 mm)	3	675.3	95.8	(544.0, 806.5)
D3L1 (25.4 mm)	2	108.63	3.69	(-52.14, 269.40)
D3L1 (31.8 mm)	2	52.5	15.4	(-108.3, 213.3)
D3L1 (38 mm)	2	77.6	48.2	(-83.2, 238.4)
D3L2 (25.4 mm)	2	673.21	14.13	(512.44, 833.98)
D3L2 (31.8 mm)	3	490.3	86.1	(359.0, 621.6)
D3L2 (38 mm)	2	357.6	17.9	(196.8, 518.3)
D3L3 (25.4 mm)	2	526.04	13.25	(365.27, 686.81)
D3L3 (31.8 mm)	3	363.3	65.5	(232.0, 494.6)
D3L3 (38 mm)	2	353.69	4.26	(192.92, 514.46)
D3L4 (25.4 mm)	2	837.7	71.1	(676.9, 998.5)
D3L4 (31.8 mm)	3	713.0	131.5	(581.7, 844.2)
D3L4 (38 mm)	2	368.2	98.4	(207.4, 529.0)

D3L5 (25.4 mm)	3	520.1	41.5	(388.8, 651.4)
D3L5 (31.8 mm)	2	302.0	26.5	(141.3, 462.8)
D3L5 (38 mm)	2	239.0	85.3	(78.2, 399.8)
D5L1 (25.4 mm)	2	623	234	(463, 784)
D5L1 (31.8 mm)	2	430	181	(269, 591)
D5L1 (38 mm)	3	449.9	137.3	(318.6, 581.2)
D6L1 (25.4 mm)	2	1188.9	56.4	(1028.1, 1349.7)
D6L1 (31.8 mm)	2	841.1	131.3	(680.4, 1001.9)
D6L1 (38 mm)	2	681.2	17.0	(520.5, 842.0)

Pooled StDev = 112.107

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping								
D6L1 (25.4 mm)	2	1188.9	A								
D6L1 (31.8 mm)	2	841.1	A	B							
D3L4 (25.4 mm)	2	837.7	A	B							
D2L1 (25.4 mm)	2	835.3	A	B							
D3L4 (31.8 mm)	3	713.0		B	C						
D6L1 (38 mm)	2	681.2		B	C	D	E				
D2L1 (38 mm)	3	675.3		B	C	D					
D3L2 (25.4 mm)	2	673.21		B	C	D	E				
D1L1 (25.4 mm)	3	644.5		B	C	D	E				
D5L1 (25.4 mm)	2	623		B	C	D	E				
D1L1 (31.8 mm)	3	597		B	C	D	E				
D2L1 (31.8 mm)	3	585		B	C	D	E				
D1L1 (38 mm)	2	553.6		B	C	D	E	F			
D3L3 (25.4 mm)	2	526.04		B	C	D	E	F	G	H	
D3L5 (25.4 mm)	3	520.1		B	C	D	E				
D3L2 (31.8 mm)	3	490.3		B	C	D	E	F			

D5L1 (38 mm)	3	449.9		B	C	D	E	F	G	H	I
D5L1 (31.8 mm)	2	430		B	C	D	E	F	G	H	I
D3L4 (38 mm)	2	368.2			C	D	E	F	G	H	I
D3L3 (31.8 mm)	3	363.3			C	D	E	F	G	H	I
D3L2 (38 mm)	2	357.6			C	D	E	F	G	H	I
D3L3 (38 mm)	2	353.69			C	D	E	F	G	H	I
D3L5 (31.8 mm)	2	302.0				D	E	F	G	H	I
D3L5 (38 mm)	2	239.0					E	F	G	H	I
D3L1 (25.4 mm)	2	108.63						F		H	I
D3L1 (38 mm)	2	77.6							G	H	I
D3L1 (31.8 mm)	2	52.5									I

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D1L1 (31.8 m - D1L1 (25.4 m	-47.6	91.5	(-414.0, 318.7)	-0.52	1.000
D1L1 (38 mm) - D1L1 (25.4 m	-91	102	(-500, 319)	-0.89	1.000
D2L1 (25.4 m - D1L1 (25.4 m	191	102	(-219, 600)	1.86	0.974
D2L1 (31.8 m - D1L1 (25.4 m	-59.4	91.5	(-425.8, 306.9)	-0.65	1.000
D2L1 (38 mm) - D1L1 (25.4 m	30.8	91.5	(-335.6, 397.1)	0.34	1.000
D3L1 (25.4 m - D1L1 (25.4 m	-536	102	(-945, -126)	-5.24	0.002
D3L1 (31.8 m - D1L1 (25.4 m	-592	102	(-1002, -182)	-5.78	0.000

D3L1 (38 mm) - D1L1 (25.4 m	-567	102	(-977, -157)	-5.54	0.001
D3L2 (25.4 m - D1L1 (25.4 m	29	102	(-381, 438)	0.28	1.000
D3L2 (31.8 m - D1L1 (25.4 m	-154.2	91.5	(-520.6, 212.1)	-1.68	0.992
D3L2 (38 mm) - D1L1 (25.4 m	-287	102	(-697, 123)	-2.80	0.514
D3L3 (25.4 m - D1L1 (25.4 m	-118	102	(-528, 291)	-1.16	1.000
D3L3 (31.8 m - D1L1 (25.4 m	-281.2	91.5	(-647.6, 85.1)	-3.07	0.346
D3L3 (38 mm) - D1L1 (25.4 m	-291	102	(-700, 119)	-2.84	0.488
D3L4 (25.4 m - D1L1 (25.4 m	193	102	(-216, 603)	1.89	0.970
D3L4 (31.8 m - D1L1 (25.4 m	68.4	91.5	(-297.9, 434.8)	0.75	1.000
D3L4 (38 mm) - D1L1 (25.4 m	-276	102	(-686, 133)	-2.70	0.584
D3L5 (25.4 m - D1L1 (25.4 m	-124.4	91.5	(-490.7, 241.9)	-1.36	1.000
D3L5 (31.8 m - D1L1 (25.4 m	-342	102	(-752, 67)	-3.35	0.211
D3L5 (38 mm) - D1L1 (25.4 m	-405	102	(-815, 4)	-3.96	0.055
D5L1 (25.4 m - D1L1 (25.4 m	-21	102	(-431, 388)	-0.21	1.000
D5L1 (31.8 m - D1L1 (25.4 m	-215	102	(-624, 195)	-2.10	0.918

D5L1 (38 mm) - D1L1 (25.4 m	-194.6	91.5	(-560.9, 171.7)	-2.13	0.908
D6L1 (25.4 m - D1L1 (25.4 m	544	102	(135, 954)	5.32	0.001
D6L1 (31.8 m - D1L1 (25.4 m	197	102	(-213, 606)	1.92	0.964
D6L1 (38 mm) - D1L1 (25.4 m	37	102	(-373, 446)	0.36	1.000
D1L1 (38 mm) - D1L1 (31.8 m	-43	102	(-453, 366)	-0.42	1.000
D2L1 (25.4 m - D1L1 (31.8 m	238	102	(-171, 648)	2.33	0.817
D2L1 (31.8 m - D1L1 (31.8 m	-11.8	91.5	(-378.1, 354.6)	-0.13	1.000
D2L1 (38 mm) - D1L1 (31.8 m	78.4	91.5	(-288.0, 444.7)	0.86	1.000
D3L1 (25.4 m - D1L1 (31.8 m	-488	102	(-898, -79)	-4.77	0.007
D3L1 (31.8 m - D1L1 (31.8 m	-544	102	(-954, -135)	-5.32	0.001
D3L1 (38 mm) - D1L1 (31.8 m	-519	102	(-929, -110)	-5.07	0.003
D3L2 (25.4 m - D1L1 (31.8 m	76	102	(-333, 486)	0.75	1.000
D3L2 (31.8 m - D1L1 (31.8 m	-106.6	91.5	(-472.9, 259.8)	-1.16	1.000
D3L2 (38 mm) - D1L1 (31.8 m	-239	102	(-649, 170)	-2.34	0.813
D3L3 (25.4 m - D1L1 (31.8 m	-71	102	(-480, 339)	-0.69	1.000

D3L3 (31.8 m - D1L1 (31.8 m	-233.6	91.5	(-599.9, 132.8)	-2.55	0.684
D3L3 (38 mm) - D1L1 (31.8 m	-243	102	(-653, 166)	-2.38	0.792
D3L4 (25.4 m - D1L1 (31.8 m	241	102	(-169, 650)	2.35	0.804
D3L4 (31.8 m - D1L1 (31.8 m	116.1	91.5	(-250.3, 482.4)	1.27	1.000
D3L4 (38 mm) - D1L1 (31.8 m	-229	102	(-638, 181)	-2.23	0.864
D3L5 (25.4 m - D1L1 (31.8 m	-76.8	91.5	(-443.1, 289.6)	-0.84	1.000
D3L5 (31.8 m - D1L1 (31.8 m	-295	102	(-704, 115)	-2.88	0.463
D3L5 (38 mm) - D1L1 (31.8 m	-358	102	(-767, 52)	-3.50	0.156
D5L1 (25.4 m - D1L1 (31.8 m	26	102	(-383, 436)	0.26	1.000
D5L1 (31.8 m - D1L1 (31.8 m	-167	102	(-577, 243)	-1.63	0.994
D5L1 (38 mm) - D1L1 (31.8 m	-147.0	91.5	(-513.3, 219.4)	-1.61	0.996
D6L1 (25.4 m - D1L1 (31.8 m	592	102	(182, 1002)	5.78	0.000
D6L1 (31.8 m - D1L1 (31.8 m	244	102	(-165, 654)	2.39	0.786
D6L1 (38 mm) - D1L1 (31.8 m	84	102	(-325, 494)	0.82	1.000
D2L1 (25.4 m - D1L1 (38 mm)	282	112	(-167, 730)	2.51	0.709

D2L1 (31.8 m - D1L1 (38 mm)	31	102	(-378, 441)	0.31	1.000
D2L1 (38 mm) - D1L1 (38 mm)	122	102	(-288, 531)	1.19	1.000
D3L1 (25.4 m - D1L1 (38 mm)	-445	112	(-894, 4)	-3.97	0.054
D3L1 (31.8 m - D1L1 (38 mm)	-501	112	(-950, -52)	-4.47	0.015
D3L1 (38 mm) - D1L1 (38 mm)	-476	112	(-925, -27)	-4.25	0.027
D3L2 (25.4 m - D1L1 (38 mm)	120	112	(-329, 568)	1.07	1.000
D3L2 (31.8 m - D1L1 (38 mm)	-63	102	(-473, 346)	-0.62	1.000
D3L2 (38 mm) - D1L1 (38 mm)	-196	112	(-645, 253)	-1.75	0.987
D3L3 (25.4 m - D1L1 (38 mm)	-28	112	(-476, 421)	-0.25	1.000
D3L3 (31.8 m - D1L1 (38 mm)	-190	102	(-600, 219)	-1.86	0.974
D3L3 (38 mm) - D1L1 (38 mm)	-200	112	(-649, 249)	-1.78	0.984
D3L4 (25.4 m - D1L1 (38 mm)	284	112	(-165, 733)	2.53	0.695
D3L4 (31.8 m - D1L1 (38 mm)	159	102	(-250, 569)	1.56	0.997
D3L4 (38 mm) - D1L1 (38 mm)	-185	112	(-634, 263)	-1.65	0.993
D3L5 (25.4 m - D1L1 (38 mm)	-33	102	(-443, 376)	-0.33	1.000

D3L5 (31.8 m - D1L1 (38 mm)	-252	112	(-700, 197)	-2.24	0.860
D3L5 (38 mm) - D1L1 (38 mm)	-315	112	(-763, 134)	-2.81	0.512
D5L1 (25.4 m - D1L1 (38 mm)	70	112	(-379, 518)	0.62	1.000
D5L1 (31.8 m - D1L1 (38 mm)	-124	112	(-572, 325)	-1.10	1.000
D5L1 (38 mm) - D1L1 (38 mm)	-104	102	(-513, 306)	-1.01	1.000
D6L1 (25.4 m - D1L1 (38 mm)	635	112	(187, 1084)	5.67	0.001
D6L1 (31.8 m - D1L1 (38 mm)	288	112	(-161, 736)	2.56	0.675
D6L1 (38 mm) - D1L1 (38 mm)	128	112	(-321, 576)	1.14	1.000
D2L1 (31.8 m - D2L1 (25.4 m	-250	102	(-660, 159)	-2.44	0.752
D2L1 (38 mm) - D2L1 (25.4 m	-160	102	(-570, 250)	-1.56	0.997
D3L1 (25.4 m - D2L1 (25.4 m	-727	112	(-1175, -278)	-6.48	0.000
D3L1 (31.8 m - D2L1 (25.4 m	-783	112	(-1231, -334)	-6.98	0.000
D3L1 (38 mm) - D2L1 (25.4 m	-758	112	(-1206, -309)	-6.76	0.000
D3L2 (25.4 m - D2L1 (25.4 m	-162	112	(-611, 287)	-1.45	0.999
D3L2 (31.8 m - D2L1 (25.4 m	-345	102	(-755, 65)	-3.37	0.202

D3L2 (38 mm) - D2L1 (25.4 m	-478	112	(-926, -29)	-4.26	0.026
D3L3 (25.4 m - D2L1 (25.4 m	-309	112	(-758, 139)	-2.76	0.544
D3L3 (31.8 m - D2L1 (25.4 m	-472	102	(-882, -62)	-4.61	0.010
D3L3 (38 mm) - D2L1 (25.4 m	-482	112	(-930, -33)	-4.30	0.024
D3L4 (25.4 m - D2L1 (25.4 m	2	112	(-446, 451)	0.02	1.000
D3L4 (31.8 m - D2L1 (25.4 m	-122	102	(-532, 287)	-1.20	1.000
D3L4 (38 mm) - D2L1 (25.4 m	-467	112	(-916, -18)	-4.17	0.033
D3L5 (25.4 m - D2L1 (25.4 m	-315	102	(-725, 94)	-3.08	0.341
D3L5 (31.8 m - D2L1 (25.4 m	-533	112	(-982, -85)	-4.76	0.007
D3L5 (38 mm) - D2L1 (25.4 m	-596	112	(-1045, -148)	-5.32	0.001
D5L1 (25.4 m - D2L1 (25.4 m	-212	112	(-661, 237)	-1.89	0.969
D5L1 (31.8 m - D2L1 (25.4 m	-405	112	(-854, 43)	-3.62	0.121
D5L1 (38 mm) - D2L1 (25.4 m	-385	102	(-795, 24)	-3.77	0.087
D6L1 (25.4 m - D2L1 (25.4 m	354	112	(-95, 802)	3.15	0.301
D6L1 (31.8 m - D2L1 (25.4 m	6	112	(-443, 455)	0.05	1.000

