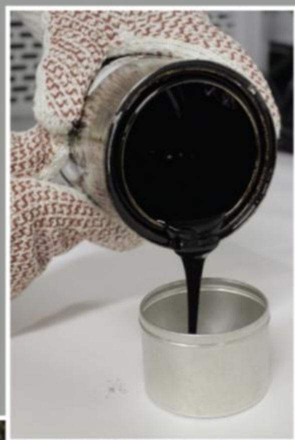

NCAT Report 19-05

THREE WHEEL POLISHING DEVICE AND DYNAMIC FRICTION TESTER ACCELERATED LABORATORY FRICTION TESTING REPEATABILITY AND REPRODUCIBILITY STUDY

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The authors gratefully acknowledge the following members of the NCAT Applications Steering Committee for their review of this technical report: Sam Johnson, Debbie Schwerman, and Tim Murphy.

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1 INTRODUCTION

Florida, Maryland, and Tennessee State highway agencies along with the National Center for Asphalt Technology (NCAT) are in a task group to develop an AASHTO standard for preparing and conditioning laboratory samples for dynamic friction tester (DFT) testing. The DFT is a proven friction measurement device that tests a circular path of approximately 37 inches. (Figure 1) Maryland State Highway Administration (MDOT SHA) uses the DFT in their standard specifications for qualifying aggregate for friction purposes. The proposed AASHTO standard will assist in implementing accelerated laboratory friction testing. This supports Strategic Objective #1 of the FHWA 2018 Strategic Plan which states "Save lives by expanding the use of data-driven, systemic safety management approaches and by increasing the adoption of proven safety solutions by all road owners."

The laboratory slab conditioning (surface polishing) is performed by the Three Wheel Polishing Device (TWPD) developed by NCAT. (Figure 1) The amount of conditioning is measured by number of cycles of the three-wheel carriage along the same path that the DFT uses to measure friction. A more detailed description of the TWPD is provided in the test protocol section below. Accelerated friction testing is intended to identify "long-term" terminal friction properties and is not tied to traffic passes. This study compared 100,000 and 150,000 cycles as sufficient polishing to achieve terminal friction of the surface.

There is very limited data on multi-laboratory repeatability/reproducibility of a TWPD/DFT testing protocol. Both MDOT SHA and NCAT have test protocols, but they are different. The proposed protocol follows the MDOT SHA procedure with some modifications.

2 OBJECTIVE

This study examined the multi-laboratory repeatability/reproducibility of a TWPD/DFT testing protocol.

3 SCOPE

The scope of the study included the evaluation of the laboratories' slab compaction, polishing with the TWPD, and friction measurement with the DFT. The depth of the study was influenced by the funding and short study completion period. One mixture from MDOT SHA and two mixtures from NCAT test sections were used. Due to the narrow time frame to complete the study, mixtures were selected from a limited supply of available in-laboratory stock of plant-produced samples. To limit the potential for bias during testing, the details of each mixture type were not reported until all testing was completed and the data was analyzed in each laboratory. Both laboratories tested the three mixtures.

Each mixture was compacted into three sets of three replicate slabs (nine slabs per mixture) to examine parts of the experimental matrix. Each slab was polished and measured at three conditioning increments to capture peak friction and terminal friction. Both laboratories performed 5 replicate DFT tests and record the measured friction values at 20, 40, and 60 kph for each test. In total, the experimental matrix involved 27 compacted slabs and 405 DFT tests.

4 MIXTURE SAMPLES

The mix designs for the three asphalt mixtures are presented in Table 1. Mix A contained 32% reclaimed asphalt pavement (RAP), Mix B contained 12% RAP, and Mix C contained 20% RAP.

5 TESTING PROTOCOL

5.1 Slab Preparation

Slab preparation was laboratory specific. MDOT SHA prepared 20x20x1.5” slabs using vibratory hammer compaction and NCAT prepared 20x20x2” slabs using a linear kneading compactor. All slabs were compacted to a target 7 percent air voids to avoid mixture surface raveling and rutting. Each laboratory prepared six slabs of their in-state mixture(s) to be split between the two laboratories for polishing and testing. In addition, each laboratory sent sufficient samples of the plant-produced loose mixture to the other laboratory for preparing three slabs using that laboratory’s slab preparation method. The slab preparation and polishing summary is provided in Table 2. Overall, NCAT compacted 12 slabs and tested 15 slabs, and MDOT SHA compacted 15 slabs and tested 12 slabs. Slab identification used the guide and a summary of all slabs is shown in Table 3.

5.2 Equipment Standards

Both TWPDs operated using a 146 lb carriage weight, 56-60 rpm rotational speed, Kenda tire, 35 psi tire inflation, and continuous water flush on the slab surface during polishing. As a point of reference, the NCAT test protocol is a 90 lb carriage and 50 psi in the tires but was not used for this study. The continuous water flush system is a recirculating system that includes a water reservoir tank, filter screen, pump, and spray bar. New tires were placed on the TWPD at the beginning of the testing. One polishing cycle equals one 360-degree revolution of the three-wheel carriage. Both DFTs were operated as prescribed in the latest ASTM E 1911 standard. The DFT began testing with a new set of rubber sliders for each slab and completed three increments of testing with five replicate friction measurements for a total of 15 drops per set of rubber sliders.

5.3 Test Protocol

Both laboratories followed the same test protocol. A set of three replicate slabs were randomly placed in order for testing. All polishing and testing on one slab were completed before beginning the next slab in the set. The polishing and testing used the following sequence.

1. TWPD polishing for 10,000 cycles.
2. DFT testing at 10,000 TWPD cycles. Five replicate tests were made and the measured friction values at 20, 40, and 60 km/h were recorded.
3. Additional TWPD polishing on the same slab surface for 90,000 cycles to complete a total of 100,000 cycles.
4. DFT testing at 100,000 TWPD cumulative cycles. Five replicate tests were made and the measured friction values at 20, 40, and 60 km/h were recorded.

5. Additional TWPD polishing on the same slab surface for 50,000 cycles to complete a total of 150,000 cycles.
6. DFT testing at 150,000 TWPD cumulative cycles. Five replicate tests were made and the measured friction values at 20, 40, and 60 km/h were recorded.

5.4 Data Logging Procedure

Each laboratory populated the data form shown in Table 4 for each set of three slabs. NCAT uses the average of five replicate results to determine the friction coefficient, while MDOT SHA does not take the first replicate result into account. This study defined the NCAT five-replicate method as Analysis Method A and the MDOT SHA four-replicate method as Analysis Method B. The individual data tables are assembled in the Appendix.

6 DATA ANALYSIS

In this study, a total of 1215 DFT measurements were collected. The experimental plan was designed to respond to the following five questions.

- Does the first DFT test influence the average of multiple replicate test values? Were the average of five replicate results and the average of the last four replicate results equal?
- Were the results between the two compaction methods statistically different?
- Were results between the laboratories' TWPD and DFT test methods statistically different?
- Does polishing slabs to 100,000 cycles and 150,000 cycles yield comparable results?
- What is the influence of measured friction speed level on test variability?

A multiple-way analysis of variance (ANOVA) was conducted to analyze the differences among group means in the sample, which was further used to identify the significant variables affecting the measured friction coefficients. A p-value less than 0.05 indicated that the variable was significant at a 95% confidence level. The detailed statistical analysis to address each question is presented.

6.1 Five Replicates vs. Four Replicates

This analysis examined the technical position that the first DFT test on the slab surface is not representative and could influence the replicate test average. The five replicate average includes the first DFT test value and the four replicate average excludes the first DFT test value. In the ANOVA, the response was the average friction coefficient at each speed level and polishing increment along with other factors including mixture type, compaction method, test method (polishing and testing devices), slab number, polishing cycle, speed level, and analysis method. Table 5 lists the factorial levels in the ANOVA. Table 6 presents the ANOVA results. The p-value of analysis method (A and B) was 0.831, which was much higher than 0.05. This indicates that the two different analysis methods provided comparable results of the average friction coefficient. Based on this result, the analysis continued to use the average of five replicate results for further investigation.