D6L1 (38 mm) - D2L1 (25.4 m	-154	112	(-603, 295)	-1.37	1.000
D2L1 (38 mm) - D2L1 (31.8 m	90.2	91.5	(-276.2, 456.5)	0.99	1.000
D3L1 (25.4 m - D2L1 (31.8 m	-476	102	(-886, -67)	-4.66	0.009
D3L1 (31.8 m - D2L1 (31.8 m	-533	102	(-942, -123)	-5.20	0.002
D3L1 (38 mm) - D2L1 (31.8 m	-508	102	(-917, -98)	-4.96	0.004
D3L2 (25.4 m - D2L1 (31.8 m	88	102	(-321, 498)	0.86	1.000
D3L2 (31.8 m - D2L1 (31.8 m	-94.8	91.5	(-461.2, 271.5)	-1.04	1.000
D3L2 (38 mm) - D2L1 (31.8 m	-228	102	(-637, 182)	-2.22	0.869
D3L3 (25.4 m - D2L1 (31.8 m	-59	102	(-469, 351)	-0.58	1.000
D3L3 (31.8 m - D2L1 (31.8 m	-221.8	91.5	(-588.1, 144.5)	-2.42	0.764
D3L3 (38 mm) - D2L1 (31.8 m	-231	102	(-641, 178)	-2.26	0.852
D3L4 (25.4 m - D2L1 (31.8 m	253	102	(-157, 662)	2.47	0.737
D3L4 (31.8 m - D2L1 (31.8 m	127.9	91.5	(-238.5, 494.2)	1.40	0.999
D3L4 (38 mm) - D2L1 (31.8 m	-217	102	(-626, 193)	-2.12	0.911
D3L5 (25.4 m - D2L1 (31.8 m	-65.0	91.5	(-431.3, 301.4)	-0.71	1.000

D3L5 (31.8 m - D2L1 (31.8 m	-283	102	(-693, 127)	-2.77	0.539
D3L5 (38 mm) - D2L1 (31.8 m	-346	102	(-756, 63)	-3.38	0.197
D5L1 (25.4 m - D2L1 (31.8 m	38	102	(-371, 448)	0.37	1.000
D5L1 (31.8 m - D2L1 (31.8 m	-155	102	(-565, 254)	-1.52	0.998
D5L1 (38 mm) - D2L1 (31.8 m	-135.2	91.5	(-501.5, 231.2)	-1.48	0.999
D6L1 (25.4 m - D2L1 (31.8 m	604	102	(194, 1013)	5.90	0.000
D6L1 (31.8 m - D2L1 (31.8 m	256	102	(-154, 666)	2.50	0.716
D6L1 (38 mm) - D2L1 (31.8 m	96	102	(-313, 506)	0.94	1.000
D3L1 (25.4 m - D2L1 (38 mm)	-567	102	(-976, -157)	-5.54	0.001
D3L1 (31.8 m - D2L1 (38 mm)	-623	102	(-1032, -213)	-6.09	0.000
D3L1 (38 mm) - D2L1 (38 mm)	-598	102	(-1007, -188)	-5.84	0.000
D3L2 (25.4 m - D2L1 (38 mm)	-2	102	(-412, 408)	-0.02	1.000
D3L2 (31.8 m - D2L1 (38 mm)	-185.0	91.5	(-551.3, 181.4)	-2.02	0.941
D3L2 (38 mm) - D2L1 (38 mm)	-318	102	(-727, 92)	-3.10	0.328
D3L3 (25.4 m - D2L1 (38 mm)	-149	102	(-559, 260)	-1.46	0.999

D3L3 (31.8 m - D2L1 (38 mm)	-312.0	91.5	(-678.3, 54.4)	-3.41	0.187
D3L3 (38 mm) - D2L1 (38 mm)	-322	102	(-731, 88)	-3.14	0.307
D3L4 (25.4 m - D2L1 (38 mm)	162	102	(-247, 572)	1.59	0.996
D3L4 (31.8 m - D2L1 (38 mm)	37.7	91.5	(-328.6, 404.0)	0.41	1.000
D3L4 (38 mm) - D2L1 (38 mm)	-307	102	(-717, 103)	-3.00	0.388
D3L5 (25.4 m - D2L1 (38 mm)	-155.1	91.5	(-521.5, 211.2)	-1.69	0.991
D3L5 (31.8 m - D2L1 (38 mm)	-373	102	(-783, 36)	-3.65	0.113
D3L5 (38 mm) - D2L1 (38 mm)	-436	102	(-846, -27)	-4.26	0.026
D5L1 (25.4 m - D2L1 (38 mm)	-52	102	(-462, 358)	-0.51	1.000
D5L1 (31.8 m - D2L1 (38 mm)	-245	102	(-655, 164)	-2.40	0.779
D5L1 (38 mm) - D2L1 (38 mm)	-225.4	91.5	(-591.7, 141.0)	-2.46	0.741
D6L1 (25.4 m - D2L1 (38 mm)	514	102	(104, 923)	5.02	0.003
D6L1 (31.8 m - D2L1 (38 mm)	166	102	(-244, 575)	1.62	0.995
D6L1 (38 mm) - D2L1 (38 mm)	6	102	(-404, 416)	0.06	1.000
D3L1 (31.8 m - D3L1 (25.4 m	-56	112	(-505, 393)	-0.50	1.000

D3L1 (38 mm) - D3L1 (25.4 m	-31	112	(-480, 418)	-0.28	1.000
D3L2 (25.4 m - D3L1 (25.4 m	565	112	(116, 1013)	5.04	0.003
D3L2 (31.8 m - D3L1 (25.4 m	382	102	(-28, 791)	3.73	0.094
D3L2 (38 mm) - D3L1 (25.4 m	249	112	(-200, 698)	2.22	0.871
D3L3 (25.4 m - D3L1 (25.4 m	417	112	(-31, 866)	3.72	0.096
D3L3 (31.8 m - D3L1 (25.4 m	255	102	(-155, 664)	2.49	0.724
D3L3 (38 mm) - D3L1 (25.4 m	245	112	(-204, 694)	2.19	0.885
D3L4 (25.4 m - D3L1 (25.4 m	729	112	(280, 1178)	6.50	0.000
D3L4 (31.8 m - D3L1 (25.4 m	604	102	(195, 1014)	5.91	0.000
D3L4 (38 mm) - D3L1 (25.4 m	260	112	(-189, 708)	2.32	0.825
D3L5 (25.4 m - D3L1 (25.4 m	411	102	(2, 821)	4.02	0.047
D3L5 (31.8 m - D3L1 (25.4 m	193	112	(-255, 642)	1.73	0.989
D3L5 (38 mm) - D3L1 (25.4 m	130	112	(-318, 579)	1.16	1.000
D5L1 (25.4 m - D3L1 (25.4 m	515	112	(66, 963)	4.59	0.011
D5L1 (31.8 m - D3L1 (25.4 m	321	112	(-127, 770)	2.86	0.473

D5L1 (38 mm) - D3L1 (25.4 m	341	102	(-68, 751)	3.33	0.216
D6L1 (25.4 m - D3L1 (25.4 m	1080	112	(632, 1529)	9.64	0.000
D6L1 (31.8 m - D3L1 (25.4 m	732	112	(284, 1181)	6.53	0.000
D6L1 (38 mm) - D3L1 (25.4 m	573	112	(124, 1021)	5.11	0.003
D3L1 (38 mm) - D3L1 (31.8 m	25	112	(-424, 474)	0.22	1.000
D3L2 (25.4 m - D3L1 (31.8 m	621	112	(172, 1069)	5.54	0.001
D3L2 (31.8 m - D3L1 (31.8 m	438	102	(28, 847)	4.28	0.025
D3L2 (38 mm) - D3L1 (31.8 m	305	112	(-144, 754)	2.72	0.570
D3L3 (25.4 m - D3L1 (31.8 m	474	112	(25, 922)	4.22	0.029
D3L3 (31.8 m - D3L1 (31.8 m	311	102	(-99, 720)	3.04	0.366
D3L3 (38 mm) - D3L1 (31.8 m	301	112	(-147, 750)	2.69	0.593
D3L4 (25.4 m - D3L1 (31.8 m	785	112	(337, 1234)	7.00	0.000
D3L4 (31.8 m - D3L1 (31.8 m	660	102	(251, 1070)	6.45	0.000
D3L4 (38 mm) - D3L1 (31.8 m	316	112	(-133, 764)	2.82	0.506
D3L5 (25.4 m - D3L1 (31.8 m	468	102	(58, 877)	4.57	0.012

D3L5 (31.8 m - D3L1 (31.8 m	250	112	(-199, 698)	2.23	0.868
D3L5 (38 mm) - D3L1 (31.8 m	187	112	(-262, 635)	1.66	0.993
D5L1 (25.4 m - D3L1 (31.8 m	571	112	(122, 1019)	5.09	0.003
D5L1 (31.8 m - D3L1 (31.8 m	377	112	(-71, 826)	3.37	0.204
D5L1 (38 mm) - D3L1 (31.8 m	397	102	(-12, 807)	3.88	0.066
D6L1 (25.4 m - D3L1 (31.8 m	1136	112	(688, 1585)	10.14	0.000
D6L1 (31.8 m - D3L1 (31.8 m	789	112	(340, 1237)	7.03	0.000
D6L1 (38 mm) - D3L1 (31.8 m	629	112	(180, 1077)	5.61	0.001
D3L2 (25.4 m - D3L1 (38 mm)	596	112	(147, 1044)	5.31	0.001
D3L2 (31.8 m - D3L1 (38 mm)	413	102	(3, 822)	4.03	0.046
D3L2 (38 mm) - D3L1 (38 mm)	280	112	(-169, 729)	2.50	0.719
D3L3 (25.4 m - D3L1 (38 mm)	448	112	(-0, 897)	4.00	0.050
D3L3 (31.8 m - D3L1 (38 mm)	286	102	(-124, 695)	2.79	0.522
D3L3 (38 mm) - D3L1 (38 mm)	276	112	(-173, 725)	2.46	0.740
D3L4 (25.4 m - D3L1 (38 mm)	760	112	(311, 1209)	6.78	0.000

D3L4 (31.8 m - D3L1 (38 mm)	635	102	(226, 1045)	6.21	0.000
D3L4 (38 mm) - D3L1 (38 mm)	291	112	(-158, 739)	2.59	0.657
D3L5 (25.4 m - D3L1 (38 mm)	443	102	(33, 852)	4.32	0.022
D3L5 (31.8 m - D3L1 (38 mm)	224	112	(-224, 673)	2.00	0.946
D3L5 (38 mm) - D3L1 (38 mm)	161	112	(-287, 610)	1.44	0.999
D5L1 (25.4 m - D3L1 (38 mm)	546	112	(97, 994)	4.87	0.005
D5L1 (31.8 m - D3L1 (38 mm)	352	112	(-96, 801)	3.14	0.307
D5L1 (38 mm) - D3L1 (38 mm)	372	102	(-37, 782)	3.64	0.116
D6L1 (25.4 m - D3L1 (38 mm)	1111	112	(663, 1560)	9.91	0.000
D6L1 (31.8 m - D3L1 (38 mm)	764	112	(315, 1212)	6.81	0.000
D6L1 (38 mm) - D3L1 (38 mm)	604	112	(155, 1052)	5.38	0.001
D3L2 (31.8 m - D3L2 (25.4 m	-183	102	(-593, 227)	-1.79	0.983
D3L2 (38 mm) - D3L2 (25.4 m	-316	112	(-764, 133)	-2.82	0.506
D3L3 (25.4 m - D3L2 (25.4 m	-147	112	(-596, 302)	-1.31	1.000
D3L3 (31.8 m - D3L2 (25.4 m	-310	102	(-719, 100)	-3.03	0.371

D3L3 (38 mm) - D3L2 (25.4 m	-320	112	(-768, 129)	-2.85	0.483
D3L4 (25.4 m - D3L2 (25.4 m	165	112	(-284, 613)	1.47	0.999
D3L4 (31.8 m - D3L2 (25.4 m	40	102	(-370, 449)	0.39	1.000
D3L4 (38 mm) - D3L2 (25.4 m	-305	112	(-754, 144)	-2.72	0.570
D3L5 (25.4 m - D3L2 (25.4 m	-153	102	(-563, 256)	-1.50	0.998
D3L5 (31.8 m - D3L2 (25.4 m	-371	112	(-820, 77)	-3.31	0.226
D3L5 (38 mm) - D3L2 (25.4 m	-434	112	(-883, 14)	-3.87	0.068
D5L1 (25.4 m - D3L2 (25.4 m	-50	112	(-499, 399)	-0.45	1.000
D5L1 (31.8 m - D3L2 (25.4 m	-243	112	(-692, 205)	-2.17	0.891
D5L1 (38 mm) - D3L2 (25.4 m	-223	102	(-633, 186)	-2.18	0.887
D6L1 (25.4 m - D3L2 (25.4 m	516	112	(67, 964)	4.60	0.011
D6L1 (31.8 m - D3L2 (25.4 m	168	112	(-281, 617)	1.50	0.998
D6L1 (38 mm) - D3L2 (25.4 m	8	112	(-441, 457)	0.07	1.000
D3L2 (38 mm) - D3L2 (31.8 m	-133	102	(-542, 277)	-1.30	1.000
D3L3 (25.4 m - D3L2 (31.8 m	36	102	(-374, 445)	0.35	1.000

D3L3 (31.8 m - D3L2 (31.8 m	-127.0	91.5	(-493.3, 239.3)	-1.39	0.999
D3L3 (38 mm) - D3L2 (31.8 m	-137	102	(-546, 273)	-1.33	1.000
D3L4 (25.4 m - D3L2 (31.8 m	347	102	(-62, 757)	3.39	0.192
D3L4 (31.8 m - D3L2 (31.8 m	222.7	91.5	(-143.7, 589.0)	2.43	0.759
D3L4 (38 mm) - D3L2 (31.8 m	-122	102	(-532, 287)	-1.19	1.000
D3L5 (25.4 m - D3L2 (31.8 m	29.8	91.5	(-336.5, 396.2)	0.33	1.000
D3L5 (31.8 m - D3L2 (31.8 m	-188	102	(-598, 221)	-1.84	0.977
D3L5 (38 mm) - D3L2 (31.8 m	-251	102	(-661, 158)	-2.46	0.745
D5L1 (25.4 m - D3L2 (31.8 m	133	102	(-277, 543)	1.30	1.000
D5L1 (31.8 m - D3L2 (31.8 m	-60	102	(-470, 349)	-0.59	1.000
D5L1 (38 mm) - D3L2 (31.8 m	-40.4	91.5	(-406.7, 326.0)	-0.44	1.000
D6L1 (25.4 m - D3L2 (31.8 m	699	102	(289, 1108)	6.83	0.000
D6L1 (31.8 m - D3L2 (31.8 m	351	102	(-59, 760)	3.43	0.180
D6L1 (38 mm) - D3L2 (31.8 m	191	102	(-219, 601)	1.87	0.973
D3L3 (25.4 m - D3L2 (38 mm)	168	112	(-280, 617)	1.50	0.998

D3L3 (31.8 m - D3L2 (38 mm)	6	102	(-404, 415)	0.06	1.000
D3L3 (38 mm) - D3L2 (38 mm)	-4	112	(-453, 445)	-0.03	1.000
D3L4 (25.4 m - D3L2 (38 mm)	480	112	(31, 929)	4.28	0.025
D3L4 (31.8 m - D3L2 (38 mm)	355	102	(-54, 765)	3.47	0.164
D3L4 (38 mm) - D3L2 (38 mm)	11	112	(-438, 459)	0.09	1.000
D3L5 (25.4 m - D3L2 (38 mm)	163	102	(-247, 572)	1.59	0.996
D3L5 (31.8 m - D3L2 (38 mm)	-56	112	(-504, 393)	-0.50	1.000
D3L5 (38 mm) - D3L2 (38 mm)	-119	112	(-567, 330)	-1.06	1.000
D5L1 (25.4 m - D3L2 (38 mm)	266	112	(-183, 714)	2.37	0.795
D5L1 (31.8 m - D3L2 (38 mm)	72	112	(-376, 521)	0.64	1.000
D5L1 (38 mm) - D3L2 (38 mm)	92	102	(-317, 502)	0.90	1.000
D6L1 (25.4 m - D3L2 (38 mm)	831	112	(383, 1280)	7.42	0.000
D6L1 (31.8 m - D3L2 (38 mm)	484	112	(35, 932)	4.31	0.023
D6L1 (38 mm) - D3L2 (38 mm)	324	112	(-125, 772)	2.89	0.459
D3L3 (31.8 m - D3L3 (25.4 m	-163	102	(-572, 247)	-1.59	0.996