6.2 Hammer Compaction vs. Kneading Compaction

In this analysis, MDOT SHA used a vibratory hammer compaction method to produce asphalt slabs, while NCAT used a linear kneading compaction method. According to the experimental plan, for each mixture type, there were two sets of three slabs for the same mixture that were compacted at the different laboratories but tested at the same laboratory. The identified sets of slabs for evaluating the influence of compaction method included: AMN & ANN, BMN & BNN, and CMM & CNM. In the ANOVA, the response was the friction coefficient for each replicate measurement, and the factors included mixture type, compaction method, slab number, polishing cycle, and speed level. Table 7 presents the factorial levels in the ANOVA and Table 8 shows the ANOVA results. The p-value of the compaction method was less than 0.001, which indicates that the two compaction methods provided statistically different results of friction coefficients. The analysis also showed the replicate slab factor to be very significant, which indicates that one or both compaction methods do not create consistent slabs.

Another approach to examining the difference between compaction methods is illustrated in Figure 2. Each bar represents the five-test average DFT(40) measurements. The average of the five readings taken at 10k, 50k and 100k cycles of polishing were very comparable for Mix A and C, whether specimens were prepared (compacted) at NCAT or at MDOT SHA. The average of the five readings taken at 10k, 50k and 100k cycles of polishing, between the specimens prepared (compacted) at NCAT and at MDOT SHA, had significant differences for Mix B.

As shown in Figure 3, the polished slabs of BMN 1-3 had significant visible raveling in the polishing wheel track, which might be attributed to the method of compaction. Slabs BNN 1-3 exhibited moderate raveling on more than 20% of the wheel paths. This unexpected raveling distress was considered an interference factor for statistical analysis. Thus, the ANOVA was performed again for the other two pairs of slabs: AMN & ANN and CMM & CNM. Table 9 shows the ANOVA results. Based on the second analysis, the p-value of compaction method became 0.771, which was much greater than the threshold value of 0.05. This indicates that the compaction method was not a significant factor affecting the measurements of friction when excluding the data of Mix B. However, the variation between replicate slabs was still very significant.

6.3 NCAT Devices vs. MDOT SHA Devices

NCAT and MDOT SHA laboratories used different models of the TWPD for polishing the slabs and the same model of DFT for measurements of the friction coefficient. The primary difference was that the NCAT TWPD was rotating in the clockwise direction, while the MDOT SHA TWPD was in the counter-clockwise direction. From the experimental plan, the identified sets of slabs for assessing the influence of testing devices included: AMM & AMN, BMM & BMN, and CNM & CNN. In the ANOVA, the response was the friction coefficient for each replicate measurement, and the factors included mixture type, testing devices, slab number, polish cycle, and speed level. Table 10 summarizes the factorial levels in the ANOVA. Table 11 presents the ANOVA results. The analysis shows that the p-value of testing device was 0.02, which was less than 0.05. Therefore, the friction coefficients measured by the two testing devices were statistically different. The analysis also shows that the mixture type and number of polishing cycles were the most significant factors.

The bar graph approach to examining the difference between compaction methods is illustrated in Figure 4. Each bar represents the five-test average DFT(40) measurements. The average of the five readings taken after 100k and 150k cycles of polishing were very comparable for Mixes A and C, whether specimens were polished and tested at NCAT or at MDOT SHA. The average of the five readings taken at 10k cycles of polishing, between the specimens polished and tested at NCAT and at MDOT SHA, had some differences for Mixes B and C.

Considering the interference of raveling, the data of Mix B were excluded for a second analysis. Table 12 shows the second ANOVA. The second analysis indicated the p-value of the testing device was less than 0.001, indicating that the testing device was still a significant variable affecting the measurement of friction coefficients.

Figure 5 compares the measured friction coefficients between NCAT and MDOT SHA labs. A linear relationship between NCAT and MDOT SHA measurements for all mixtures combined was added. The R-squared value of 0.39 implied that the friction measurements from these two labs has a poor correlation. Examining the linear relationship between the laboratories for each mixture independently shows that the slopes of the trend lines for all three mixtures are very similar, but the correlations were different. In general, the MDOT SHA laboratory measured more range in friction than the NCAT laboratory as indicated by the flat slope of the trend lines.

6.4 100,000 Cycles vs. 150,000 Cycles

As described in the experimental plan, the asphalt slabs were polished through three stages, including the first 10,000 cycles, an additional 90,000 cycles (100,000 cumulative cycles), and another 50,000 cycles (150,000 cumulative cycles). It was expected that increasing the polishing cycles would reduce the friction coefficients of the slabs. However, it was not clear whether polishing a slab for 100,000 cycles and 150,000 cycles would result in significantly different friction coefficients. In the ANOVA, the response was the friction coefficient for each replicate measurement, and the other factors included mixture type, testing devices, slab number, polish cycle, and speed level. Table 13 summarizes the factorial levels in the ANOVA. This analysis examines the difference in terminal friction values at 100,000 and 150,000 cycles, so the friction coefficients of the slabs after 10,000 cycles of polishing were not included in the analysis. Table 14 presents the ANOVA analysis results. The p-value for polishing cycles was 0.827 and indicates that the slabs with 100,000 cycles and 150,000 cycles of polishing had similar friction coefficients. Therefore, it was suggested that polishing slabs for 100,000 cycles was adequate to achieve the terminal friction coefficient.

6.5 Influence of Measurement Speed on Testing Variability

In this study, the DFT tests were reported at three speed levels (20 km/h, 40 km/h, and 60 km/h). Five replicate DFT measurements were performed on each asphalt slab and friction was reported at each speed. The variability of these replicates was quantified in terms of coefficient of variation (COV). Figure 6 presents the average COV of each speed level at different polishing cycles for all asphalt slabs. One standard deviation of COV values was also shown as error bar. As can be seen, the speed levels of 40 km/h and 60 km/h had lower COV values than that of 20 km/h. The Tukey's honestly significant difference (HSD) test was performed to determine whether the average COV of three speed levels were significantly different from each other. The confidence level was assigned as 95% ($\alpha = 0.05$). As shown in Figure 6, the three speed levels were all grouped into the same level. This indicates that the variability of the three speed levels had no statistical difference.

7 CONCLUSIONS

- The work plan for the study called for the selection of three mixtures with diverse surface characteristics. Due to the narrow time constraints of the funding sponsor, mixtures needed to be identified quickly from available bulk samples of plant produced mixture. Diversity of mixture sizes was achieved but diversity of mixture types and aggregate types was not achieved.
- Computing the friction coefficient as the average of five replicate test results and as the average of the last four replicate results are statistically equal. The ANOVA computed a very high p-value of 0.831. Dropping the first replicate value did not change the computed average friction coefficient value.
- The use of a vibratory hammer compaction method or a linear kneading compaction method to produce asphalt slabs created very statistically different friction measurements when comparing all three mixtures. The ANOVA computed a p-value less than 0.001. Both laboratories noted raveling in the wheel path for Mix B compacted with a vibratory hammer. A second analysis without Mix B results determined that there was no statistical difference between the compaction methods. The ANOVA computed a p-value of 0.771. Both compaction methods created suitable test slabs for smaller NMAS mixtures.
- The TWPD model used by each laboratory was different and operated differently. The NCAT TWPD polishes clockwise and the MDOT SHA TWPD polishes counter-clockwise. The analysis showed that there was a statistical difference. The ANOVA computed a p-value of 0.02 when examining all three mixtures and a p-value less than 0.001 when excluding Mix B. It is possible that the direction of polishing is the primary difference and the consensus of a group of highway engineering practitioners is that the TWPD should rotate in the same direction as the DFT test, counter-clockwise.
- The amount of polishing to define the friction characteristics of the mixture surface directly impacts the time to complete a test. The measured friction coefficient after 100,000 cycles of polishing was compared to the measured value after 150,000 cycles. The analysis showed that there was no difference in the results between the 100,000 cycles and 150,000 cycles. The ANOVA computed a p-value of 0.827. The friction test result at 100,000 cycles is adequate to measure the friction characteristics of a mixture.
- The DFT continuously measures the friction coefficient as the test progresses from 80 km/h to 0 km/h and reports the friction values at 60 km/h, 40 km/h, and 20 km/h. The study examined whether the measurement variability was equal or different at the three reported speeds. The analysis showed that there was no statistical difference in the variation of measurements at the three reported test speeds. The average COV values were between

0.022 and 0.017. The friction measurements at all three test speeds have very low variability and could be used for reporting friction.

While a number of testing questions were soundly answered by the study, there was still a significant difference between the friction coefficients measured by the two laboratories as displayed in Figure 5. Additional examination of the data and test protocol is warranted to better understand this difference. An additional study using more laboratories, additional slab compaction procedures, and a more diverse set of mixtures should be pursued to validate the findings of this study. An additional study is also warranted to determine the influence of the direction of the TWPD polishing procedure (counter-clockwise or clockwise rotation).