D3L3 (38 mm) - D3L3 (25.4 m	-172	112	(-621, 276)	-1.54	0.998
D3L4 (25.4 m - D3L3 (25.4 m	312	112	(-137, 760)	2.78	0.530
D3L4 (31.8 m - D3L3 (25.4 m	187	102	(-223, 596)	1.83	0.979
D3L4 (38 mm) - D3L3 (25.4 m	-158	112	(-607, 291)	-1.41	0.999
D3L5 (25.4 m - D3L3 (25.4 m	-6	102	(-416, 404)	-0.06	1.000
D3L5 (31.8 m - D3L3 (25.4 m	-224	112	(-673, 225)	-2.00	0.947
D3L5 (38 mm) - D3L3 (25.4 m	-287	112	(-736, 162)	-2.56	0.678
D5L1 (25.4 m - D3L3 (25.4 m	97	112	(-351, 546)	0.87	1.000
D5L1 (31.8 m - D3L3 (25.4 m	-96	112	(-545, 352)	-0.86	1.000
D5L1 (38 mm) - D3L3 (25.4 m	-76	102	(-486, 333)	-0.74	1.000
D6L1 (25.4 m - D3L3 (25.4 m	663	112	(214, 1112)	5.91	0.000
D6L1 (31.8 m - D3L3 (25.4 m	315	112	(-134, 764)	2.81	0.509
D6L1 (38 mm) - D3L3 (25.4 m	155	112	(-293, 604)	1.38	0.999
D3L3 (38 mm) - D3L3 (31.8 m	-10	102	(-419, 400)	-0.09	1.000
D3L4 (25.4 m - D3L3 (31.8 m	474	102	(65, 884)	4.64	0.010

D3L4 (31.8 m - D3L3 (31.8 m	349.7	91.5	(-16.7, 716.0)	3.82	0.077
D3L4 (38 mm) - D3L3 (31.8 m	5	102	(-405, 414)	0.05	1.000
D3L5 (25.4 m - D3L3 (31.8 m	156.8	91.5	(-209.5, 523.2)	1.71	0.990
D3L5 (31.8 m - D3L3 (31.8 m	-61	102	(-471, 348)	-0.60	1.000
D3L5 (38 mm) - D3L3 (31.8 m	-124	102	(-534, 285)	-1.21	1.000
D5L1 (25.4 m - D3L3 (31.8 m	260	102	(-150, 670)	2.54	0.691
D5L1 (31.8 m - D3L3 (31.8 m	67	102	(-343, 476)	0.65	1.000
D5L1 (38 mm) - D3L3 (31.8 m	86.6	91.5	(-279.7, 453.0)	0.95	1.000
D6L1 (25.4 m - D3L3 (31.8 m	826	102	(416, 1235)	8.07	0.000
D6L1 (31.8 m - D3L3 (31.8 m	478	102	(68, 887)	4.67	0.009
D6L1 (38 mm) - D3L3 (31.8 m	318	102	(-92, 728)	3.11	0.326
D3L4 (25.4 m - D3L3 (38 mm)	484	112	(35, 933)	4.32	0.022
D3L4 (31.8 m - D3L3 (38 mm)	359	102	(-50, 769)	3.51	0.152
D3L4 (38 mm) - D3L3 (38 mm)	14	112	(-434, 463)	0.13	1.000
D3L5 (25.4 m - D3L3 (38 mm)	166	102	(-243, 576)	1.63	0.995

D3L5 (31.8 m - D3L3 (38 mm)	-52	112	(-500, 397)	-0.46	1.000
D3L5 (38 mm) - D3L3 (38 mm)	-115	112	(-563, 334)	-1.02	1.000
D5L1 (25.4 m - D3L3 (38 mm)	270	112	(-179, 718)	2.40	0.775
D5L1 (31.8 m - D3L3 (38 mm)	76	112	(-373, 525)	0.68	1.000
D5L1 (38 mm) - D3L3 (38 mm)	96	102	(-313, 506)	0.94	1.000
D6L1 (25.4 m - D3L3 (38 mm)	835	112	(387, 1284)	7.45	0.000
D6L1 (31.8 m - D3L3 (38 mm)	487	112	(39, 936)	4.35	0.021
D6L1 (38 mm) - D3L3 (38 mm)	328	112	(-121, 776)	2.92	0.436
D3L4 (31.8 m - D3L4 (25.4 m	-125	102	(-534, 285)	-1.22	1.000
D3L4 (38 mm) - D3L4 (25.4 m	-470	112	(-918, -21)	-4.19	0.031
D3L5 (25.4 m - D3L4 (25.4 m	-318	102	(-727, 92)	-3.10	0.328
D3L5 (31.8 m - D3L4 (25.4 m	-536	112	(-984, -87)	-4.78	0.007
D3L5 (38 mm) - D3L4 (25.4 m	-599	112	(-1047, -150)	-5.34	0.001
D5L1 (25.4 m - D3L4 (25.4 m	-214	112	(-663, 234)	-1.91	0.966
D5L1 (31.8 m - D3L4 (25.4 m	-408	112	(-857, 41)	-3.64	0.116

D5L1 (38 mm) - D3L4 (25.4 m	-388	102	(-797, 22)	-3.79	0.082
D6L1 (25.4 m - D3L4 (25.4 m	351	112	(-97, 800)	3.13	0.312
D6L1 (31.8 m - D3L4 (25.4 m	3	112	(-445, 452)	0.03	1.000
D6L1 (38 mm) - D3L4 (25.4 m	-156	112	(-605, 292)	-1.40	0.999
D3L4 (38 mm) - D3L4 (31.8 m	-345	102	(-754, 65)	-3.37	0.202
D3L5 (25.4 m - D3L4 (31.8 m	-192.8	91.5	(-559.2, 173.5)	-2.11	0.915
D3L5 (31.8 m - D3L4 (31.8 m	-411	102	(-821, -1)	-4.02	0.048
D3L5 (38 mm) - D3L4 (31.8 m	-474	102	(-884, -64)	-4.63	0.010
D5L1 (25.4 m - D3L4 (31.8 m	-90	102	(-499, 320)	-0.88	1.000
D5L1 (31.8 m - D3L4 (31.8 m	-283	102	(-693, 126)	-2.77	0.539
D5L1 (38 mm) - D3L4 (31.8 m	-263.0	91.5	(-629.4, 103.3)	-2.87	0.467
D6L1 (25.4 m - D3L4 (31.8 m	476	102	(66, 886)	4.65	0.009
D6L1 (31.8 m - D3L4 (31.8 m	128	102	(-281, 538)	1.25	1.000
D6L1 (38 mm) - D3L4 (31.8 m	-32	102	(-441, 378)	-0.31	1.000
D3L5 (25.4 m - D3L4 (38 mm)	152	102	(-258, 562)	1.48	0.998

D3L5 (31.8 m - D3L4 (38 mm)	-66	112	(-515, 383)	-0.59	1.000
D3L5 (38 mm) - D3L4 (38 mm)	-129	112	(-578, 319)	-1.15	1.000
D5L1 (25.4 m - D3L4 (38 mm)	255	112	(-194, 704)	2.28	0.845
D5L1 (31.8 m - D3L4 (38 mm)	62	112	(-387, 510)	0.55	1.000
D5L1 (38 mm) - D3L4 (38 mm)	82	102	(-328, 491)	0.80	1.000
D6L1 (25.4 m - D3L4 (38 mm)	821	112	(372, 1269)	7.32	0.000
D6L1 (31.8 m - D3L4 (38 mm)	473	112	(24, 922)	4.22	0.029
D6L1 (38 mm) - D3L4 (38 mm)	313	112	(-136, 762)	2.79	0.521
D3L5 (31.8 m - D3L5 (25.4 m	-218	102	(-628, 191)	-2.13	0.907
D3L5 (38 mm) - D3L5 (25.4 m	-281	102	(-691, 128)	-2.75	0.552
D5L1 (25.4 m - D3L5 (25.4 m	103	102	(-306, 513)	1.01	1.000
D5L1 (31.8 m - D3L5 (25.4 m	-90	102	(-500, 319)	-0.88	1.000
D5L1 (38 mm) - D3L5 (25.4 m	-70.2	91.5	(-436.5, 296.1)	-0.77	1.000
D6L1 (25.4 m - D3L5 (25.4 m	669	102	(259, 1078)	6.53	0.000
D6L1 (31.8 m - D3L5 (25.4 m	321	102	(-89, 731)	3.14	0.310

D6L1 (38 mm) - D3L5 (25.4 m	161	102	(-248, 571)	1.57	0.997
D3L5 (38 mm) - D3L5 (31.8 m	-63	112	(-512, 386)	-0.56	1.000
D5L1 (25.4 m - D3L5 (31.8 m	321	112	(-127, 770)	2.87	0.473
D5L1 (31.8 m - D3L5 (31.8 m	128	112	(-321, 576)	1.14	1.000
D5L1 (38 mm) - D3L5 (31.8 m	148	102	(-262, 557)	1.45	0.999
D6L1 (25.4 m - D3L5 (31.8 m	887	112	(438, 1336)	7.91	0.000
D6L1 (31.8 m - D3L5 (31.8 m	539	112	(90, 988)	4.81	0.006
D6L1 (38 mm) - D3L5 (31.8 m	379	112	(-69, 828)	3.38	0.197
D5L1 (25.4 m - D3L5 (38 mm)	384	112	(-64, 833)	3.43	0.180
D5L1 (31.8 m - D3L5 (38 mm)	191	112	(-258, 639)	1.70	0.991
D5L1 (38 mm) - D3L5 (38 mm)	211	102	(-199, 620)	2.06	0.930
D6L1 (25.4 m - D3L5 (38 mm)	950	112	(501, 1399)	8.47	0.000
D6L1 (31.8 m - D3L5 (38 mm)	602	112	(153, 1051)	5.37	0.001
D6L1 (38 mm) - D3L5 (38 mm)	442	112	(-6, 891)	3.94	0.057
D5L1 (31.8 m - D5L1 (25.4 m	-193	112	(-642, 255)	-1.73	0.989

D5L1 (38 mm) - D5L1 (25.4 m	-173	102	(-583, 236)	-1.69	0.991
D6L1 (25.4 m - D5L1 (25.4 m	566	112	(117, 1014)	5.05	0.003
D6L1 (31.8 m - D5L1 (25.4 m	218	112	(-231, 667)	1.94	0.960
D6L1 (38 mm) - D5L1 (25.4 m	58	112	(-391, 507)	0.52	1.000
D5L1 (38 mm) - D5L1 (31.8 m	20	102	(-389, 430)	0.20	1.000
D6L1 (25.4 m - D5L1 (31.8 m	759	112	(310, 1208)	6.77	0.000
D6L1 (31.8 m - D5L1 (31.8 m	411	112	(-37, 860)	3.67	0.108
D6L1 (38 mm) - D5L1 (31.8 m	251	112	(-197, 700)	2.24	0.861
D6L1 (25.4 m - D5L1 (38 mm)	739	102	(329, 1149)	7.22	0.000
D6L1 (31.8 m - D5L1 (38 mm)	391	102	(-18, 801)	3.82	0.076
D6L1 (38 mm) - D5L1 (38 mm)	231	102	(-178, 641)	2.26	0.852
D6L1 (31.8 m - D6L1 (25.4 m	-348	112	(-796, 101)	-3.10	0.329
D6L1 (38 mm) - D6L1 (25.4 m	-508	112	(-956, -59)	-4.53	0.013
D6L1 (38 mm) - D6L1 (31.8 m	-160	112	(-609, 289)	-1.43	0.999

Individual confidence level = 99.97%

B.18. Statistical Analysis of Cracking Resistance Index (CRI) of PMLC computed from the SCB-J_c Test

One-way ANOVA: CRI (SCB-J_c) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	27	D1L1 (25.4 mm), D1L1 (31.8 mm), D1L1 (38 mm), D2L1 (25.4 mm), D2L1 (31.8 mm), D2L1 (38 mm), D3L1 (25.4 mm), D3L1 (31.8 mm), D3L1 (38 mm), D3L2 (25.4 mm), D3L2 (31.8 mm), D3L2 (38 mm), D3L3 (25.4 mm), D3L3 (31.8 mm), D3L3 (38 mm), D3L4 (25.4 mm), D3L4 (31.8 mm), D3L4 (38 mm), D3L5 (25.4 mm), D3L5 (31.8 mm), D3L5 (38 mm), D5L1 (25.4 mm), D5L1 (31.8 mm), D5L1 (38 mm), D6L1 (25.4 mm), D6L1 (31.8 mm), D6L1 (38 mm)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	26	2351037	90425	13.70	0.000

Error	36	237647	6601		
Total	62	2588684			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
81.2484	90.82%	84.19%	70.68%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1 (25.4 mm)	3	739.0	36.2	(643.9, 834.1)
D1L1 (31.8 mm)	3	833.6	83.4	(738.5, 928.8)
D1L1 (38 mm)	2	989.4	126.4	(872.9, 1105.9)
D2L1 (25.4 mm)	2	494.2	51.2	(377.7, 610.7)
D2L1 (31.8 mm)	3	803	177	(708, 899)
D2L1 (38 mm)	3	650.4	48.5	(555.2, 745.5)
D3L1 (25.4 mm)	2	172.17	5.63	(55.66, 288.69)
D3L1 (31.8 mm)	2	348.0	68.9	(231.5, 464.5)
D3L1 (38 mm)	2	281.5	38.6	(165.0, 398.0)
D3L2 (25.4 mm)	2	603.7	71.7	(487.2, 720.3)
D3L2 (31.8 mm)	3	474.1	50.4	(378.9, 569.2)
D3L2 (38 mm)	2	554.8	135.1	(438.3, 671.3)
D3L3 (25.4 mm)	2	446.8	21.8	(330.2, 563.3)
D3L3 (31.8 mm)	3	409.5	53.4	(314.3, 504.6)
D3L3 (38 mm)	2	735.0	60.2	(618.5, 851.5)
D3L4 (25.4 mm)	2	596.52	2.23	(480.01, 713.04)
D3L4 (31.8 mm)	3	704.80	10.15	(609.67, 799.94)
D3L4 (38 mm)	2	786.1	89.3	(669.6, 902.6)
D3L5 (25.4 mm)	3	456.4	55.5	(361.2, 551.5)
D3L5 (31.8 mm)	2	565	159	(448, 681)

D3L5 (38 mm)	2	509.2	49.5	(392.7, 625.7)
D5L1 (25.4 mm)	2	556.8	73.9	(440.3, 673.3)
D5L1 (31.8 mm)	2	550.0	16.5	(433.5, 666.5)
D5L1 (38 mm)	3	745.5	64.7	(650.4, 840.7)
D6L1 (25.4 mm)	2	860.5	72.7	(744.0, 977.0)
D6L1 (31.8 mm)	2	825.2	27.4	(708.7, 941.8)
D6L1 (38 mm)	2	966	169	(849, 1082)