Table 1. Summary of Material Samples

Property	**Mix A**	**Mix B**	**Mix C**
Sieve Size			
25.0 mm (1”)	100	100	100
19.0 mm (3/4”)	100	97	100
12.5 mm (1/2”)	100	92	98
9.5 mm (3/8”)	95	75	87
4.75 mm (#4)	66	55	65
2.36 mm (#8)	39	39	51
1.18 mm (#16)	27	25	42
0.60 mm (#30)	20	15	31
0.30 mm (#50)	14	8	19
0.15 mm (#100)	9	5	11
0.075 mm (#200)	6.4	4	8
Asphalt Content (%)	5.2	4.6	5.4
P_{be} (%)[1]	4.8	4.26	4.83
Air Voids (%)	4.0	5.7	2.6
VMA[2]	15.1	15.4	13.9
VFA[3]	73.5	63.2	81.3
Dust:Binder Ratio	1.34	0.94	1.36
PG Asphalt Grade	PG 64 -22 S	PG 70 -10	PG 64 -28
Aggregate Type	granite	gravel	gravel

Note: [1]Pbe = Effective asphalt binder content; [2]VMA = Voids in mineral aggregates; [3]VFA = Voids filled with asphalt

Table 2. Slab Preparation, Polishing, and Testing Summary

Mixture Label	Action	Responsible Lab
Mix A (MDOT SHA source)	Acquire loose mixture quantity and split into 9 slab quantities	MDOT SHA
	Compact 6 slabs	MDOT SHA
	Ship 3 slabs and loose mixture for 3 slabs to NCAT	MDOT SHA
	Polish and test 3 slabs	MDOT SHA
	Receive 3 slabs and loose mixture	NCAT
	Compact 3 slabs from loose mixture	NCAT
	Polish and test 6 slabs	NCAT
Mix B (NCAT Mix 1)	Acquire loose mixture quantity and split into 9 slab quantities	NCAT
	Ship loose mixture for 6 slabs to MDOT SHA	NCAT
	Compact 3 slabs from loose mixture	NCAT
	Receive loose mixture from NCAT	MDOT SHA
	Compact 6 slabs	MDOT SHA
	Ship 3 slabs to NCAT	MDOT SHA
	Polish and test 3 slabs	MDOT SHA
	Receive 3 slabs from MDOT SHA	NCAT
	Polish and test 6 slabs	NCAT
Mix C (NCAT Mix 2)	Acquire loose mixture quantity and split into 9 slab quantities	NCAT
	Compact 6 slabs	NCAT
	Ship 3 slabs and loose mixture for 3 slabs to MDOT SHA	NCAT
	Polish and test 3 slabs	NCAT
	Receive 3 slabs and loose mixture	MDOT SHA
	Compact 3 slabs from loose mixture	MDOT SHA
	Polish and test 6 slabs	MDOT SHA

Table 3. Summary of All Test Slab Designations

Mix Label	Compaction	Polishing and Testing	Mixture Designation
Mix A (MDOT SHA source)	MDOT SHA	MDOT SHA	AMM 1-3
	MDOT SHA	NCAT	AMN 1-3
	NCAT	NCAT	ANN 1-3
Mix B (NCAT Mix 1)	MDOT SHA	MDOT SHA	BMM 1-3
	MDOT SHA	NCAT	BMN 1-3
	NCAT	NCAT	BNN 1-3
Mix C (NCAT Mix 2)	NCAT	NCAT	CNN 1-3
	NCAT	MDOT SHA	CNM 1-3
	MDOT SHA	MDOT SHA	CMM 1-3
A, B, or C = Mixture designation M or N = MDOT SHA (M) or NCAT (N) slab compaction practice M or N = MDOT SHA (M) or NCAT (N) slab polishing device and DFT testing 1, 2, or 3 = replicate slab number			
Example: BMN2 = Mix B, MDOT SHA compaction, NCAT polishing/testing, slab #2			

Table 4. DFT Measurement Data Form

Slab Identification	Slab ID			Slab ID			Slab ID		
Test measurement speed (kph)	**20**	**40**	**60**	**20**	**40**	**60**	**20**	**40**	**60**
10,000 Cycle DFT test 1									
10,000 Cycle DFT test 2									
10,000 Cycle DFT test 3									
10,000 Cycle DFT test 4									
10,000 Cycle DFT test 5									
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5									
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5									
10,000 cycle DFT average of tests 2, 3, 4, and 5. (omit test 1)									
10,000 cycle DFT standard deviation of tests 2, 3, 4, and 5. (omit test 1)									
100,000 Cycle DFT test 1									
100,000 Cycle DFT test 2									
100,000 Cycle DFT test 3									
100,000 Cycle DFT test 4									
100,000 Cycle DFT test 5									
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5									
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5									
100,000 cycle DFT average of tests 2, 3, 4, and 5. (omit test 1)									
100,000 cycle DFT standard deviation of tests 2, 3, 4, and 5. (omit test 1)									
150,000 Cycle DFT test 1									
150,000 Cycle DFT test 2									
150,000 Cycle DFT test 3									
150,000 Cycle DFT test 4									
150,000 Cycle DFT test 5									
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5									
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5									
150,000 cycle DFT average of tests 2, 3, 4, and 5. (omit test 1)									
150,000 cycle DFT standard deviation of tests 2, 3, 4, and 5. (omit test 1)									
Rows for additional analysis									

Table 5. ANOVA Factorial Levels for Evaluation of Four or Five Replicate Analysis Methods

Factor	Type	Levels	Values
Mixture Type	Fixed	3	A, B, C
Compaction Method	Fixed	2	MDOT SHA, NCAT
Test Method	Fixed	2	MDOT SHA, NCAT
Slab No	Fixed	3	1, 2, 3
Polishing Cycle	Fixed	3	10k, 100k, 150k
Speed Level	Fixed	3	20, 40, 60
Analysis Method	Fixed	2	A, B

Table 6. ANOVA Results for Analysis Method

Source	DF[1]	Adj SS[2]	Adj MS[3]	F-Value	P-Value
Mixture Type	2	0.665	0.333	254.80	<0.001
Compaction Method	1	0.034	0.034	26.36	<0.001
Test Method	1	0.005	0.005	3.46	0.063
Specimen No	2	0.007	0.003	2.55	0.080
Polishing Cycle	2	0.717	0.359	274.55	<0.001
Speed Level	2	<0.001	<0.001	0.17	0.842
Analysis Method	1	<0.001	<0.001	0.05	0.831
Error	474	0.619	0.001		
Total	485	2.087			

Note: [1]DF = Total degrees of freedom; [2]Adj SS = Adjusted sums of squares; [3]Adj MS = Adjusted mean squares

Table 7. ANOVA Factorial Levels for Evaluation of Compaction Method

Factor	Type	Levels	Values
Mixture Type	Fixed	3	A, B, C
Compaction Method	Fixed	2	M, N
Slab Number	Fixed	3	1, 2, 3
Polishing Cycle	Fixed	3	10000, 100000, 150000
Speed Level	Fixed	3	20, 40, 60

Table 8. ANOVA Results for Compaction Method

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Mixture Type	2	1.045	0.523	454.18	<0.001
Compaction Method	1	0.091	0.091	79.36	<0.001
Specimen No	2	0.032	0.016	13.95	<0.001
Polishing Cycle	2	1.396	0.698	606.48	<0.001
Speed Level	2	0.002	<0.001	0.78	0.460
Error	800	0.920	0.001		
Total	809	3.486			

Table 9. ANOVA Results for Compaction Method Excluding Mix B

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Mixture Type	1	0.305	0.305	547.11	<0.001
Compaction Method	1	<0.001	<0.001	0.08	0.771
Slab Number	2	0.019	0.010	17.15	<0.001
Polishing Cycle	2	0.502	0.251	449.86	<0.001
Speed Level	2	<0.001	<0.001	0.76	0.470
Error	531	0.296	<0.001		
Total	539	1.124			

Table 10. ANOVA Factorial Levels for Evaluation of Testing Devices

Factor	Type	Levels	Values
Mixture Type	Fixed	3	A, B, C
Testing Device	Fixed	2	M, N
Slab Number	Fixed	3	1, 2, 3
Polishing Cycle	Fixed	3	10000, 100000, 150000
Speed Level	Fixed	3	20, 40, 60

Table 11. ANOVA Results for Testing Devices

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Mixture Type	2	1.721	0.861	543.87	<0.001
Testing Device	1	0.009	0.009	5.44	0.02
Slab Number	2	0.016	0.008	5.1	0.006
Polishing Cycle	2	1.166	0.583	368.39	<0.001
Speed Level	2	0.008	0.004	2.41	0.091
Error	800	1.266	0.002		
Total	809	4.186			