Pooled StDev = 81.2484

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping								
D1L1 (38 mm)	2	989.4	A								
D6L1 (38 mm)	2	966	A								
D6L1 (25.4 mm)	2	860.5	A	B							
D1L1 (31.8 mm)	3	833.6	A	B							
D6L1 (31.8 mm)	2	825.2	A	B	C						
D2L1 (31.8 mm)	3	803	A	B	C						
D3L4 (38 mm)	2	786.1	A	B	C	D					
D5L1 (38 mm)	3	745.5	A	B	C	D					
D1L1 (25.4 mm)	3	739.0	A	B	C	D	E				
D3L3 (38 mm)	2	735.0	A	B	C	D	E	F			
D3L4 (31.8 mm)	3	704.80	A	B	C	D	E	F			
D2L1 (38 mm)	3	650.4		B	C	D	E	F	G		
D3L2 (25.4 mm)	2	603.7		B	C	D	E	F	G	H	
D3L4 (25.4 mm)	2	596.52		B	C	D	E	F	G	H	
D3L5 (31.8 mm)	2	565		B	C	D	E	F	G	H	
D5L1 (25.4 mm)	2	556.8		B	C	D	E	F	G	H	
D3L2 (38 mm)	2	554.8		B	C	D	E	F	G	H	

D5L1 (31.8 mm)	2	550.0		B	C	D	E	F	G	H	
D3L5 (38 mm)	2	509.2			C	D	E	F	G	H	
D2L1 (25.4 mm)	2	494.2				D	E	F	G	H	I
D3L2 (31.8 mm)	3	474.1					E	F	G	H	
D3L5 (25.4 mm)	3	456.4						F	G	H	I
D3L3 (25.4 mm)	2	446.8					E	F	G	H	I
D3L3 (31.8 mm)	3	409.5							G	H	I
D3L1 (31.8 mm)	2	348.0								H	I
D3L1 (38 mm)	2	281.5								H	I
D3L1 (25.4 mm)	2	172.17									I

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D1L1 (31.8 m - D1L1 (25.4 m	94.6	66.3	(-170.9, 360.1)	1.43	0.999
D1L1 (38 mm) - D1L1 (25.4 m	250.4	74.2	(-46.4, 547.3)	3.38	0.199
D2L1 (25.4 m - D1L1 (25.4 m	-244.8	74.2	(-541.6, 52.1)	-3.30	0.231
D2L1 (31.8 m - D1L1 (25.4 m	64.4	66.3	(-201.1, 329.9)	0.97	1.000
D2L1 (38 mm) - D1L1 (25.4 m	-88.6	66.3	(-354.2, 176.9)	-1.34	1.000
D3L1 (25.4 m - D1L1 (25.4 m	-566.8	74.2	(-863.7, -270.0)	-7.64	0.000
D3L1 (31.8 m - D1L1 (25.4 m	-391.0	74.2	(-687.8, -94.1)	-5.27	0.002

D3L1 (38 mm) - D1L1 (25.4 m	-457.5	74.2	(-754.4, -160.7)	-6.17	0.000
D3L2 (25.4 m - D1L1 (25.4 m	-135.3	74.2	(-432.1, 161.6)	-1.82	0.979
D3L2 (31.8 m - D1L1 (25.4 m	-264.9	66.3	(-530.4, 0.6)	-3.99	0.051
D3L2 (38 mm) - D1L1 (25.4 m	-184.2	74.2	(-481.1, 112.6)	-2.48	0.727
D3L3 (25.4 m - D1L1 (25.4 m	-292.3	74.2	(-589.1, 4.6)	-3.94	0.058
D3L3 (31.8 m - D1L1 (25.4 m	-329.5	66.3	(-595.0, -64.0)	-4.97	0.004
D3L3 (38 mm) - D1L1 (25.4 m	-4.0	74.2	(-300.9, 292.8)	-0.05	1.000
D3L4 (25.4 m - D1L1 (25.4 m	-142.5	74.2	(-439.3, 154.4)	-1.92	0.964
D3L4 (31.8 m - D1L1 (25.4 m	-34.2	66.3	(-299.7, 231.3)	-0.52	1.000
D3L4 (38 mm) - D1L1 (25.4 m	47.1	74.2	(-249.8, 343.9)	0.63	1.000
D3L5 (25.4 m - D1L1 (25.4 m	-282.6	66.3	(-548.1, -17.1)	-4.26	0.026
D3L5 (31.8 m - D1L1 (25.4 m	-174.1	74.2	(-471.0, 122.7)	-2.35	0.808
D3L5 (38 mm) - D1L1 (25.4 m	-229.8	74.2	(-526.7, 67.0)	-3.10	0.331
D5L1 (25.4 m - D1L1 (25.4 m	-182.2	74.2	(-479.0, 114.6)	-2.46	0.744
D5L1 (31.8 m - D1L1 (25.4 m	-189.0	74.2	(-485.8, 107.8)	-2.55	0.686

D5L1 (38 mm) - D1L1 (25.4 m	6.5	66.3	(-259.0, 272.0)	0.10	1.000
D6L1 (25.4 m - D1L1 (25.4 m	121.5	74.2	(-175.4, 418.3)	1.64	0.994
D6L1 (31.8 m - D1L1 (25.4 m	86.2	74.2	(-210.6, 383.1)	1.16	1.000
D6L1 (38 mm) - D1L1 (25.4 m	226.7	74.2	(-70.2, 523.5)	3.06	0.355
D1L1 (38 mm) - D1L1 (31.8 m	155.8	74.2	(-141.1, 452.6)	2.10	0.917
D2L1 (25.4 m - D1L1 (31.8 m	-339.4	74.2	(-636.3, -42.6)	-4.58	0.011
D2L1 (31.8 m - D1L1 (31.8 m	-30.2	66.3	(-295.7, 235.3)	-0.46	1.000
D2L1 (38 mm) - D1L1 (31.8 m	-183.3	66.3	(-448.8, 82.2)	-2.76	0.541
D3L1 (25.4 m - D1L1 (31.8 m	-661.5	74.2	(-958.3, -364.6)	-8.92	0.000
D3L1 (31.8 m - D1L1 (31.8 m	-485.6	74.2	(-782.5, -188.8)	-6.55	0.000
D3L1 (38 mm) - D1L1 (31.8 m	-552.2	74.2	(-849.0, -255.3)	-7.44	0.000
D3L2 (25.4 m - D1L1 (31.8 m	-229.9	74.2	(-526.8, 66.9)	-3.10	0.330
D3L2 (31.8 m - D1L1 (31.8 m	-359.6	66.3	(-625.1, -94.1)	-5.42	0.001
D3L2 (38 mm) - D1L1 (31.8 m	-278.9	74.2	(-575.7, 18.0)	-3.76	0.088
D3L3 (25.4 m - D1L1 (31.8 m	-386.9	74.2	(-683.7, -90.1)	-5.22	0.002

D3L3 (31.8 m - D1L1 (31.8 m	-424.2	66.3	(-689.7, -158.7)	-6.39	0.000
D3L3 (38 mm) - D1L1 (31.8 m	-98.7	74.2	(-395.5, 198.2)	-1.33	1.000
D3L4 (25.4 m - D1L1 (31.8 m	-237.1	74.2	(-534.0, 59.7)	-3.20	0.279
D3L4 (31.8 m - D1L1 (31.8 m	-128.8	66.3	(-394.4, 136.7)	-1.94	0.960
D3L4 (38 mm) - D1L1 (31.8 m	-47.6	74.2	(-344.4, 249.3)	-0.64	1.000
D3L5 (25.4 m - D1L1 (31.8 m	-377.3	66.3	(-642.8, -111.8)	-5.69	0.001
D3L5 (31.8 m - D1L1 (31.8 m	-268.8	74.2	(-565.6, 28.1)	-3.62	0.119
D3L5 (38 mm) - D1L1 (31.8 m	-324.5	74.2	(-621.3, -27.6)	-4.37	0.019
D5L1 (25.4 m - D1L1 (31.8 m	-276.8	74.2	(-573.7, 20.0)	-3.73	0.094
D5L1 (31.8 m - D1L1 (31.8 m	-283.6	74.2	(-580.5, 13.2)	-3.82	0.076
D5L1 (38 mm) - D1L1 (31.8 m	-88.1	66.3	(-353.6, 177.4)	-1.33	1.000
D6L1 (25.4 m - D1L1 (31.8 m	26.8	74.2	(-270.0, 323.7)	0.36	1.000
D6L1 (31.8 m - D1L1 (31.8 m	-8.4	74.2	(-305.2, 288.4)	-0.11	1.000
D6L1 (38 mm) - D1L1 (31.8 m	132.0	74.2	(-164.8, 428.9)	1.78	0.984
D2L1 (25.4 m - D1L1 (38 mm)	-495.2	81.2	(-820.4, -170.0)	-6.09	0.000

D2L1 (31.8 m - D1L1 (38 mm)	-186.0	74.2	(-482.8, 110.9)	-2.51	0.712
D2L1 (38 mm) - D1L1 (38 mm)	-339.1	74.2	(-635.9, -42.2)	-4.57	0.011
D3L1 (25.4 m - D1L1 (38 mm)	-817.3	81.2	(-1142.4, -492.1)	-10.06	0.000
D3L1 (31.8 m - D1L1 (38 mm)	-641.4	81.2	(-966.6, -316.2)	-7.89	0.000
D3L1 (38 mm) - D1L1 (38 mm)	-707.9	81.2	(-1033.1, -382.8)	-8.71	0.000
D3L2 (25.4 m - D1L1 (38 mm)	-385.7	81.2	(-710.9, -60.5)	-4.75	0.007
D3L2 (31.8 m - D1L1 (38 mm)	-515.3	74.2	(-812.2, -218.5)	-6.95	0.000
D3L2 (38 mm) - D1L1 (38 mm)	-434.6	81.2	(-759.8, -109.5)	-5.35	0.001
D3L3 (25.4 m - D1L1 (38 mm)	-542.7	81.2	(-867.8, -217.5)	-6.68	0.000
D3L3 (31.8 m - D1L1 (38 mm)	-580.0	74.2	(-876.8, -283.1)	-7.82	0.000
D3L3 (38 mm) - D1L1 (38 mm)	-254.4	81.2	(-579.6, 70.7)	-3.13	0.313
D3L4 (25.4 m - D1L1 (38 mm)	-392.9	81.2	(-718.1, -67.7)	-4.84	0.006
D3L4 (31.8 m - D1L1 (38 mm)	-284.6	74.2	(-581.5, 12.2)	-3.84	0.074
D3L4 (38 mm) - D1L1 (38 mm)	-203.3	81.2	(-528.5, 121.8)	-2.50	0.715
D3L5 (25.4 m - D1L1 (38 mm)	-533.1	74.2	(-829.9, -236.2)	-7.19	0.000

D3L5 (31.8 m - D1L1 (38 mm)	-424.5	81.2	(-749.7, -99.4)	-5.23	0.002
D3L5 (38 mm) - D1L1 (38 mm)	-480.3	81.2	(-805.4, -155.1)	-5.91	0.000
D5L1 (25.4 m - D1L1 (38 mm)	-432.6	81.2	(-757.8, -107.4)	-5.32	0.001
D5L1 (31.8 m - D1L1 (38 mm)	-439.4	81.2	(-764.6, -114.2)	-5.41	0.001
D5L1 (38 mm) - D1L1 (38 mm)	-243.9	74.2	(-540.7, 53.0)	-3.29	0.236
D6L1 (25.4 m - D1L1 (38 mm)	-128.9	81.2	(-454.1, 196.2)	-1.59	0.996
D6L1 (31.8 m - D1L1 (38 mm)	-164.2	81.2	(-489.4, 161.0)	-2.02	0.941
D6L1 (38 mm) - D1L1 (38 mm)	-23.7	81.2	(-348.9, 301.4)	-0.29	1.000
D2L1 (31.8 m - D2L1 (25.4 m	309.2	74.2	(12.4, 606.1)	4.17	0.033
D2L1 (38 mm) - D2L1 (25.4 m	156.1	74.2	(-140.7, 453.0)	2.11	0.916
D3L1 (25.4 m - D2L1 (25.4 m	-322.0	81.2	(-647.2, 3.1)	-3.96	0.055
D3L1 (31.8 m - D2L1 (25.4 m	-146.2	81.2	(-471.4, 179.0)	-1.80	0.982
D3L1 (38 mm) - D2L1 (25.4 m	-212.7	81.2	(-537.9, 112.4)	-2.62	0.639
D3L2 (25.4 m - D2L1 (25.4 m	109.5	81.2	(-215.7, 434.7)	1.35	1.000
D3L2 (31.8 m - D2L1 (25.4 m	-20.1	74.2	(-317.0, 276.7)	-0.27	1.000

D3L2 (38 mm) - D2L1 (25.4 m	60.6	81.2	(-264.6, 385.7)	0.75	1.000
D3L3 (25.4 m - D2L1 (25.4 m	-47.5	81.2	(-372.6, 277.7)	-0.58	1.000
D3L3 (31.8 m - D2L1 (25.4 m	-84.8	74.2	(-381.6, 212.1)	-1.14	1.000
D3L3 (38 mm) - D2L1 (25.4 m	240.8	81.2	(-84.4, 565.9)	2.96	0.410
D3L4 (25.4 m - D2L1 (25.4 m	102.3	81.2	(-222.9, 427.5)	1.26	1.000
D3L4 (31.8 m - D2L1 (25.4 m	210.6	74.2	(-86.3, 507.4)	2.84	0.490
D3L4 (38 mm) - D2L1 (25.4 m	291.9	81.2	(-33.3, 617.0)	3.59	0.128
D3L5 (25.4 m - D2L1 (25.4 m	-37.8	74.2	(-334.7, 259.0)	-0.51	1.000
D3L5 (31.8 m - D2L1 (25.4 m	70.7	81.2	(-254.5, 395.8)	0.87	1.000
D3L5 (38 mm) - D2L1 (25.4 m	15.0	81.2	(-310.2, 340.1)	0.18	1.000
D5L1 (25.4 m - D2L1 (25.4 m	62.6	81.2	(-262.6, 387.8)	0.77	1.000
D5L1 (31.8 m - D2L1 (25.4 m	55.8	81.2	(-269.4, 381.0)	0.69	1.000
D5L1 (38 mm) - D2L1 (25.4 m	251.3	74.2	(-45.5, 548.2)	3.39	0.195
D6L1 (25.4 m - D2L1 (25.4 m	366.3	81.2	(41.1, 691.4)	4.51	0.014
D6L1 (31.8 m - D2L1 (25.4 m	331.0	81.2	(5.9, 656.2)	4.07	0.042

D6L1 (38 mm) - D2L1 (25.4 m	471.5	81.2	(146.3, 796.6)	5.80	0.000
D2L1 (38 mm) - D2L1 (31.8 m	-153.1	66.3	(-418.6, 112.4)	-2.31	0.829
D3L1 (25.4 m - D2L1 (31.8 m	-631.3	74.2	(-928.1, -334.4)	-8.51	0.000
D3L1 (31.8 m - D2L1 (31.8 m	-455.4	74.2	(-752.3, -158.6)	-6.14	0.000
D3L1 (38 mm) - D2L1 (31.8 m	-522.0	74.2	(-818.8, -225.1)	-7.04	0.000
D3L2 (25.4 m - D2L1 (31.8 m	-199.7	74.2	(-496.5, 97.1)	-2.69	0.589
D3L2 (31.8 m - D2L1 (31.8 m	-329.4	66.3	(-594.9, -63.9)	-4.96	0.004
D3L2 (38 mm) - D2L1 (31.8 m	-248.7	74.2	(-545.5, 48.2)	-3.35	0.209
D3L3 (25.4 m - D2L1 (31.8 m	-356.7	74.2	(-653.5, -59.8)	-4.81	0.006
D3L3 (31.8 m - D2L1 (31.8 m	-394.0	66.3	(-659.5, -128.5)	-5.94	0.000
D3L3 (38 mm) - D2L1 (31.8 m	-68.4	74.2	(-365.3, 228.4)	-0.92	1.000
D3L4 (25.4 m - D2L1 (31.8 m	-206.9	74.2	(-503.8, 89.9)	-2.79	0.523
D3L4 (31.8 m - D2L1 (31.8 m	-98.6	66.3	(-364.1, 166.9)	-1.49	0.998
D3L4 (38 mm) - D2L1 (31.8 m	-17.4	74.2	(-314.2, 279.5)	-0.23	1.000
D3L5 (25.4 m - D2L1 (31.8 m	-347.1	66.3	(-612.6, -81.6)	-5.23	0.002

D3L5 (31.8 m - D2L1 (31.8 m	-238.6	74.2	(-535.4, 58.3)	-3.22	0.270
D3L5 (38 mm) - D2L1 (31.8 m	-294.3	74.2	(-591.1, 2.6)	-3.97	0.054
D5L1 (25.4 m - D2L1 (31.8 m	-246.6	74.2	(-543.5, 50.2)	-3.33	0.220
D5L1 (31.8 m - D2L1 (31.8 m	-253.4	74.2	(-550.3, 43.4)	-3.42	0.184
D5L1 (38 mm) - D2L1 (31.8 m	-57.9	66.3	(-323.4, 207.6)	-0.87	1.000
D6L1 (25.4 m - D2L1 (31.8 m	57.0	74.2	(-239.8, 353.9)	0.77	1.000
D6L1 (31.8 m - D2L1 (31.8 m	21.8	74.2	(-275.0, 318.7)	0.29	1.000
D6L1 (38 mm) - D2L1 (31.8 m	162.2	74.2	(-134.6, 459.1)	2.19	0.885
D3L1 (25.4 m - D2L1 (38 mm)	-478.2	74.2	(-775.0, -181.3)	-6.45	0.000
D3L1 (31.8 m - D2L1 (38 mm)	-302.3	74.2	(-599.2, -5.5)	-4.08	0.041
D3L1 (38 mm) - D2L1 (38 mm)	-368.9	74.2	(-665.7, -72.0)	-4.97	0.004
D3L2 (25.4 m - D2L1 (38 mm)	-46.6	74.2	(-343.5, 250.2)	-0.63	1.000
D3L2 (31.8 m - D2L1 (38 mm)	-176.3	66.3	(-441.8, 89.2)	-2.66	0.613
D3L2 (38 mm) - D2L1 (38 mm)	-95.6	74.2	(-392.4, 201.3)	-1.29	1.000
D3L3 (25.4 m - D2L1 (38 mm)	-203.6	74.2	(-500.4, 93.2)	-2.75	0.553

D3L3 (31.8 m - D2L1 (38 mm)	-240.9	66.3	(-506.4, 24.6)	-3.63	0.117
D3L3 (38 mm) - D2L1 (38 mm)	84.6	74.2	(-212.2, 381.5)	1.14	1.000
D3L4 (25.4 m - D2L1 (38 mm)	-53.8	74.2	(-350.7, 243.0)	-0.73	1.000
D3L4 (31.8 m - D2L1 (38 mm)	54.4	66.3	(-211.1, 319.9)	0.82	1.000
D3L4 (38 mm) - D2L1 (38 mm)	135.7	74.2	(-161.1, 432.6)	1.83	0.978
D3L5 (25.4 m - D2L1 (38 mm)	-194.0	66.3	(-459.5, 71.5)	-2.92	0.435
D3L5 (31.8 m - D2L1 (38 mm)	-85.5	74.2	(-382.3, 211.4)	-1.15	1.000
D3L5 (38 mm) - D2L1 (38 mm)	-141.2	74.2	(-438.0, 155.7)	-1.90	0.967
D5L1 (25.4 m - D2L1 (38 mm)	-93.6	74.2	(-390.4, 203.3)	-1.26	1.000
D5L1 (31.8 m - D2L1 (38 mm)	-100.4	74.2	(-397.2, 196.5)	-1.35	1.000
D5L1 (38 mm) - D2L1 (38 mm)	95.2	66.3	(-170.3, 360.7)	1.43	0.999
D6L1 (25.4 m - D2L1 (38 mm)	210.1	74.2	(-86.7, 507.0)	2.83	0.494
D6L1 (31.8 m - D2L1 (38 mm)	174.9	74.2	(-122.0, 471.7)	2.36	0.802
D6L1 (38 mm) - D2L1 (38 mm)	315.3	74.2	(18.5, 612.2)	4.25	0.027
D3L1 (31.8 m - D3L1 (25.4 m	175.8	81.2	(-149.3, 501.0)	2.16	0.894

D3L1 (38 mm) - D3L1 (25.4 m	109.3	81.2	(-215.9, 434.5)	1.35	1.000
D3L2 (25.4 m - D3L1 (25.4 m	431.6	81.2	(106.4, 756.7)	5.31	0.001
D3L2 (31.8 m - D3L1 (25.4 m	301.9	74.2	(5.1, 598.7)	4.07	0.042
D3L2 (38 mm) - D3L1 (25.4 m	382.6	81.2	(57.4, 707.8)	4.71	0.008
D3L3 (25.4 m - D3L1 (25.4 m	274.6	81.2	(-50.6, 599.8)	3.38	0.198
D3L3 (31.8 m - D3L1 (25.4 m	237.3	74.2	(-59.6, 534.1)	3.20	0.278
D3L3 (38 mm) - D3L1 (25.4 m	562.8	81.2	(237.6, 888.0)	6.93	0.000
D3L4 (25.4 m - D3L1 (25.4 m	424.3	81.2	(99.2, 749.5)	5.22	0.002
D3L4 (31.8 m - D3L1 (25.4 m	532.6	74.2	(235.8, 829.5)	7.18	0.000
D3L4 (38 mm) - D3L1 (25.4 m	613.9	81.2	(288.7, 939.1)	7.56	0.000
D3L5 (25.4 m - D3L1 (25.4 m	284.2	74.2	(-12.6, 581.0)	3.83	0.075
D3L5 (31.8 m - D3L1 (25.4 m	392.7	81.2	(67.5, 717.9)	4.83	0.006
D3L5 (38 mm) - D3L1 (25.4 m	337.0	81.2	(11.8, 662.2)	4.15	0.035
D5L1 (25.4 m - D3L1 (25.4 m	384.6	81.2	(59.5, 709.8)	4.73	0.007
D5L1 (31.8 m - D3L1 (25.4 m	377.8	81.2	(52.7, 703.0)	4.65	0.009

D5L1 (38 mm) - D3L1 (25.4 m	573.4	74.2	(276.5, 870.2)	7.73	0.000
D6L1 (25.4 m - D3L1 (25.4 m	688.3	81.2	(363.1, 1013.5)	8.47	0.000
D6L1 (31.8 m - D3L1 (25.4 m	653.1	81.2	(327.9, 978.2)	8.04	0.000
D6L1 (38 mm) - D3L1 (25.4 m	793.5	81.2	(468.3, 1118.7)	9.77	0.000
D3L1 (38 mm) - D3L1 (31.8 m	-66.5	81.2	(-391.7, 258.6)	-0.82	1.000
D3L2 (25.4 m - D3L1 (31.8 m	255.7	81.2	(-69.4, 580.9)	3.15	0.304
D3L2 (31.8 m - D3L1 (31.8 m	126.1	74.2	(-170.8, 422.9)	1.70	0.991
D3L2 (38 mm) - D3L1 (31.8 m	206.8	81.2	(-118.4, 531.9)	2.54	0.688
D3L3 (25.4 m - D3L1 (31.8 m	98.7	81.2	(-226.4, 423.9)	1.22	1.000
D3L3 (31.8 m - D3L1 (31.8 m	61.5	74.2	(-235.4, 358.3)	0.83	1.000
D3L3 (38 mm) - D3L1 (31.8 m	387.0	81.2	(61.8, 712.1)	4.76	0.007
D3L4 (25.4 m - D3L1 (31.8 m	248.5	81.2	(-76.7, 573.7)	3.06	0.353
D3L4 (31.8 m - D3L1 (31.8 m	356.8	74.2	(59.9, 653.6)	4.81	0.006
D3L4 (38 mm) - D3L1 (31.8 m	438.1	81.2	(112.9, 763.2)	5.39	0.001
D3L5 (25.4 m - D3L1 (31.8 m	108.4	74.2	(-188.5, 405.2)	1.46	0.999

D3L5 (31.8 m - D3L1 (31.8 m	216.9	81.2	(-108.3, 542.0)	2.67	0.605
D3L5 (38 mm) - D3L1 (31.8 m	161.2	81.2	(-164.0, 486.3)	1.98	0.951
D5L1 (25.4 m - D3L1 (31.8 m	208.8	81.2	(-116.4, 534.0)	2.57	0.672
D5L1 (31.8 m - D3L1 (31.8 m	202.0	81.2	(-123.2, 527.2)	2.49	0.726
D5L1 (38 mm) - D3L1 (31.8 m	397.5	74.2	(100.7, 694.4)	5.36	0.001
D6L1 (25.4 m - D3L1 (31.8 m	512.5	81.2	(187.3, 837.6)	6.31	0.000
D6L1 (31.8 m - D3L1 (31.8 m	477.2	81.2	(152.1, 802.4)	5.87	0.000
D6L1 (38 mm) - D3L1 (31.8 m	617.7	81.2	(292.5, 942.8)	7.60	0.000
D3L2 (25.4 m - D3L1 (38 mm)	322.3	81.2	(-2.9, 647.4)	3.97	0.054
D3L2 (31.8 m - D3L1 (38 mm)	192.6	74.2	(-104.2, 489.4)	2.60	0.654
D3L2 (38 mm) - D3L1 (38 mm)	273.3	81.2	(-51.9, 598.5)	3.36	0.204
D3L3 (25.4 m - D3L1 (38 mm)	165.3	81.2	(-159.9, 490.4)	2.03	0.938
D3L3 (31.8 m - D3L1 (38 mm)	128.0	74.2	(-168.9, 424.8)	1.73	0.989
D3L3 (38 mm) - D3L1 (38 mm)	453.5	81.2	(128.3, 778.7)	5.58	0.001
D3L4 (25.4 m - D3L1 (38 mm)	315.0	81.2	(-10.1, 640.2)	3.88	0.067

D3L4 (31.8 m - D3L1 (38 mm)	423.3	74.2	(126.5, 720.2)	5.71	0.001
D3L4 (38 mm) - D3L1 (38 mm)	504.6	81.2	(179.4, 829.8)	6.21	0.000
D3L5 (25.4 m - D3L1 (38 mm)	174.9	74.2	(-122.0, 471.7)	2.36	0.802
D3L5 (31.8 m - D3L1 (38 mm)	283.4	81.2	(-41.8, 608.6)	3.49	0.159
D3L5 (38 mm) - D3L1 (38 mm)	227.7	81.2	(-97.5, 552.9)	2.80	0.515
D5L1 (25.4 m - D3L1 (38 mm)	275.3	81.2	(-49.8, 600.5)	3.39	0.195
D5L1 (31.8 m - D3L1 (38 mm)	268.5	81.2	(-56.7, 593.7)	3.30	0.229
D5L1 (38 mm) - D3L1 (38 mm)	464.1	74.2	(167.2, 760.9)	6.26	0.000
D6L1 (25.4 m - D3L1 (38 mm)	579.0	81.2	(253.8, 904.2)	7.13	0.000
D6L1 (31.8 m - D3L1 (38 mm)	543.8	81.2	(218.6, 868.9)	6.69	0.000
D6L1 (38 mm) - D3L1 (38 mm)	684.2	81.2	(359.0, 1009.4)	8.42	0.000
D3L2 (31.8 m - D3L2 (25.4 m	-129.7	74.2	(-426.5, 167.2)	-1.75	0.987
D3L2 (38 mm) - D3L2 (25.4 m	-49.0	81.2	(-374.1, 276.2)	-0.60	1.000
D3L3 (25.4 m - D3L2 (25.4 m	-157.0	81.2	(-482.2, 168.2)	-1.93	0.962
D3L3 (31.8 m - D3L2 (25.4 m	-194.3	74.2	(-491.1, 102.6)	-2.62	0.639

D3L3 (38 mm) - D3L2 (25.4 m	131.2	81.2	(-193.9, 456.4)	1.62	0.995
D3L4 (25.4 m - D3L2 (25.4 m	-7.2	81.2	(-332.4, 318.0)	-0.09	1.000
D3L4 (31.8 m - D3L2 (25.4 m	101.1	74.2	(-195.8, 397.9)	1.36	1.000
D3L4 (38 mm) - D3L2 (25.4 m	182.3	81.2	(-142.8, 507.5)	2.24	0.860
D3L5 (25.4 m - D3L2 (25.4 m	-147.4	74.2	(-444.2, 149.5)	-1.99	0.950
D3L5 (31.8 m - D3L2 (25.4 m	-38.9	81.2	(-364.0, 286.3)	-0.48	1.000
D3L5 (38 mm) - D3L2 (25.4 m	-94.6	81.2	(-419.7, 230.6)	-1.16	1.000
D5L1 (25.4 m - D3L2 (25.4 m	-46.9	81.2	(-372.1, 278.2)	-0.58	1.000
D5L1 (31.8 m - D3L2 (25.4 m	-53.7	81.2	(-378.9, 271.4)	-0.66	1.000
D5L1 (38 mm) - D3L2 (25.4 m	141.8	74.2	(-155.0, 438.7)	1.91	0.966
D6L1 (25.4 m - D3L2 (25.4 m	256.7	81.2	(-68.4, 581.9)	3.16	0.298
D6L1 (31.8 m - D3L2 (25.4 m	221.5	81.2	(-103.7, 546.7)	2.73	0.566
D6L1 (38 mm) - D3L2 (25.4 m	361.9	81.2	(36.8, 687.1)	4.45	0.016
D3L2 (38 mm) - D3L2 (31.8 m	80.7	74.2	(-216.1, 377.6)	1.09	1.000
D3L3 (25.4 m - D3L2 (31.8 m	-27.3	74.2	(-324.2, 269.5)	-0.37	1.000

D3L3 (31.8 m - D3L2 (31.8 m	-64.6	66.3	(-330.1, 200.9)	-0.97	1.000
D3L3 (38 mm) - D3L2 (31.8 m	260.9	74.2	(-35.9, 557.8)	3.52	0.150
D3L4 (25.4 m - D3L2 (31.8 m	122.4	74.2	(-174.4, 419.3)	1.65	0.994
D3L4 (31.8 m - D3L2 (31.8 m	230.7	66.3	(-34.8, 496.2)	3.48	0.163
D3L4 (38 mm) - D3L2 (31.8 m	312.0	74.2	(15.2, 608.8)	4.21	0.030
D3L5 (25.4 m - D3L2 (31.8 m	-17.7	66.3	(-283.2, 247.8)	-0.27	1.000
D3L5 (31.8 m - D3L2 (31.8 m	90.8	74.2	(-206.0, 387.7)	1.22	1.000
D3L5 (38 mm) - D3L2 (31.8 m	35.1	74.2	(-261.7, 331.9)	0.47	1.000
D5L1 (25.4 m - D3L2 (31.8 m	82.7	74.2	(-214.1, 379.6)	1.12	1.000
D5L1 (31.8 m - D3L2 (31.8 m	75.9	74.2	(-220.9, 372.8)	1.02	1.000
D5L1 (38 mm) - D3L2 (31.8 m	271.5	66.3	(6.0, 537.0)	4.09	0.040
D6L1 (25.4 m - D3L2 (31.8 m	386.4	74.2	(89.6, 683.2)	5.21	0.002
D6L1 (31.8 m - D3L2 (31.8 m	351.2	74.2	(54.3, 648.0)	4.73	0.007
D6L1 (38 mm) - D3L2 (31.8 m	491.6	74.2	(194.8, 788.4)	6.63	0.000
D3L3 (25.4 m - D3L2 (38 mm)	-108.0	81.2	(-433.2, 217.1)	-1.33	1.000