Table 12. ANOVA Results for Testing Devices Excluding Mix B

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Mixture Type	1	0.094	0.094	134.75	<0.001
Testing Device	1	0.064	0.064	90.77	<0.001
Slab Number	2	0.007	0.003	4.92	0.008
Polishing Cycle	2	0.466	0.233	332.61	<0.001
Speed Level	2	<0.001	<0.001	0.30	0.737
Error	531	0.372	<0.001		
Total	539	1.003			

Table 13. ANOVA Factorial Levels for Evaluation of Polishing Cycles

Factor	Type	Levels	Values
Mixture Type	Fixed	3	A, B, C
Compaction Method	Fixed	2	M, N
Testing Device	Fixed	2	M, N
Slab Number	Fixed	3	1, 2, 3
Polishing Cycle	Fixed	2	100000, 150000
Speed Level	Fixed	3	20, 40, 60

Table 14. ANOVA Results for Polishing Cycles

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Mixture Type	2	0.056	0.028	13.77	<0.001
Compaction Method	1	0.002	0.002	0.86	0.355
Testing Device	1	0.070	0.070	34.32	<0.001
Slab Number	2	0.028	0.014	6.95	0.001
Polishing Cycle	1	<0.001	<0.001	0.05	0.827
Speed Level	2	0.024	0.012	5.98	0.003
Error	800	1.627	0.002		
Total	809	1.791			

Figure 1. Photo of TWPD (Left) and DFT (Right)

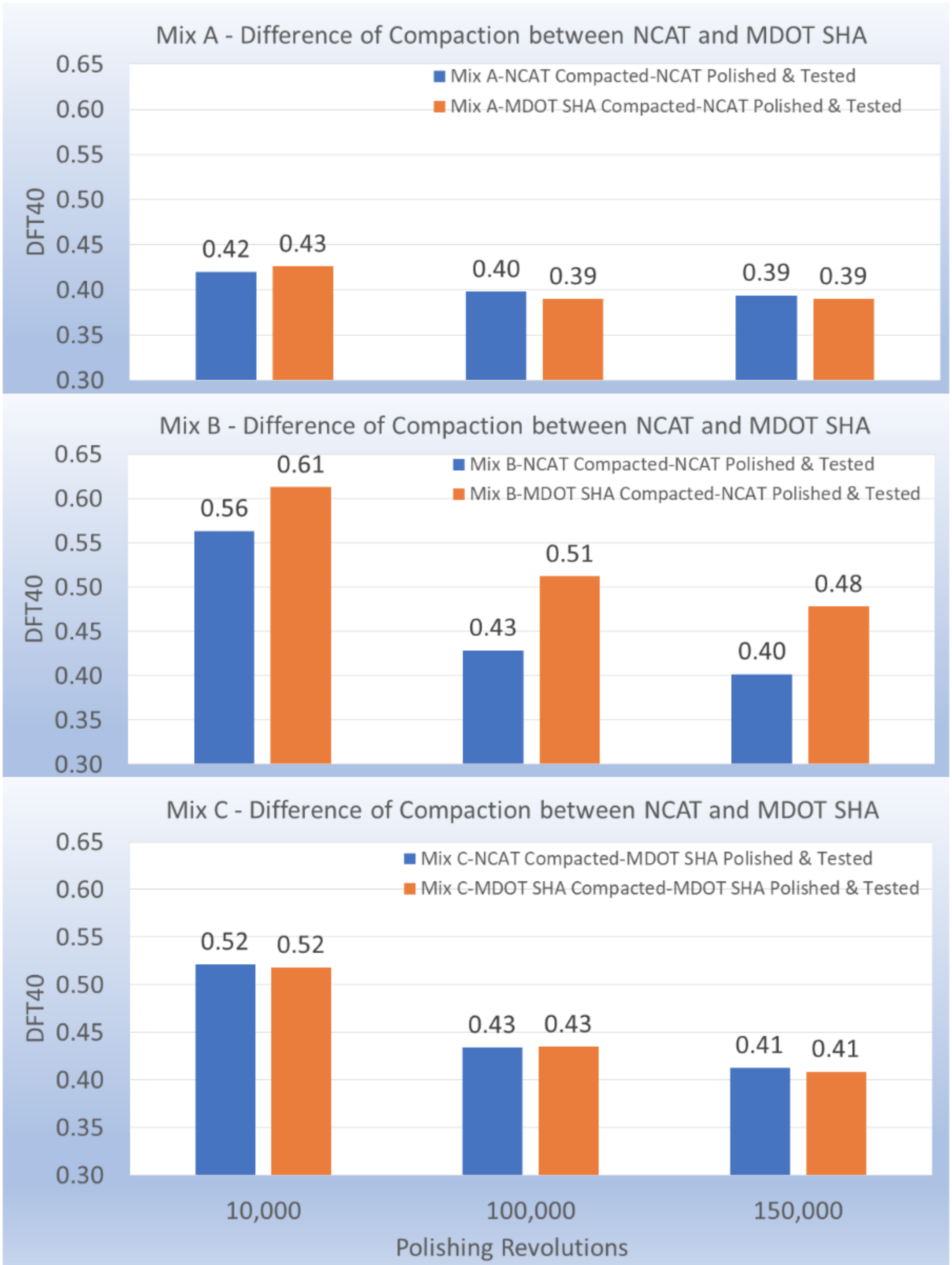

Figure 2. Comparison of Compaction Methods

Figure 3. Polished Slab of Mix BMN

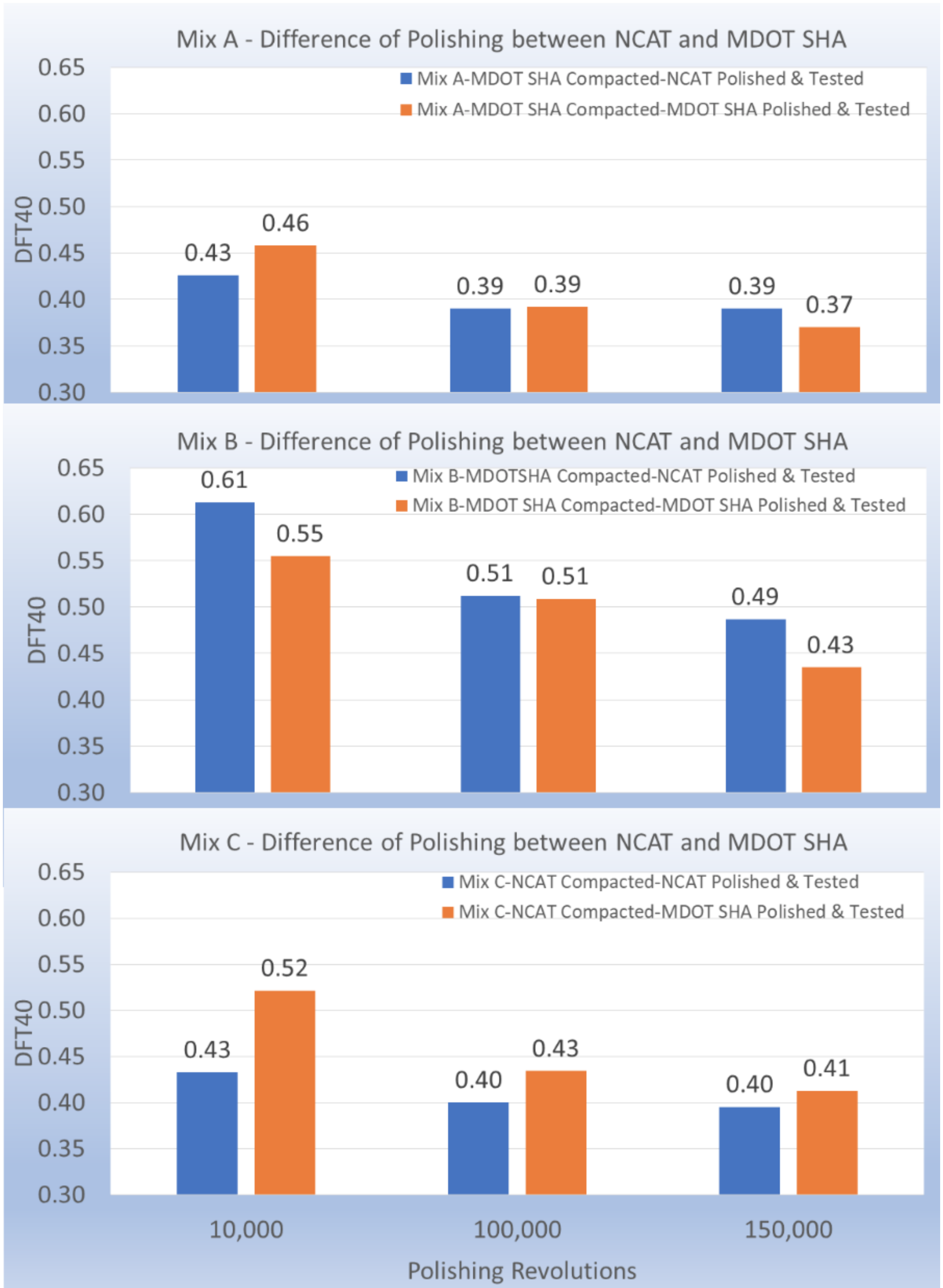

Figure 4. Comparison of Polishing and Testing Methods

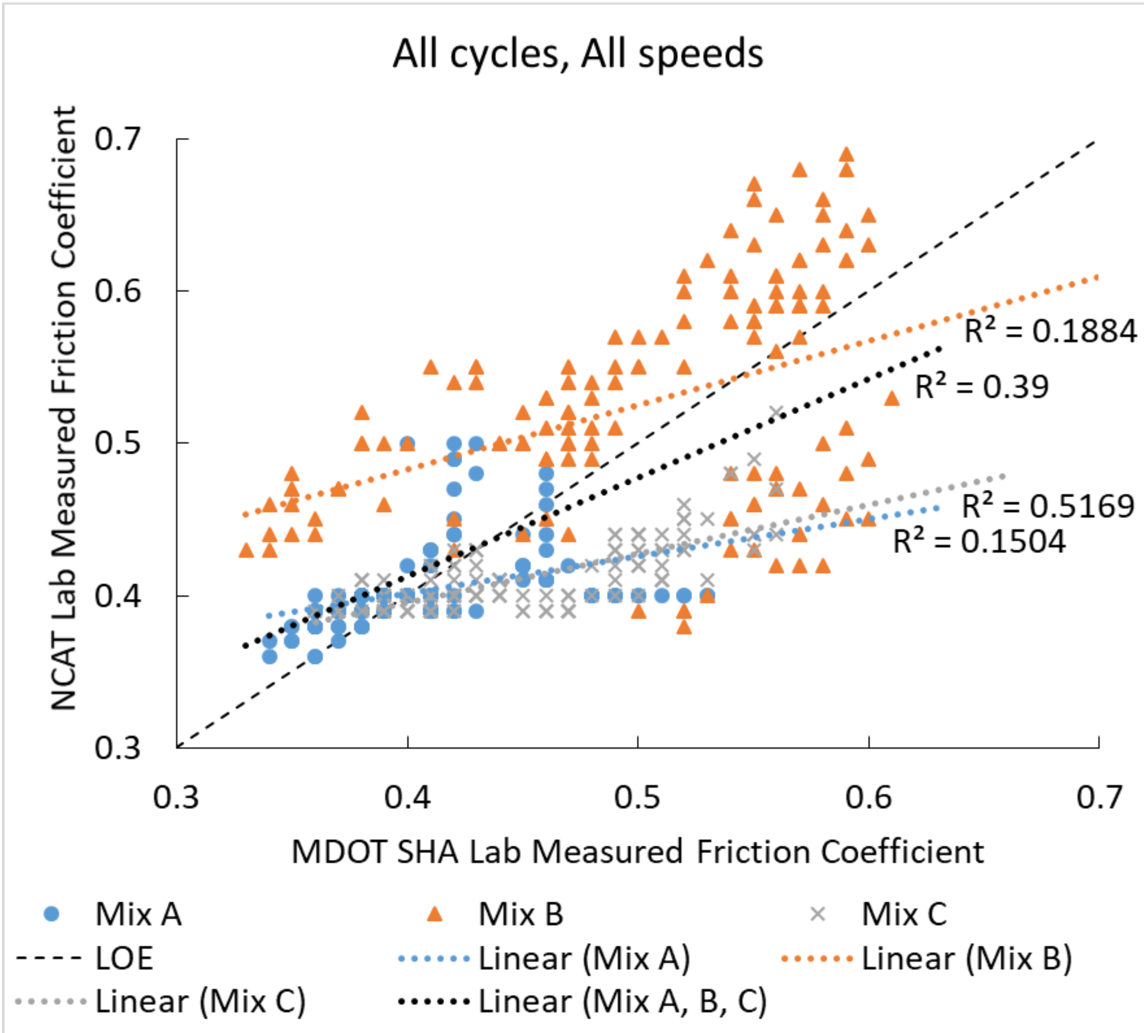

Figure 5. Comparison of Measured Friction between NCAT and MDOT SHA Laboratories

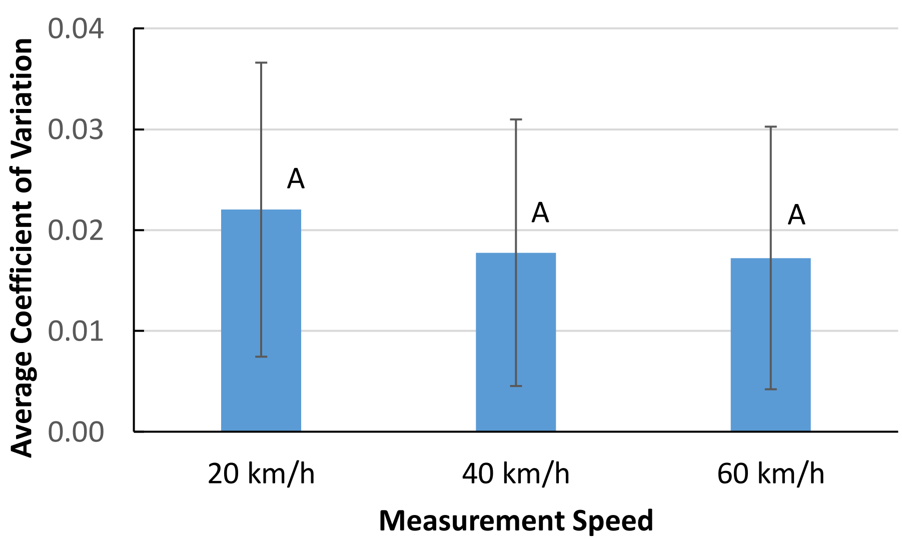

Figure 6. Variability of DFT Measurements at Different Speed Levels

8 APPENDIX – TEST DATA TABLES

Test Slabs AMM

Slab Identification	Slab ID: AMM#1			Slab ID: AMM#2			Slab ID: AMM#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.43	0.42	0.4	0.53	0.53	0.5	0.46	0.45	0.45
10,000 cycles DFT test 2	0.43	0.42	0.42	0.52	0.52	0.49	0.46	0.46	0.47
10,000 cycles DFT test 3	0.42	0.42	0.42	0.51	0.5	0.48	0.46	0.45	0.46
10,000 cycles DFT test 4	0.42	0.41	0.41	0.49	0.49	0.48	0.46	0.46	0.46
10,000 cycles DFT test 5	0.41	0.41	0.4	0.48	0.48	0.48	0.45	0.45	0.46
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.42	0.42	0.41	0.51	0.50	0.49	0.46	0.45	0.46
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.008	0.005	0.010	0.021	0.021	0.009	0.004	0.005	0.007
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.42	0.42	0.41	0.50	0.50	0.48	0.46	0.46	0.46
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.008	0.006	0.010	0.018	0.017	0.005	0.005	0.006	0.005
100,000 cycles DFT test 1	0.38	0.38	0.39	0.41	0.41	0.41	0.39	0.4	0.41
100,000 cycles DFT test 2	0.38	0.38	0.39	0.41	0.41	0.43	0.38	0.39	0.4
100,000 cycles DFT test 3	0.37	0.37	0.38	0.42	0.42	0.42	0.39	0.39	0.41
100,000 cycles DFT test 4	0.36	0.37	0.38	0.41	0.41	0.41	0.38	0.39	0.4
100,000 cycles DFT test 5	0.36	0.36	0.38	0.4	0.41	0.41	0.38	0.39	0.4
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.37	0.37	0.38	0.41	0.41	0.42	0.38	0.39	0.40
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.010	0.008	0.005	0.007	0.004	0.009	0.005	0.004	0.005
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.37	0.37	0.38	0.41	0.41	0.42	0.38	0.39	0.40
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.010	0.008	0.005	0.008	0.005	0.010	0.005	0.000	0.005
150,000 cycles DFT test 1	0.36	0.36	0.37	0.37	0.38	0.39	0.39	0.39	0.39
150,000 cycles DFT test 2	0.35	0.36	0.37	0.37	0.38	0.39	0.38	0.38	0.38
150,000 cycles DFT test 3	0.35	0.36	0.36	0.36	0.37	0.38	0.38	0.38	0.39
150,000 cycles DFT test 4	0.34	0.35	0.36	0.36	0.37	0.38	0.38	0.38	0.39
150,000 cycles DFT test 5	0.34	0.35	0.36	0.36	0.36	0.38	0.37	0.38	0.39
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.35	0.36	0.36	0.36	0.37	0.38	0.38	0.38	0.39
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.008	0.005	0.005	0.005	0.008	0.005	0.007	0.004	0.004
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.35	0.36	0.36	0.36	0.37	0.38	0.38	0.38	0.39
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.006	0.006	0.005	0.005	0.008	0.005	0.005	0.000	0.005