D3L3 (31.8 m - D3L2 (38 mm)	-145.3	74.2	(-442.2, 151.5)	-1.96	0.956
D3L3 (38 mm) - D3L2 (38 mm)	180.2	81.2	(-145.0, 505.4)	2.22	0.872
D3L4 (25.4 m - D3L2 (38 mm)	41.7	81.2	(-283.4, 366.9)	0.51	1.000
D3L4 (31.8 m - D3L2 (38 mm)	150.0	74.2	(-146.8, 446.9)	2.02	0.941
D3L4 (38 mm) - D3L2 (38 mm)	231.3	81.2	(-93.9, 556.5)	2.85	0.485
D3L5 (25.4 m - D3L2 (38 mm)	-98.4	74.2	(-395.3, 198.4)	-1.33	1.000
D3L5 (31.8 m - D3L2 (38 mm)	10.1	81.2	(-315.1, 335.3)	0.12	1.000
D3L5 (38 mm) - D3L2 (38 mm)	-45.6	81.2	(-370.8, 279.6)	-0.56	1.000
D5L1 (25.4 m - D3L2 (38 mm)	2.0	81.2	(-323.2, 327.2)	0.02	1.000
D5L1 (31.8 m - D3L2 (38 mm)	-4.8	81.2	(-330.0, 320.4)	-0.06	1.000
D5L1 (38 mm) - D3L2 (38 mm)	190.8	74.2	(-106.1, 487.6)	2.57	0.670
D6L1 (25.4 m - D3L2 (38 mm)	305.7	81.2	(-19.5, 630.9)	3.76	0.088
D6L1 (31.8 m - D3L2 (38 mm)	270.5	81.2	(-54.7, 595.6)	3.33	0.219
D6L1 (38 mm) - D3L2 (38 mm)	410.9	81.2	(85.7, 736.1)	5.06	0.003
D3L3 (31.8 m - D3L3 (25.4 m	-37.3	74.2	(-334.1, 259.6)	-0.50	1.000

D3L3 (38 mm) - D3L3 (25.4 m	288.2	81.2	(-36.9, 613.4)	3.55	0.141
D3L4 (25.4 m - D3L3 (25.4 m	149.8	81.2	(-175.4, 474.9)	1.84	0.977
D3L4 (31.8 m - D3L3 (25.4 m	258.0	74.2	(-38.8, 554.9)	3.48	0.162
D3L4 (38 mm) - D3L3 (25.4 m	339.3	81.2	(14.2, 664.5)	4.18	0.032
D3L5 (25.4 m - D3L3 (25.4 m	9.6	74.2	(-287.2, 306.5)	0.13	1.000
D3L5 (31.8 m - D3L3 (25.4 m	118.1	81.2	(-207.0, 443.3)	1.45	0.999
D3L5 (38 mm) - D3L3 (25.4 m	62.4	81.2	(-262.8, 387.6)	0.77	1.000
D5L1 (25.4 m - D3L3 (25.4 m	110.1	81.2	(-215.1, 435.2)	1.35	1.000
D5L1 (31.8 m - D3L3 (25.4 m	103.3	81.2	(-221.9, 428.4)	1.27	1.000
D5L1 (38 mm) - D3L3 (25.4 m	298.8	74.2	(2.0, 595.6)	4.03	0.047
D6L1 (25.4 m - D3L3 (25.4 m	413.7	81.2	(88.6, 738.9)	5.09	0.003
D6L1 (31.8 m - D3L3 (25.4 m	378.5	81.2	(53.3, 703.7)	4.66	0.009
D6L1 (38 mm) - D3L3 (25.4 m	518.9	81.2	(193.8, 844.1)	6.39	0.000
D3L3 (38 mm) - D3L3 (31.8 m	325.5	74.2	(28.7, 622.4)	4.39	0.019
D3L4 (25.4 m - D3L3 (31.8 m	187.1	74.2	(-109.8, 483.9)	2.52	0.703

D3L4 (31.8 m - D3L3 (31.8 m	295.3	66.3	(29.8, 560.8)	4.45	0.016
D3L4 (38 mm) - D3L3 (31.8 m	376.6	74.2	(79.8, 673.5)	5.08	0.003
D3L5 (25.4 m - D3L3 (31.8 m	46.9	66.3	(-218.6, 312.4)	0.71	1.000
D3L5 (31.8 m - D3L3 (31.8 m	155.4	74.2	(-141.4, 452.3)	2.10	0.919
D3L5 (38 mm) - D3L3 (31.8 m	99.7	74.2	(-197.1, 396.6)	1.34	1.000
D5L1 (25.4 m - D3L3 (31.8 m	147.3	74.2	(-149.5, 444.2)	1.99	0.950
D5L1 (31.8 m - D3L3 (31.8 m	140.5	74.2	(-156.3, 437.4)	1.89	0.969
D5L1 (38 mm) - D3L3 (31.8 m	336.1	66.3	(70.6, 601.6)	5.07	0.003
D6L1 (25.4 m - D3L3 (31.8 m	451.0	74.2	(154.2, 747.9)	6.08	0.000
D6L1 (31.8 m - D3L3 (31.8 m	415.8	74.2	(118.9, 712.6)	5.61	0.001
D6L1 (38 mm) - D3L3 (31.8 m	556.2	74.2	(259.4, 853.1)	7.50	0.000
D3L4 (25.4 m - D3L3 (38 mm)	-138.5	81.2	(-463.6, 186.7)	-1.70	0.990
D3L4 (31.8 m - D3L3 (38 mm)	-30.2	74.2	(-327.0, 266.7)	-0.41	1.000
D3L4 (38 mm) - D3L3 (38 mm)	51.1	81.2	(-274.1, 376.3)	0.63	1.000
D3L5 (25.4 m - D3L3 (38 mm)	-278.6	74.2	(-575.5, 18.2)	-3.76	0.089

D3L5 (31.8 m - D3L3 (38 mm)	-170.1	81.2	(-495.3, 155.1)	-2.09	0.920
D3L5 (38 mm) - D3L3 (38 mm)	-225.8	81.2	(-551.0, 99.4)	-2.78	0.530
D5L1 (25.4 m - D3L3 (38 mm)	-178.2	81.2	(-503.4, 147.0)	-2.19	0.882
D5L1 (31.8 m - D3L3 (38 mm)	-185.0	81.2	(-510.2, 140.2)	-2.28	0.844
D5L1 (38 mm) - D3L3 (38 mm)	10.6	74.2	(-286.3, 307.4)	0.14	1.000
D6L1 (25.4 m - D3L3 (38 mm)	125.5	81.2	(-199.7, 450.7)	1.54	0.997
D6L1 (31.8 m - D3L3 (38 mm)	90.3	81.2	(-234.9, 415.4)	1.11	1.000
D6L1 (38 mm) - D3L3 (38 mm)	230.7	81.2	(-94.5, 555.9)	2.84	0.490
D3L4 (31.8 m - D3L4 (25.4 m	108.3	74.2	(-188.6, 405.1)	1.46	0.999
D3L4 (38 mm) - D3L4 (25.4 m	189.6	81.2	(-135.6, 514.7)	2.33	0.815
D3L5 (25.4 m - D3L4 (25.4 m	-140.2	74.2	(-437.0, 156.7)	-1.89	0.970
D3L5 (31.8 m - D3L4 (25.4 m	-31.6	81.2	(-356.8, 293.5)	-0.39	1.000
D3L5 (38 mm) - D3L4 (25.4 m	-87.4	81.2	(-412.5, 237.8)	-1.08	1.000
D5L1 (25.4 m - D3L4 (25.4 m	-39.7	81.2	(-364.9, 285.5)	-0.49	1.000
D5L1 (31.8 m - D3L4 (25.4 m	-46.5	81.2	(-371.7, 278.7)	-0.57	1.000

D5L1 (38 mm) - D3L4 (25.4 m	149.0	74.2	(-147.8, 445.9)	2.01	0.944
D6L1 (25.4 m - D3L4 (25.4 m	264.0	81.2	(-61.2, 589.1)	3.25	0.254
D6L1 (31.8 m - D3L4 (25.4 m	228.7	81.2	(-96.5, 553.9)	2.82	0.506
D6L1 (38 mm) - D3L4 (25.4 m	369.2	81.2	(44.0, 694.3)	4.54	0.012
D3L4 (38 mm) - D3L4 (31.8 m	81.3	74.2	(-215.6, 378.1)	1.10	1.000
D3L5 (25.4 m - D3L4 (31.8 m	-248.4	66.3	(-513.9, 17.1)	-3.74	0.091
D3L5 (31.8 m - D3L4 (31.8 m	-139.9	74.2	(-436.8, 156.9)	-1.89	0.970
D3L5 (38 mm) - D3L4 (31.8 m	-195.6	74.2	(-492.5, 101.2)	-2.64	0.626
D5L1 (25.4 m - D3L4 (31.8 m	-148.0	74.2	(-444.8, 148.8)	-2.00	0.948
D5L1 (31.8 m - D3L4 (31.8 m	-154.8	74.2	(-451.6, 142.0)	-2.09	0.922
D5L1 (38 mm) - D3L4 (31.8 m	40.7	66.3	(-224.8, 306.3)	0.61	1.000
D6L1 (25.4 m - D3L4 (31.8 m	155.7	74.2	(-141.2, 452.5)	2.10	0.918
D6L1 (31.8 m - D3L4 (31.8 m	120.4	74.2	(-176.4, 417.3)	1.62	0.995
D6L1 (38 mm) - D3L4 (31.8 m	260.9	74.2	(-36.0, 557.7)	3.52	0.150
D3L5 (25.4 m - D3L4 (38 mm)	-329.7	74.2	(-626.6, -32.9)	-4.45	0.016

D3L5 (31.8 m - D3L4 (38 mm)	-221.2	81.2	(-546.4, 104.0)	-2.72	0.569
D3L5 (38 mm) - D3L4 (38 mm)	-276.9	81.2	(-602.1, 48.3)	-3.41	0.187
D5L1 (25.4 m - D3L4 (38 mm)	-229.3	81.2	(-554.4, 95.9)	-2.82	0.502
D5L1 (31.8 m - D3L4 (38 mm)	-236.1	81.2	(-561.3, 89.1)	-2.91	0.447
D5L1 (38 mm) - D3L4 (38 mm)	-40.5	74.2	(-337.4, 256.3)	-0.55	1.000
D6L1 (25.4 m - D3L4 (38 mm)	74.4	81.2	(-250.8, 399.6)	0.92	1.000
D6L1 (31.8 m - D3L4 (38 mm)	39.2	81.2	(-286.0, 364.3)	0.48	1.000
D6L1 (38 mm) - D3L4 (38 mm)	179.6	81.2	(-145.6, 504.8)	2.21	0.875
D3L5 (31.8 m - D3L5 (25.4 m	108.5	74.2	(-188.3, 405.4)	1.46	0.999
D3L5 (38 mm) - D3L5 (25.4 m	52.8	74.2	(-244.0, 349.6)	0.71	1.000
D5L1 (25.4 m - D3L5 (25.4 m	100.4	74.2	(-196.4, 397.3)	1.35	1.000
D5L1 (31.8 m - D3L5 (25.4 m	93.6	74.2	(-203.2, 390.5)	1.26	1.000
D5L1 (38 mm) - D3L5 (25.4 m	289.2	66.3	(23.7, 554.7)	4.36	0.020
D6L1 (25.4 m - D3L5 (25.4 m	404.1	74.2	(107.3, 700.9)	5.45	0.001
D6L1 (31.8 m - D3L5 (25.4 m	368.9	74.2	(72.0, 665.7)	4.97	0.004

D6L1 (38 mm) - D3L5 (25.4 m	509.3	74.2	(212.5, 806.2)	6.87	0.000
D3L5 (38 mm) - D3L5 (31.8 m	-55.7	81.2	(-380.9, 269.5)	-0.69	1.000
D5L1 (25.4 m - D3L5 (31.8 m	-8.1	81.2	(-333.3, 317.1)	-0.10	1.000
D5L1 (31.8 m - D3L5 (31.8 m	-14.9	81.2	(-340.1, 310.3)	-0.18	1.000
D5L1 (38 mm) - D3L5 (31.8 m	180.7	74.2	(-116.2, 477.5)	2.44	0.757
D6L1 (25.4 m - D3L5 (31.8 m	295.6	81.2	(-29.6, 620.8)	3.64	0.116
D6L1 (31.8 m - D3L5 (31.8 m	260.4	81.2	(-64.8, 585.5)	3.20	0.275
D6L1 (38 mm) - D3L5 (31.8 m	400.8	81.2	(75.6, 726.0)	4.93	0.004
D5L1 (25.4 m - D3L5 (38 mm)	47.6	81.2	(-277.5, 372.8)	0.59	1.000
D5L1 (31.8 m - D3L5 (38 mm)	40.8	81.2	(-284.3, 366.0)	0.50	1.000
D5L1 (38 mm) - D3L5 (38 mm)	236.4	74.2	(-60.5, 533.2)	3.19	0.284
D6L1 (25.4 m - D3L5 (38 mm)	351.3	81.2	(26.1, 676.5)	4.32	0.022
D6L1 (31.8 m - D3L5 (38 mm)	316.1	81.2	(-9.1, 641.2)	3.89	0.065
D6L1 (38 mm) - D3L5 (38 mm)	456.5	81.2	(131.3, 781.7)	5.62	0.001
D5L1 (31.8 m - D5L1 (25.4 m	-6.8	81.2	(-332.0, 318.4)	-0.08	1.000

D5L1 (38 mm) - D5L1 (25.4 m	188.7	74.2	(-108.1, 485.6)	2.54	0.688
D6L1 (25.4 m - D5L1 (25.4 m	303.7	81.2	(-21.5, 628.8)	3.74	0.093
D6L1 (31.8 m - D5L1 (25.4 m	268.4	81.2	(-56.7, 593.6)	3.30	0.229
D6L1 (38 mm) - D5L1 (25.4 m	408.9	81.2	(83.7, 734.1)	5.03	0.003
D5L1 (38 mm) - D5L1 (31.8 m	195.5	74.2	(-101.3, 492.4)	2.64	0.627
D6L1 (25.4 m - D5L1 (31.8 m	310.5	81.2	(-14.7, 635.6)	3.82	0.076
D6L1 (31.8 m - D5L1 (31.8 m	275.2	81.2	(-49.9, 600.4)	3.39	0.195
D6L1 (38 mm) - D5L1 (31.8 m	415.7	81.2	(90.5, 740.9)	5.12	0.003
D6L1 (25.4 m - D5L1 (38 mm)	114.9	74.2	(-181.9, 411.8)	1.55	0.997
D6L1 (31.8 m - D5L1 (38 mm)	79.7	74.2	(-217.1, 376.5)	1.07	1.000
D6L1 (38 mm) - D5L1 (38 mm)	220.1	74.2	(-76.7, 517.0)	2.97	0.407
D6L1 (31.8 m - D6L1 (25.4 m	-35.2	81.2	(-360.4, 289.9)	-0.43	1.000
D6L1 (38 mm) - D6L1 (25.4 m	105.2	81.2	(-220.0, 430.4)	1.29	1.000
D6L1 (38 mm) - D6L1 (31.8 m	140.4	81.2	(-184.7, 465.6)	1.73	0.989

Individual confidence level = 99.97%

B.19. Statistical Analysis of Coefficient of Variation (COV) of LMLC and PMLC computed from all performance tests

One-way ANOVA: COV versus Performance Measures

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Performance Measures	13	CRI (15 mm), CRI (25.4 mm), CRI (31.8 mm), CRI (38 mm), CRI (IDT), FI (15 mm), FI (IDT), G_f (15 mm), G_f (25.4 mm), Gf (31.8 mm), G_f (38 mm), G_f (IDT), IDT Strength

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Performance Measures	12	0.6149	0.051240	7.26	0.000
Error	182	1.2844	0.007057		
Total	194	1.8993			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0840076	32.37%	27.92%	22.37%

Means

Performance Measures	N	Mean	StDev	95% CI
CRI (15 mm)	15	0.1124	0.0557	(0.0696, 0.1552)
CRI (25.4 mm)	15	0.0553	0.0418	(0.0125, 0.0981)
CRI (31.8 mm)	15	0.1064	0.0803	(0.0636, 0.1492)
CRI (38 mm)	15	0.0998	0.0415	(0.0570, 0.1426)
CRI (IDT)	15	0.0937	0.0408	(0.0509, 0.1365)
FI (15 mm)	15	0.2630	0.1064	(0.2202, 0.3058)
FI (IDT)	15	0.1978	0.1163	(0.1550, 0.2406)
G_f (15 mm)	15	0.1389	0.0784	(0.0961, 0.1817)
G_f (25.4 mm)	15	0.1251	0.1231	(0.0823, 0.1679)
G_f (31.8 mm)	15	0.1898	0.0806	(0.1470, 0.2326)
G_f (38 mm)	15	0.1934	0.1364	(0.1506, 0.2362)
G_f (IDT)	15	0.1090	0.0456	(0.0662, 0.1518)
IDT Strength	15	0.0816	0.0612	(0.0388, 0.1244)

Pooled StDev = 0.0840076

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Performance Measures	N	Mean	Grouping			
FI (15 mm)	15	0.2630	A			
FI (IDT)	15	0.1978	A	B		
G_f (38 mm)	15	0.1934	A	B	C	
G_f (31.8 mm)	15	0.1898	A	B	C	
G_f (15 mm)	15	0.1389		B	C	D
G_f (25.4 mm)	15	0.1251		B	C	D

CRI (15 mm)	15	0.1124		B	C	D
G_f (IDT)	15	0.1090		B	C	D
CRI (31.8 mm)	15	0.1064		B	C	D
CRI (38 mm)	15	0.0998		B	C	D
CRI (IDT)	15	0.0937			C	D
IDT Strength	15	0.0816				D
CRI (25.4 mm)	15	0.0553				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
CRI (25.4 mm - CRI (15 mm)	-0.0571	0.0307	(-0.1601, 0.0459)	-1.86	0.815
CRI (31.8 mm - CRI (15 mm)	-0.0060	0.0307	(-0.1090, 0.0971)	-0.19	1.000
CRI (38 mm) - CRI (15 mm)	-0.0126	0.0307	(-0.1156, 0.0905)	-0.41	1.000
CRI (IDT) - CRI (15 mm)	-0.0187	0.0307	(-0.1217, 0.0844)	-0.61	1.000
FI (15 mm) - CRI (15 mm)	0.1506	0.0307	(0.0476, 0.2536)	4.91	0.000
FI (IDT) - CRI (15 mm)	0.0854	0.0307	(-0.0176, 0.1885)	2.79	0.218
G_f (15 mm) - CRI (15 mm)	0.0266	0.0307	(-0.0765, 0.1296)	0.87	1.000
G_f (25.4 mm) - CRI (15 mm)	0.0127	0.0307	(-0.0903, 0.1157)	0.41	1.000

G_f (31.8 mm) - CRI (15 mm)	0.0774	0.0307	(-0.0256, 0.1804)	2.52	0.366
G_f (38 mm) - CRI (15 mm)	0.0810	0.0307	(-0.0220, 0.1840)	2.64	0.294
G_f (IDT) - CRI (15 mm)	-0.0034	0.0307	(-0.1064, 0.0997)	-0.11	1.000
IDT Strength - CRI (15 mm)	-0.0308	0.0307	(-0.1338, 0.0722)	-1.00	0.999
CRI (31.8 mm - CRI (25.4 mm	0.0511	0.0307	(-0.0519, 0.1542)	1.67	0.905
CRI (38 mm) - CRI (25.4 mm	0.0445	0.0307	(-0.0585, 0.1476)	1.45	0.964
CRI (IDT) - CRI (25.4 mm	0.0384	0.0307	(-0.0646, 0.1415)	1.25	0.989
FI (15 mm) - CRI (25.4 mm	0.2077	0.0307	(0.1047, 0.3107)	6.77	0.000
FI (IDT) - CRI (25.4 mm	0.1425	0.0307	(0.0395, 0.2456)	4.65	0.000
G_f (15 mm) - CRI (25.4 mm	0.0836	0.0307	(-0.0194, 0.1867)	2.73	0.247
G_f (25.4 mm) - CRI (25.4 mm	0.0698	0.0307	(-0.0332, 0.1728)	2.28	0.538
G_f (31.8 mm) - CRI (25.4 mm	0.1345	0.0307	(0.0315, 0.2375)	4.38	0.001
G_f (38 mm) - CRI (25.4 mm	0.1381	0.0307	(0.0351, 0.2411)	4.50	0.001
G_f (IDT) - CRI (25.4 mm	0.0537	0.0307	(-0.0493, 0.1568)	1.75	0.870
IDT Strength - CRI (25.4 mm	0.0263	0.0307	(-0.0767, 0.1293)	0.86	1.000

CRI (38 mm) - CRI (31.8 mm	-0.0066	0.0307	(-0.1096, 0.0964)	-0.22	1.000
CRI (IDT) - CRI (31.8 mm	-0.0127	0.0307	(-0.1157, 0.0903)	-0.41	1.000
FI (15 mm) - CRI (31.8 mm	0.1566	0.0307	(0.0535, 0.2596)	5.10	0.000
FI (IDT) - CRI (31.8 mm	0.0914	0.0307	(-0.0116, 0.1944)	2.98	0.139
G_f (15 mm) - CRI (31.8 mm	0.0325	0.0307	(-0.0705, 0.1355)	1.06	0.998
G_f (25.4 mm) - CRI (31.8 mm	0.0187	0.0307	(-0.0844, 0.1217)	0.61	1.000
Gf (31.8 mm) - CRI (31.8 mm	0.0833	0.0307	(-0.0197, 0.1864)	2.72	0.252
G_f (38 mm) - CRI (31.8 mm	0.0869	0.0307	(-0.0161, 0.1900)	2.83	0.196
G_f (IDT) - CRI (31.8 mm	0.0026	0.0307	(-0.1004, 0.1056)	0.08	1.000
IDT Strength - CRI (31.8 mm	-0.0248	0.0307	(-0.1279, 0.0782)	-0.81	1.000
CRI (IDT) - CRI (38 mm)	-0.0061	0.0307	(-0.1091, 0.0969)	-0.20	1.000
FI (15 mm) - CRI (38 mm)	0.1632	0.0307	(0.0602, 0.2662)	5.32	0.000
FI (IDT) - CRI (38 mm)	0.0980	0.0307	(-0.0050, 0.2010)	3.20	0.079
G_f (15 mm) - CRI (38 mm)	0.0391	0.0307	(-0.0639, 0.1422)	1.28	0.987
G_f (25.4 mm) - CRI (38 mm)	0.0253	0.0307	(-0.0778, 0.1283)	0.82	1.000

G_f (31.8 mm) - CRI (38 mm)	0.0900	0.0307	(-0.0131, 0.1930)	2.93	0.156
G_f (38 mm) - CRI (38 mm)	0.0936	0.0307	(-0.0095, 0.1966)	3.05	0.117
G_f (IDT) - CRI (38 mm)	0.0092	0.0307	(-0.0938, 0.1122)	0.30	1.000
IDT Strength - CRI (38 mm)	-0.0182	0.0307	(-0.1212, 0.0848)	-0.59	1.000
FI (15 mm) - CRI (IDT)	0.1693	0.0307	(0.0662, 0.2723)	5.52	0.000
FI (IDT) - CRI (IDT)	0.1041	0.0307	(0.0011, 0.2071)	3.39	0.045
G_f (15 mm) - CRI (IDT)	0.0452	0.0307	(-0.0578, 0.1482)	1.47	0.960
G_f (25.4 mm) - CRI (IDT)	0.0314	0.0307	(-0.0717, 0.1344)	1.02	0.998
G_f (31.8 mm) - CRI (IDT)	0.0961	0.0307	(-0.0070, 0.1991)	3.13	0.094
G_f (38 mm) - CRI (IDT)	0.0997	0.0307	(-0.0034, 0.2027)	3.25	0.068
G_f (IDT) - CRI (IDT)	0.0153	0.0307	(-0.0877, 0.1183)	0.50	1.000
IDT Strength - CRI (IDT)	-0.0121	0.0307	(-0.1152, 0.0909)	-0.40	1.000
FI (IDT) - FI (15 mm)	-0.0652	0.0307	(-0.1682, 0.0379)	-2.12	0.647
G_f (15 mm) - FI (15 mm)	-0.1241	0.0307	(-0.2271, -0.0210)	-4.04	0.005
G_f (25.4 mm) - FI (15 mm)	-0.1379	0.0307	(-0.2409, -0.0349)	-4.50	0.001

G_f (31.8 mm) - FI (15 mm)	-0.0732	0.0307	(-0.1763, 0.0298)	-2.39	0.458
G_f (38 mm) - FI (15 mm)	-0.0696	0.0307	(-0.1727, 0.0334)	-2.27	0.542
G_f (IDT) - FI (15 mm)	-0.1540	0.0307	(-0.2570, -0.0509)	-5.02	0.000
IDT Strength - FI (15 mm)	-0.1814	0.0307	(-0.2844, -0.0784)	-5.91	0.000
G_f (15 mm) - FI (IDT)	-0.0589	0.0307	(-0.1619, 0.0441)	-1.92	0.782
G_f (25.4 mm) - FI (IDT)	-0.0727	0.0307	(-0.1758, 0.0303)	-2.37	0.469
Gf (31.8 mm) - FI (IDT)	-0.0080	0.0307	(-0.1111, 0.0950)	-0.26	1.000
G_f (38 mm) - FI (IDT)	-0.0044	0.0307	(-0.1075, 0.0986)	-0.15	1.000
G_f (IDT) - FI (IDT)	-0.0888	0.0307	(-0.1918, 0.0142)	-2.89	0.171
IDT Strength - FI (IDT)	-0.1162	0.0307	(-0.2193, -0.0132)	-3.79	0.013
G_f (25.4 mm) - G_f (15 mm)	-0.0139	0.0307	(-0.1169, 0.0892)	-0.45	1.000
G_f (31.8 mm) - G_f (15 mm)	0.0508	0.0307	(-0.0522, 0.1539)	1.66	0.909
G_f (38 mm) - G_f (15 mm)	0.0544	0.0307	(-0.0486, 0.1575)	1.77	0.860
G_f (IDT) - G_f (15 mm)	-0.0299	0.0307	(-0.1329, 0.0731)	-0.98	0.999
IDT Strength - G_f (15 mm)	-0.0573	0.0307	(-0.1604, 0.0457)	-1.87	0.811

G_f (31.8 mm) - G_f (25.4 mm)	0.0647	0.0307	(-0.0383, 0.1677)	2.11	0.658
G_f (38 mm) - G_f (25.4 mm)	0.0683	0.0307	(-0.0347, 0.1713)	2.23	0.573
G_f (IDT) - G_f (25.4 mm)	-0.0161	0.0307	(-0.1191, 0.0870)	-0.52	1.000
IDT Strength - G_f (25.4 mm)	-0.0435	0.0307	(-0.1465, 0.0595)	-1.42	0.970
G_f (38 mm) - G_f (31.8 mm)	0.0036	0.0307	(-0.0994, 0.1066)	0.12	1.000
G_f (IDT) - G_f (31.8 mm)	-0.0807	0.0307	(-0.1838, 0.0223)	-2.63	0.299
IDT Strength - G_f (31.8 mm)	-0.1082	0.0307	(-0.2112, -0.0051)	-3.53	0.030
G_f (IDT) - G_f (38 mm)	-0.0843	0.0307	(-0.1874, 0.0187)	-2.75	0.236
IDT Strength - G_f (38 mm)	-0.1118	0.0307	(-0.2148, -0.0087)	-3.64	0.020
IDT Strength - G_f (IDT)	-0.0274	0.0307	(-0.1305, 0.0756)	-0.89	1.000

B.20. Statistical Analysis of rut depth of LMLC computed from the APA Test

One-way ANOVA: APA Rut Depth (mm) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	24.069	4.81371	59.69	0.000
Error	18	1.452	0.08065		
Total	23	25.520			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.283992	94.31%	92.73%	89.89%

Means

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	4	1.0315	0.0264	(0.7332, 1.3298)
58-5%	4	1.501	0.224	(1.203, 1.799)

58-5.75%	4	3.1133	0.1307	(2.8149, 3.4116)
70-4.25%	4	2.809	0.369	(2.511, 3.107)
70-5%	4	2.727	0.363	(2.428, 3.025)
70-5.75%	4	4.032	0.385	(3.734, 4.331)

Pooled StDev = 0.283992

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping		
70-5.75%	4	4.032	A		
58-5.75%	4	3.1133		B	
70-4.25%	4	2.809		B	
70-5%	4	2.727		B	
58-5%	4	1.501			C
58-4.25%	4	1.0315			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	0.470	0.201	(-0.168, 1.107)	2.34	0.230
58-5.75% - 58-4.25%	2.082	0.201	(1.444, 2.719)	10.37	0.000
70-4.25% - 58-4.25%	1.777	0.201	(1.140, 2.415)	8.85	0.000
70-5% - 58-4.25%	1.695	0.201	(1.058, 2.333)	8.44	0.000
70-5.75% - 58-4.25%	3.001	0.201	(2.363, 3.638)	14.94	0.000
58-5.75% - 58-5%	1.612	0.201	(0.975, 2.250)	8.03	0.000

70-4.25% - 58-5%	1.308	0.201	(0.670, 1.945)	6.51	0.000
70-5% - 58-5%	1.226	0.201	(0.588, 1.863)	6.10	0.000
70-5.75% - 58-5%	2.531	0.201	(1.894, 3.169)	12.60	0.000
70-4.25% - 58-5.75%	-0.304	0.201	(-0.942, 0.333)	-1.52	0.659
70-5% - 58-5.75%	-0.387	0.201	(-1.024, 0.251)	-1.93	0.419
70-5.75% - 58-5.75%	0.919	0.201	(0.281, 1.557)	4.58	0.003
70-5% - 70-4.25%	-0.082	0.201	(-0.720, 0.555)	-0.41	0.998
70-5.75% - 70-4.25%	1.223	0.201	(0.586, 1.861)	6.09	0.000
70-5.75% - 70-5%	1.306	0.201	(0.668, 1.943)	6.50	0.000

Individual confidence level = 99.48%

B.21. Statistical Analysis of rut depth of PMLC computed from the APA Test

One-way ANOVA: APA Rut Depth (mm) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	24.953	3.1191	12.04	0.000
Error	31	8.032	0.2591		
Total	39	32.985			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.509022	75.65%	69.36%	62.19%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	4	2.086	0.215	(1.567, 2.605)
D2L1	4	3.70959	0.00504	(3.19052, 4.22867)
D3L1	4	2.5173	0.1902	(1.9982, 3.0363)
D3L2	8	3.631	0.740	(3.264, 3.998)
D3L3	4	4.297	1.002	(3.778, 4.816)
D3L4	4	2.3061	0.1905	(1.7870, 2.8252)
D3L5	4	2.120	0.252	(1.600, 2.639)
D5L1	4	4.0659	0.0667	(3.5468, 4.5850)
D6L1	4	3.177	0.457	(2.658, 3.696)