Test Slabs AMN

Slab Identification	Slab ID: AMN#1			Slab ID: AMN#2			Slab ID: AMN#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.5	0.5	0.5	0.4	0.4	0.4	0.48	0.44	0.42
10,000 cycles DFT test 2	0.48	0.49	0.49	0.4	0.4	0.4	0.47	0.43	0.42
10,000 cycles DFT test 3	0.47	0.44	0.45	0.4	0.4	0.4	0.46	0.42	0.41
10,000 cycles DFT test 4	0.44	0.43	0.43	0.4	0.4	0.4	0.44	0.41	0.41
10,000 cycles DFT test 5	0.43	0.42	0.42	0.4	0.4	0.4	0.42	0.41	0.41
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.46	0.46	0.46	0.40	0.40	0.40	0.45	0.42	0.41
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.029	0.036	0.036	0.000	0.000	0.000	0.024	0.013	0.005
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.46	0.45	0.45	0.40	0.40	0.40	0.45	0.42	0.41
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.024	0.031	0.031	0.000	0.000	0.000	0.022	0.010	0.005
100,000 cycles DFT test 1	0.38	0.39	0.39	0.39	0.39	0.39	0.4	0.4	0.4
100,000 cycles DFT test 2	0.38	0.4	0.4	0.4	0.39	0.39	0.4	0.4	0.4
100,000 cycles DFT test 3	0.37	0.38	0.39	0.4	0.39	0.39	0.4	0.39	0.4
100,000 cycles DFT test 4	0.36	0.38	0.38	0.4	0.39	0.39	0.39	0.39	0.4
100,000 cycles DFT test 5	0.36	0.38	0.38	0.4	0.39	0.39	0.4	0.39	0.4
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.37	0.39	0.39	0.40	0.39	0.39	0.40	0.39	0.40
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.010	0.009	0.008	0.004	0.000	0.000	0.004	0.005	0.000
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.37	0.39	0.39	0.40	0.39	0.39	0.40	0.39	0.40
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.010	0.010	0.010	0.000	0.000	0.000	0.005	0.005	0.000
150,000 cycles DFT test 1	0.38	0.39	0.39	0.39	0.39	0.39	0.4	0.4	0.4
150,000 cycles DFT test 2	0.37	0.38	0.39	0.39	0.39	0.39	0.4	0.4	0.4
150,000 cycles DFT test 3	0.37	0.38	0.39	0.39	0.39	0.39	0.4	0.4	0.4
150,000 cycles DFT test 4	0.36	0.38	0.39	0.4	0.39	0.39	0.4	0.4	0.4
150,000 cycles DFT test 5	0.37	0.38	0.39	0.39	0.38	0.39	0.4	0.4	0.4
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.37	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.007	0.004	0.000	0.004	0.004	0.000	0.000	0.000	0.000
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.37	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.005	0.000	0.000	0.005	0.005	0.000	0.000	0.000	0.000

Test Slabs ANN

Slab Identification	Slab ID: ANN#1			Slab ID: ANN#2			Slab ID: ANN#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.47	0.43	0.41	0.46	0.41	0.4	0.51	0.48	0.42
10,000 cycles DFT test 2	0.45	0.43	0.41	0.45	0.41	0.41	0.48	0.41	0.41
10,000 cycles DFT test 3	0.44	0.42	0.4	0.45	0.41	0.41	0.47	0.44	0.42
10,000 cycles DFT test 4	0.44	0.41	0.4	0.41	0.4	0.4	0.45	0.42	0.41
10,000 cycles DFT test 5	0.43	0.41	0.41	0.41	0.4	0.4	0.44	0.42	0.41
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.45	0.42	0.41	0.44	0.41	0.40	0.47	0.43	0.41
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.015	0.010	0.005	0.024	0.005	0.005	0.027	0.028	0.005
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.44	0.42	0.41	0.43	0.41	0.41	0.46	0.42	0.41
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.008	0.010	0.006	0.023	0.006	0.006	0.018	0.013	0.005
100,000 cycles DFT test 1	0.4	0.4	0.4	0.42	0.4	0.4	0.42	0.4	0.4
100,000 cycles DFT test 2	0.39	0.4	0.39	0.41	0.39	0.4	0.42	0.41	0.4
100,000 cycles DFT test 3	0.4	0.4	0.4	0.41	0.39	0.4	0.42	0.4	0.4
100,000 cycles DFT test 4	0.39	0.4	0.39	0.41	0.4	0.4	0.42	0.4	0.4
100,000 cycles DFT test 5	0.39	0.39	0.39	0.4	0.39	0.39	0.42	0.4	0.4
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.39	0.40	0.39	0.41	0.39	0.40	0.42	0.40	0.40
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.005	0.004	0.005	0.007	0.005	0.004	0.000	0.004	0.000
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.39	0.40	0.39	0.41	0.39	0.40	0.42	0.40	0.40
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.005	0.005	0.005	0.005	0.005	0.005	0.000	0.005	0.000
150,000 cycles DFT test 1	0.4	0.4	0.4	0.39	0.4	0.4	0.41	0.4	0.4
150,000 cycles DFT test 2	0.39	0.39	0.39	0.39	0.39	0.39	0.41	0.4	0.4
150,000 cycles DFT test 3	0.39	0.39	0.39	0.39	0.39	0.39	0.4	0.39	0.39
150,000 cycles DFT test 4	0.39	0.39	0.39	0.39	0.39	0.39	0.4	0.4	0.4
150,000 cycles DFT test 5	0.39	0.39	0.39	0.39	0.39	0.39	0.38	0.4	0.4
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.40	0.40
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.004	0.004	0.004	0.000	0.004	0.004	0.012	0.004	0.004
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.40	0.40
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.005	0.005

Test Slabs BMM

Slab Identification	Slab ID: BMM#1			Slab ID: BMM#2			Slab ID: BMM#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.58	0.58	0.59	0.59	0.57	0.57	0.57	0.55	0.56
10,000 cycles DFT test 2	0.58	0.57	0.59	0.59	0.58	0.57	0.56	0.55	0.56
10,000 cycles DFT test 3	0.57	0.56	0.6	0.58	0.57	0.55	0.55	0.54	0.54
10,000 cycles DFT test 4	0.56	0.55	0.59	0.57	0.56	0.55	0.54	0.53	0.52
10,000 cycles DFT test 5	0.55	0.54	0.6	0.56	0.55	0.52	0.52	0.52	0.51
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.57	0.56	0.59	0.58	0.57	0.55	0.55	0.54	0.54
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.013	0.016	0.005	0.013	0.011	0.020	0.019	0.013	0.023
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.57	0.56	0.60	0.58	0.57	0.55	0.54	0.54	0.53
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.013	0.013	0.006	0.013	0.013	0.021	0.017	0.013	0.022
100,000 cycles DFT test 1	0.58	0.61	0.59	0.48	0.48	0.5	0.45	0.47	0.5
100,000 cycles DFT test 2	0.57	0.6	0.6	0.46	0.47	0.48	0.45	0.47	0.49
100,000 cycles DFT test 3	0.54	0.59	0.57	0.47	0.47	0.49	0.45	0.47	0.5
100,000 cycles DFT test 4	0.56	0.58	0.59	0.46	0.47	0.48	0.44	0.46	0.49
100,000 cycles DFT test 5	0.54	0.56	0.58	0.46	0.47	0.48	0.44	0.46	0.49
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.56	0.59	0.59	0.47	0.47	0.49	0.45	0.47	0.49
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.018	0.019	0.011	0.009	0.004	0.009	0.005	0.005	0.005
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.55	0.58	0.59	0.46	0.47	0.48	0.45	0.47	0.49
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.015	0.017	0.013	0.005	0.000	0.005	0.006	0.006	0.005
150,000 cycles DFT test 1	0.53	0.56	0.54	0.35	0.37	0.46	0.35	0.38	0.43
150,000 cycles DFT test 2	0.52	0.57	0.57	0.34	0.37	0.42	0.37	0.4	0.43
150,000 cycles DFT test 3	0.5	0.56	0.55	0.34	0.36	0.45	0.35	0.38	0.42
150,000 cycles DFT test 4	0.52	0.55	0.55	0.34	0.36	0.47	0.35	0.38	0.41
150,000 cycles DFT test 5	0.52	0.54	0.55	0.33	0.35	0.42	0.39	0.39	0.43
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.52	0.56	0.55	0.34	0.36	0.44	0.36	0.39	0.42
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.011	0.011	0.011	0.007	0.008	0.023	0.018	0.009	0.009
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.52	0.56	0.56	0.34	0.36	0.44	0.37	0.39	0.42
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.010	0.013	0.010	0.005	0.008	0.024	0.019	0.010	0.010

Test Slabs BMN

Slab Identification	Slab ID: BMN#1			Slab ID: BMN#2			Slab ID: BMN#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.66	0.65	0.69	0.64	0.6	0.57	0.68	0.67	0.61
10,000 cycles DFT test 2	0.63	0.62	0.68	0.62	0.59	0.59	0.65	0.66	0.61
10,000 cycles DFT test 3	0.62	0.6	0.65	0.6	0.59	0.58	0.63	0.64	0.6
10,000 cycles DFT test 4	0.59	0.59	0.62	0.59	0.59	0.57	0.61	0.62	0.58
10,000 cycles DFT test 5	0.59	0.58	0.63	0.56	0.58	0.55	0.6	0.61	0.57
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.62	0.61	0.65	0.60	0.59	0.57	0.63	0.64	0.59
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.029	0.028	0.030	0.030	0.007	0.015	0.032	0.025	0.018
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.61	0.60	0.65	0.59	0.59	0.57	0.62	0.63	0.59
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.021	0.017	0.026	0.025	0.005	0.017	0.022	0.022	0.018
100,000 cycles DFT test 1	0.42	0.53	0.48	0.53	0.51	0.55	0.52	0.55	0.57
100,000 cycles DFT test 2	0.42	0.49	0.45	0.53	0.52	0.54	0.5	0.54	0.57
100,000 cycles DFT test 3	0.43	0.51	0.44	0.5	0.5	0.51	0.5	0.52	0.55
100,000 cycles DFT test 4	0.42	0.5	0.45	0.49	0.49	0.5	0.5	0.53	0.55
100,000 cycles DFT test 5	0.45	0.47	0.46	0.49	0.51	0.49	0.5	0.51	0.54
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.43	0.50	0.46	0.51	0.51	0.52	0.50	0.53	0.56
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.013	0.022	0.015	0.020	0.011	0.026	0.009	0.016	0.013
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.43	0.49	0.45	0.50	0.51	0.51	0.50	0.53	0.55
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.014	0.017	0.008	0.019	0.013	0.022	0.000	0.013	0.013
150,000 cycles DFT test 1	0.4	0.48	0.45	0.47	0.47	0.45	0.48	0.52	0.55
150,000 cycles DFT test 2	0.39	0.47	0.44	0.46	0.47	0.45	0.47	0.5	0.55
150,000 cycles DFT test 3	0.39	0.47	0.46	0.44	0.45	0.44	0.46	0.5	0.54
150,000 cycles DFT test 4	0.39	0.48	0.43	0.43	0.44	0.44	0.47	0.5	0.55
150,000 cycles DFT test 5	0.38	0.48	0.46	0.43	0.44	0.43	0.46	0.5	0.54
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.39	0.48	0.45	0.45	0.45	0.44	0.47	0.50	0.55
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.007	0.005	0.013	0.018	0.015	0.008	0.008	0.009	0.005
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.39	0.48	0.45	0.44	0.45	0.44	0.47	0.50	0.55
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.005	0.006	0.015	0.014	0.014	0.008	0.006	0.000	0.006

Test Slabs BNN

Slab Identification	Slab ID: BNN#1			Slab ID: BNN#2			Slab ID: BNN#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.59	0.58	0.53	0.58	0.56	0.51	0.57	0.58	0.54
10,000 cycles DFT test 2	0.58	0.56	0.52	0.58	0.58	0.53	0.58	0.56	0.54
10,000 cycles DFT test 3	0.54	0.55	0.51	0.56	0.56	0.52	0.58	0.58	0.54
10,000 cycles DFT test 4	0.54	0.56	0.51	0.55	0.56	0.53	0.56	0.56	0.54
10,000 cycles DFT test 5	0.53	0.55	0.51	0.52	0.54	0.51	0.56	0.57	0.54
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.56	0.56	0.52	0.56	0.56	0.52	0.57	0.57	0.54
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.027	0.012	0.009	0.025	0.014	0.010	0.010	0.010	0.000
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.55	0.56	0.51	0.55	0.56	0.52	0.57	0.57	0.54
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.022	0.006	0.005	0.025	0.016	0.010	0.012	0.010	0.000
100,000 cycles DFT test 1	0.4	0.41	0.4	0.43	0.44	0.45	0.45	0.43	0.41
100,000 cycles DFT test 2	0.4	0.41	0.4	0.44	0.44	0.44	0.46	0.45	0.43
100,000 cycles DFT test 3	0.4	0.41	0.4	0.45	0.44	0.45	0.46	0.45	0.45
100,000 cycles DFT test 4	0.4	0.41	0.4	0.44	0.41	0.42	0.45	0.46	0.43
100,000 cycles DFT test 5	0.4	0.4	0.4	0.46	0.43	0.46	0.45	0.44	0.44
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.40	0.41	0.40	0.44	0.43	0.44	0.45	0.45	0.43
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.000	0.004	0.000	0.011	0.013	0.015	0.005	0.011	0.015
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.40	0.41	0.40	0.45	0.43	0.44	0.46	0.45	0.44
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.000	0.005	0.000	0.010	0.014	0.017	0.006	0.008	0.010
150,000 cycles DFT test 1	0.4	0.41	0.41	0.41	0.4	0.4	0.41	0.4	0.4
150,000 cycles DFT test 2	0.4	0.41	0.41	0.42	0.4	0.4	0.41	0.4	0.4
150,000 cycles DFT test 3	0.4	0.4	0.4	0.42	0.4	0.41	0.4	0.4	0.4
150,000 cycles DFT test 4	0.4	0.41	0.41	0.41	0.4	0.4	0.4	0.4	0.4
150,000 cycles DFT test 5	0.39	0.4	0.4	0.41	0.4	0.4	0.4	0.4	0.4
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.40	0.41	0.41	0.41	0.40	0.40	0.40	0.40	0.40
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.004	0.005	0.005	0.005	0.000	0.004	0.005	0.000	0.000
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.40	0.41	0.41	0.42	0.40	0.40	0.40	0.40	0.40
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.005	0.006	0.006	0.006	0.000	0.005	0.005	0.000	0.000