Pooled StDev = 0.509022

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping		
D3L3	4	4.297	A		
D5L1	4	4.0659	A		
D2L1	4	3.70959	A	B	
D3L2	8	3.631	A		
D6L1	4	3.177	A	B	C
D3L1	4	2.5173		B	C
D3L4	4	2.3061			C
D3L5	4	2.120			C
D1L1	4	2.086			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	1.624	0.360	(0.425, 2.823)	4.51	0.002
D3L1 - D1L1	0.432	0.360	(-0.767, 1.630)	1.20	0.951
D3L2 - D1L1	1.545	0.312	(0.507, 2.583)	4.96	0.001
D3L3 - D1L1	2.211	0.360	(1.013, 3.410)	6.14	0.000
D3L4 - D1L1	0.220	0.360	(-0.978, 1.419)	0.61	0.999
D3L5 - D1L1	0.034	0.360	(-1.165, 1.233)	0.09	1.000
D5L1 - D1L1	1.980	0.360	(0.782, 3.179)	5.50	0.000
D6L1 - D1L1	1.092	0.360	(-0.107, 2.291)	3.03	0.097
D3L1 - D2L1	-1.192	0.360	(-2.391, 0.006)	-3.31	0.052
D3L2 - D2L1	-0.079	0.312	(-1.117, 0.959)	-0.25	1.000
D3L3 - D2L1	0.587	0.360	(-0.611, 1.786)	1.63	0.780
D3L4 - D2L1	-1.404	0.360	(-2.602, -0.205)	-3.90	0.012
D3L5 - D2L1	-1.590	0.360	(-2.789, -0.391)	-4.42	0.003
D5L1 - D2L1	0.356	0.360	(-0.842, 1.555)	0.99	0.984
D6L1 - D2L1	-0.532	0.360	(-1.731, 0.667)	-1.48	0.857
D3L2 - D3L1	1.114	0.312	(0.075, 2.152)	3.57	0.028
D3L3 - D3L1	1.780	0.360	(0.581, 2.979)	4.94	0.001
D3L4 - D3L1	-0.211	0.360	(-1.410, 0.988)	-0.59	1.000
D3L5 - D3L1	-0.398	0.360	(-1.596, 0.801)	-1.11	0.969
D5L1 - D3L1	1.549	0.360	(0.350, 2.747)	4.30	0.004
D6L1 - D3L1	0.660	0.360	(-0.539, 1.859)	1.83	0.661
D3L3 - D3L2	0.666	0.312	(-0.372, 1.704)	2.14	0.468
D3L4 - D3L2	-1.325	0.312	(-2.363, -0.287)	-4.25	0.005
D3L5 - D3L2	-1.511	0.312	(-2.550, -0.473)	-4.85	0.001
D5L1 - D3L2	0.435	0.312	(-0.603, 1.473)	1.40	0.891
D6L1 - D3L2	-0.453	0.312	(-1.492, 0.585)	-1.45	0.867

D3L4 - D3L3	-1.991	0.360	(-3.190, -0.792)	-5.53	0.000
D3L5 - D3L3	-2.178	0.360	(-3.376, -0.979)	-6.05	0.000
D5L1 - D3L3	-0.231	0.360	(-1.430, 0.968)	-0.64	0.999
D6L1 - D3L3	-1.120	0.360	(-2.318, 0.079)	-3.11	0.082
D3L5 - D3L4	-0.187	0.360	(-1.385, 1.012)	-0.52	1.000
D5L1 - D3L4	1.760	0.360	(0.561, 2.959)	4.89	0.001
D6L1 - D3L4	0.871	0.360	(-0.327, 2.070)	2.42	0.309
D5L1 - D3L5	1.946	0.360	(0.748, 3.145)	5.41	0.000
D6L1 - D3L5	1.058	0.360	(-0.141, 2.257)	2.94	0.118
D6L1 - D5L1	-0.889	0.360	(-2.087, 0.310)	-2.47	0.285

Individual confidence level = 99.78%

B.22. Statistical Analysis of rut depth of LMLC computed from the HWTT Test

One-way ANOVA: HWTT Rut Depth (mm) versus Projects (LMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (LMLC)	6	58-4.25%, 58-5%, 58-5.75%, 70-4.25%, 70-5%, 70-5.75%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (LMLC)	5	79.98	15.9953	41.33	0.000
Error	42	16.25	0.3870		
Total	47	96.23			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.622088	83.11%	81.10%	77.94%

Mean

Projects (LMLC)	N	Mean	StDev	95% CI
58-4.25%	8	3.0167	0.0918	(2.5728, 3.4606)
58-5%	8	4.532	0.679	(4.088, 4.976)
58-5.75%	8	6.168	1.175	(5.725, 6.612)
70-4.25%	8	2.695	0.375	(2.251, 3.138)
70-5%	8	2.6031	0.2753	(2.1592, 3.0469)
70-5.75%	8	4.640	0.505	(4.196, 5.084)

Pooled StDev = 0.622088

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (LMLC)	N	Mean	Grouping		
58-5.75%	8	6.168	A		
70-5.75%	8	4.640		B	
58-5%	8	4.532		B	
58-4.25%	8	3.0167			C
70-4.25%	8	2.695			C
70-5%	8	2.6031			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
58-5% - 58-4.25%	1.515	0.311	(0.587, 2.444)	4.87	0.000
58-5.75% - 58-4.25%	3.152	0.311	(2.224, 4.080)	10.13	0.000
70-4.25% - 58-4.25%	-0.322	0.311	(-1.250, 0.606)	-1.04	0.903
70-5% - 58-4.25%	-0.414	0.311	(-1.342, 0.515)	-1.33	0.767
70-5.75% - 58-4.25%	1.623	0.311	(0.695, 2.551)	5.22	0.000
58-5.75% - 58-5%	1.636	0.311	(0.708, 2.564)	5.26	0.000
70-4.25% - 58-5%	-1.838	0.311	(-2.766, -0.909)	-5.91	0.000
70-5% - 58-5%	-1.929	0.311	(-2.857, -1.001)	-6.20	0.000
70-5.75% - 58-5%	0.108	0.311	(-0.820, 1.036)	0.35	0.999
70-4.25% - 58-5.75%	-3.474	0.311	(-4.402, -2.546)	-11.17	0.000
70-5% - 58-5.75%	-3.565	0.311	(-4.493, -2.637)	-11.46	0.000
70-5.75% - 58-5.75%	-1.528	0.311	(-2.457, -0.600)	-4.91	0.000
70-5% - 70-4.25%	-0.092	0.311	(-1.020, 0.837)	-0.29	1.000
70-5.75% - 70-4.25%	1.945	0.311	(1.017, 2.874)	6.25	0.000
70-5.75% - 70-5%	2.037	0.311	(1.109, 2.965)	6.55	0.000

Individual confidence level = 99.53%

B.23. Statistical Analysis of rut depth of PMLC computed from the HWTT Test

One-way ANOVA: HWTT Rut Depth (mm) versus Projects (PMLC)

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Projects (PMLC)	9	D1L1, D2L1, D3L1, D3L2, D3L3, D3L4, D3L5, D5L1, D6L1

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Projects (PMLC)	8	92.47	11.5583	29.42	0.000
Error	63	24.75	0.3929		
Total	71	117.22			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.626794	78.88%	76.20%	72.42%

Means

Projects (PMLC)	N	Mean	StDev	95% CI
D1L1	8	3.384	0.807	(2.941, 3.827)
D2L1	8	1.9272	0.1597	(1.4844, 2.3701)
D3L1	8	2.511	0.589	(2.068, 2.954)
D3L2	8	2.0542	0.0298	(1.6114, 2.4970)
D3L3	8	5.416	0.463	(4.973, 5.859)
D3L4	8	4.075	0.546	(3.632, 4.517)
D3L5	8	2.061	0.842	(1.618, 2.504)
D5L1	8	2.531	0.707	(2.088, 2.974)
D6L1	8	4.073	0.889	(3.630, 4.516)

Pooled StDev = 0.626794

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Projects (PMLC)	N	Mean	Grouping			
D3L3	8	5.416	A			
D3L4	8	4.075		B		
D6L1	8	4.073		B		
D1L1	8	3.384		B	C	
D5L1	8	2.531			C	D
D3L1	8	2.511			C	D
D3L5	8	2.061				D
D3L2	8	2.0542				D
D2L1	8	1.9272				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
D2L1 - D1L1	-1.457	0.313	(-2.463, -0.450)	-4.65	0.001
D3L1 - D1L1	-0.873	0.313	(-1.879, 0.133)	-2.79	0.140
D3L2 - D1L1	-1.330	0.313	(-2.336, -0.324)	-4.24	0.002
D3L3 - D1L1	2.032	0.313	(1.026, 3.038)	6.48	0.000
D3L4 - D1L1	0.691	0.313	(-0.315, 1.697)	2.20	0.416
D3L5 - D1L1	-1.323	0.313	(-2.329, -0.317)	-4.22	0.002
D5L1 - D1L1	-0.853	0.313	(-1.859, 0.153)	-2.72	0.161
D6L1 - D1L1	0.689	0.313	(-0.317, 1.695)	2.20	0.419
D3L1 - D2L1	0.584	0.313	(-0.422, 1.590)	1.86	0.641
D3L2 - D2L1	0.127	0.313	(-0.879, 1.133)	0.41	1.000
D3L3 - D2L1	3.489	0.313	(2.483, 4.495)	11.13	0.000
D3L4 - D2L1	2.147	0.313	(1.141, 3.153)	6.85	0.000
D3L5 - D2L1	0.134	0.313	(-0.872, 1.140)	0.43	1.000
D5L1 - D2L1	0.604	0.313	(-0.402, 1.610)	1.93	0.599
D6L1 - D2L1	2.146	0.313	(1.140, 3.152)	6.85	0.000
D3L2 - D3L1	-0.457	0.313	(-1.463, 0.549)	-1.46	0.870
D3L3 - D3L1	2.905	0.313	(1.899, 3.911)	9.27	0.000
D3L4 - D3L1	1.564	0.313	(0.558, 2.570)	4.99	0.000
D3L5 - D3L1	-0.450	0.313	(-1.456, 0.556)	-1.44	0.880
D5L1 - D3L1	0.020	0.313	(-0.986, 1.026)	0.06	1.000
D6L1 - D3L1	1.562	0.313	(0.556, 2.568)	4.98	0.000
D3L3 - D3L2	3.362	0.313	(2.356, 4.368)	10.73	0.000
D3L4 - D3L2	2.020	0.313	(1.014, 3.026)	6.45	0.000
D3L5 - D3L2	0.007	0.313	(-0.999, 1.013)	0.02	1.000
D5L1 - D3L2	0.477	0.313	(-0.529, 1.483)	1.52	0.841
D6L1 - D3L2	2.019	0.313	(1.013, 3.025)	6.44	0.000

D3L4 - D3L3	-1.341	0.313	(-2.347, -0.335)	-4.28	0.002
D3L5 - D3L3	-3.355	0.313	(-4.361, -2.349)	-10.70	0.000
D5L1 - D3L3	-2.885	0.313	(-3.891, -1.879)	-9.21	0.000
D6L1 - D3L3	-1.343	0.313	(-2.349, -0.337)	-4.28	0.002
D3L5 - D3L4	-2.013	0.313	(-3.020, -1.007)	-6.42	0.000
D5L1 - D3L4	-1.544	0.313	(-2.550, -0.538)	-4.93	0.000
D6L1 - D3L4	-0.001	0.313	(-1.008, 1.005)	-0.00	1.000
D5L1 - D3L5	0.470	0.313	(-0.536, 1.476)	1.50	0.852
D6L1 - D3L5	2.012	0.313	(1.006, 3.018)	6.42	0.000
D6L1 - D5L1	1.542	0.313	(0.536, 2.548)	4.92	0.000

APPENDIX C: STATISTICAL ANALYSIS FOR CRI-IDT REGRESSION MODEL

C.1. Regression Analysis: CRI (IDT) versus RAP, Binder Content, BG1, MIX1

Method

Categorical predictor coding	(1, 0)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	7	273626	39089	9.74	0.004
RAP	1	102637	102637	25.56	0.001
Binder Content	1	118406	118406	29.49	0.001
BG1	4	51795	12949	3.23	0.084
MIX1	1	14151	14151	3.52	0.103
Error	7	28106	4015		
Total	14	301731			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
63.3649	90.69%	81.37%	*

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-325	206	-1.58	0.158	
RAP	-5.96	1.18	-5.06	0.001	1.79
Binder Content	219.9	40.5	5.43	0.001	1.21
BG1					
1	-143.6	71.5	-2.01	0.085	2.21
2	-250.3	95.3	-2.63	0.034	2.11
3	-44.9	50.7	-0.88	0.406	2.39
4	-306.7	96.3	-3.18	0.015	2.16
MIX1					
1	104.3	55.6	1.88	0.103	2.26

Regression Equation

CRI (IDT)	=	-325 - 5.96 RAP + 219.9 Binder Content + 0.0 BG1_0 - 143.6 BG1_1 - 250.3 BG1_2 - 44.9 BG1_3 - 306.7 BG1_4 + 0.0 MIX1_0 + 104.3 MIX1_1

Fits and Diagnostics for All Observations

Obs	CRI (IDT)	Fit	Resid	Std Resid	
1	579.4	622.4	-43.1	-1.22	
2	619.5	585.6	33.9	0.69	
3	436.0	475.6	-39.7	-0.80	
4	663.6	594.9	68.7	1.18	
5	561.2	518.1	43.1	1.22	
6	514.7	616.9	-102.2	-1.75	
7	459.4	459.4	-0.0	*	X
8	654.3	611.3	43.1	1.22	
9	716.7	716.7	0.0	*	X
10	573.7	564.9	8.8	0.20	
11	725.6	729.8	-4.2	-0.08	
12	886.4	894.8	-8.4	-0.20	
13	568.8	609.8	-41.0	-0.98	
14	826.6	774.7	51.9	1.00	
15	928.8	939.6	-10.8	-0.26	

C.2. Regression Analysis: CRI (IDT) versus RAP, Binder Content

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	217586	108793	15.52	0.000
RAP	1	181023	181023	25.82	0.000
Binder Content	1	91021	91021	12.98	0.004
Error	12	84145	7012		
Lack-of-Fit	6	69513	11586	4.75	0.040
Pure Error	6	14632	2439		
Total	14	301731			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
83.7383	72.11%	67.46%	60.59%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-180	257	-0.70	0.498	
RAP	-6.16	1.21	-5.08	0.000	1.08
Binder Content	182.4	50.6	3.60	0.004	1.08

Regression Equation

CRI (IDT)	=	-180 - 6.16 RAP + 182.4 Binder Content

Fits and Diagnostics for All Observations

Obs	CRI (IDT)	Fit	Resid	Std Resid
1	579.4	602.2	-22.8	-0.29
2	619.5	552.0	67.4	0.96
3	436.0	460.8	-24.8	-0.35
4	663.6	583.9	79.7	1.00
5	561.2	602.2	-41.0	-0.51
6	514.7	602.2	-87.5	-1.10
7	459.4	602.2	-142.8	-1.79
8	654.3	511.0	143.3	1.87
9	716.7	805.1	-88.4	-1.17
10	573.7	595.3	-21.6	-0.32
11	725.6	732.2	-6.5	-0.08
12	886.4	869.0	17.4	0.25
13	568.8	595.3	-26.6	-0.40
14	826.6	732.2	94.4	1.21
15	928.8	869.0	59.8	0.86