Test Slabs CMM

Slab Identification	Slab ID: CMM#1			Slab ID: CMM#2			Slab ID: CMM#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.54	0.53	0.5	0.51	0.5	0.5	0.53	0.52	0.53
10,000 cycles DFT test 2	0.55	0.54	0.49	0.52	0.51	0.51	0.53	0.52	0.51
10,000 cycles DFT test 3	0.54	0.53	0.5	0.51	0.5	0.49	0.52	0.52	0.5
10,000 cycles DFT test 4	0.53	0.53	0.51	0.51	0.5	0.49	0.52	0.52	0.5
10,000 cycles DFT test 5	0.52	0.53	0.51	0.5	0.5	0.49	0.51	0.52	0.52
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.54	0.53	0.50	0.51	0.50	0.50	0.52	0.52	0.51
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.011	0.004	0.008	0.007	0.004	0.009	0.008	0.000	0.013
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.54	0.53	0.50	0.51	0.50	0.50	0.52	0.52	0.51
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.013	0.005	0.010	0.008	0.005	0.010	0.008	0.000	0.010
100,000 cycles DFT test 1	0.43	0.44	0.46	0.44	0.44	0.45	0.44	0.44	0.45
100,000 cycles DFT test 2	0.43	0.44	0.45	0.44	0.44	0.44	0.44	0.44	0.45
100,000 cycles DFT test 3	0.43	0.43	0.45	0.43	0.43	0.43	0.44	0.44	0.46
100,000 cycles DFT test 4	0.42	0.43	0.45	0.42	0.43	0.44	0.42	0.43	0.44
100,000 cycles DFT test 5	0.42	0.43	0.44	0.42	0.42	0.43	0.43	0.44	0.44
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.43	0.43	0.45	0.43	0.43	0.44	0.43	0.44	0.45
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.005	0.005	0.007	0.010	0.008	0.008	0.009	0.004	0.008
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.43	0.43	0.45	0.43	0.43	0.44	0.43	0.44	0.45
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.006	0.005	0.005	0.010	0.008	0.006	0.010	0.005	0.010
150,000 cycles DFT test 1	0.43	0.43	0.45	0.4	0.4	0.41	0.41	0.41	0.42
150,000 cycles DFT test 2	0.43	0.43	0.45	0.4	0.4	0.41	0.4	0.41	0.42
150,000 cycles DFT test 3	0.42	0.42	0.44	0.4	0.4	0.4	0.4	0.41	0.41
150,000 cycles DFT test 4	0.41	0.42	0.43	0.39	0.39	0.4	0.39	0.4	0.4
150,000 cycles DFT test 5	0.41	0.41	0.43	0.39	0.4	0.41	0.39	0.4	0.41
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.42	0.42	0.44	0.40	0.40	0.41	0.40	0.41	0.41
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.010	0.008	0.010	0.005	0.004	0.005	0.008	0.005	0.008
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.42	0.42	0.44	0.40	0.40	0.41	0.40	0.41	0.41
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.010	0.008	0.010	0.006	0.005	0.006	0.006	0.006	0.008

Test Slabs CNM

Slab Identification	Slab ID: CNM#1			Slab ID: CNM#2			Slab ID: CNM#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.52	0.51	0.48	0.56	0.56	0.53	0.5	0.5	0.49
10,000 cycles DFT test 2	0.53	0.52	0.49	0.56	0.55	0.51	0.51	0.5	0.49
10,000 cycles DFT test 3	0.52	0.52	0.49	0.55	0.55	0.51	0.5	0.5	0.5
10,000 cycles DFT test 4	0.52	0.51	0.51	0.54	0.55	0.51	0.49	0.5	0.5
10,000 cycles DFT test 5	0.52	0.51	0.49	0.54	0.55	0.5	0.49	0.49	0.5
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.52	0.51	0.49	0.55	0.55	0.51	0.50	0.50	0.50
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.004	0.005	0.011	0.010	0.004	0.011	0.008	0.004	0.005
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.52	0.52	0.50	0.55	0.55	0.51	0.50	0.50	0.50
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.005	0.006	0.010	0.010	0.000	0.005	0.010	0.005	0.005
100,000 cycles DFT test 1	0.47	0.48	0.47	0.38	0.4	0.41	0.43	0.44	0.44
100,000 cycles DFT test 2	0.47	0.47	0.46	0.38	0.4	0.42	0.43	0.43	0.43
100,000 cycles DFT test 3	0.47	0.47	0.47	0.39	0.4	0.42	0.43	0.44	0.44
100,000 cycles DFT test 4	0.46	0.47	0.46	0.39	0.39	0.41	0.42	0.44	0.44
100,000 cycles DFT test 5	0.45	0.46	0.45	0.38	0.39	0.42	0.42	0.43	0.43
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.46	0.47	0.46	0.38	0.40	0.42	0.43	0.44	0.44
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.009	0.007	0.008	0.005	0.005	0.005	0.005	0.005	0.005
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.46	0.47	0.46	0.39	0.40	0.42	0.43	0.44	0.44
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.010	0.005	0.008	0.006	0.006	0.005	0.006	0.006	0.006
150,000 cycles DFT test 1	0.41	0.42	0.41	0.37	0.39	0.4	0.42	0.44	0.43
150,000 cycles DFT test 2	0.41	0.41	0.42	0.37	0.39	0.4	0.42	0.45	0.44
150,000 cycles DFT test 3	0.4	0.41	0.41	0.37	0.39	0.4	0.41	0.43	0.44
150,000 cycles DFT test 4	0.4	0.42	0.41	0.37	0.39	0.4	0.41	0.44	0.44
150,000 cycles DFT test 5	0.39	0.41	0.41	0.36	0.38	0.4	0.41	0.42	0.43
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.40	0.41	0.41	0.37	0.39	0.40	0.41	0.44	0.44
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.008	0.005	0.004	0.004	0.004	0.000	0.005	0.011	0.005
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.40	0.41	0.41	0.37	0.39	0.40	0.41	0.44	0.44
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.008	0.005	0.005	0.005	0.005	0.000	0.005	0.013	0.005

Test Slabs CNN

Slab Identification	Slab ID: CNN#1			Slab ID: CNN#2			Slab ID: CNN#3		
Test measurement speed (kph)	20	40	60	20	40	60	20	40	60
10,000 cycles DFT test 1	0.46	0.44	0.42	0.52	0.44	0.41	0.44	0.43	0.44
10,000 cycles DFT test 2	0.45	0.45	0.42	0.47	0.44	0.41	0.43	0.42	0.44
10,000 cycles DFT test 3	0.45	0.44	0.41	0.49	0.44	0.41	0.44	0.42	0.44
10,000 cycles DFT test 4	0.43	0.43	0.41	0.48	0.44	0.41	0.43	0.42	0.43
10,000 cycles DFT test 5	0.43	0.42	0.4	0.48	0.43	0.4	0.43	0.43	0.44
10,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.44	0.44	0.41	0.49	0.44	0.41	0.43	0.42	0.44
10,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.013	0.011	0.008	0.019	0.004	0.004	0.005	0.005	0.004
10,000 cycles DFT average of tests 2, 3, 4, and 5	0.44	0.44	0.41	0.48	0.44	0.41	0.43	0.42	0.44
10,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.012	0.013	0.008	0.008	0.005	0.005	0.005	0.005	0.005
100,000 cycles DFT test 1	0.4	0.4	0.39	0.41	0.4	0.4	0.43	0.41	0.41
100,000 cycles DFT test 2	0.4	0.39	0.4	0.41	0.4	0.4	0.43	0.42	0.41
100,000 cycles DFT test 3	0.4	0.39	0.39	0.41	0.4	0.4	0.43	0.41	0.41
100,000 cycles DFT test 4	0.39	0.39	0.39	0.4	0.39	0.39	0.43	0.41	0.41
100,000 cycles DFT test 5	0.39	0.39	0.39	0.41	0.4	0.4	0.42	0.4	0.4
100,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.40	0.39	0.39	0.41	0.40	0.40	0.43	0.41	0.41
100,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.007	0.004
100,000 cycles DFT average of tests 2, 3, 4, and 5	0.40	0.39	0.39	0.41	0.40	0.40	0.43	0.41	0.41
100,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.006	0.000	0.005	0.005	0.005	0.005	0.005	0.008	0.005
150,000 cycles DFT test 1	0.39	0.4	0.4	0.4	0.4	0.4	0.42	0.4	0.4
150,000 cycles DFT test 2	0.39	0.39	0.39	0.39	0.39	0.39	0.41	0.4	0.4
150,000 cycles DFT test 3	0.39	0.39	0.39	0.39	0.39	0.39	0.42	0.4	0.41
150,000 cycles DFT test 4	0.39	0.39	0.39	0.39	0.4	0.4	0.42	0.4	0.4
150,000 cycles DFT test 5	0.39	0.39	0.4	0.39	0.39	0.39	0.41	0.4	0.4
150,000 cycles DFT average of tests 1, 2, 3, 4, and 5	0.39	0.39	0.39	0.39	0.39	0.39	0.42	0.40	0.40
150,000 cycles DFT standard deviation of tests 1, 2, 3, 4, and 5	0.000	0.004	0.005	0.004	0.005	0.005	0.005	0.000	0.004
150,000 cycles DFT average of tests 2, 3, 4, and 5	0.39	0.39	0.39	0.39	0.39	0.39	0.42	0.40	0.40
150,000 cycles DFT standard deviation of tests 2, 3, 4, and 5	0.000	0.000	0.005	0.000	0.005	0.005	0.006	0.000	0.005