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## **TECHNICAL MEMORANDUM**

### **Task Report: Comparative Evaluation of Locked-Wheel and SCRIM Friction Testers**

**DATE:** April 3, 2017

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## INTRODUCTION

The Texas A&M Transportation Institute and the Virginia Tech Transportation Institute collected friction measurements with the Sideway-force Coefficient Routine Investigation Machine (SCRIM) and two locked-wheel skid trailers to compare these friction testers. For this comparison, VTTI and TTI conducted side-by-side testing of the SCRIM and the locked-wheel ASTM E 274 (1) friction measurement systems on 6 skid pads located at the RELIS Campus of Texas A&M University. This collaborative effort was conducted in September 2016 under a study funded by the Virginia Transportation Research Council.

The SCRIM measures wet-road skid resistance by applying the test wheel at an angle of 20° on the road surface under a known load. Unlike the locked-wheel skid trailer, the SCRIM is capable of continuous friction measurements. The vertical load and the sideway force generated during skidding of the test wheel are measured by transducers, which are then used to compute the friction coefficient that is referred to in this report as the SCRIM Reading (SR). This coefficient corresponds to a slip speed equal to 34 percent of the test speed unlike the skid number from locked-wheel systems, which corresponds to 100 percent slip.

This technical memorandum compares the SCRIM and the locked-wheel friction numbers from the joint testing conducted by TTI and VTTI at the RELIS Campus skid pads. The memorandum 1) identifies the sections tested, the types of data collected, and the friction testers used to collect the data; 2) presents the results from comparisons of the SCRIM and locked-wheel test readings; and 3) provides tables of the test measurements in the appendix.

## TEST SECTIONS

Table 1 identifies the skid pads where friction measurements were collected. All 6 test sections are located along runway 35C of the Texas A&M RELIS Campus. Close-up pictures of the surfaces tested are given in Figure 1 to Figure 6. As will be seen later in the data collected from this evaluation, the sections covered a good range of surface textures (measured in terms of mean profile depth) and friction numbers.

**Table 1. Skid Pads for Comparing Locked-Wheel and SCRIM Friction Testers.**

Skid Pad	Surface Type	GPS Coordinates at Start of Section	
		Latitude (°N)	Longitude (°W)
1	Portland cement concrete	30° 37.9254'	96° 28.9206'
2	Jennite Flush Seal	30° 37.9254'	96° 28.9092'
2A	Jennite Flush Seal	30° 37.9260'	96° 28.9044'
5	Rounded gravel hot mix	30° 37.8498'	96° 28.9044'
6	Rounded gravel chip seal	30° 37.7478'	96° 28.9044'
7	Lightweight aggregate chip seal	30° 37.7484'	96° 28.9080'

## DATA COLLECTION

Skid measurements were collected using the SCRIM continuous friction measurement system shown in Figure 7 and the locked-wheel skid trailers pictured in Figure 8 and Figure 9. Both locked-wheel skid trailers are dual-channel systems and use smooth ASTM E524 (2) test tires. TTI's ASTM E 274 skid system meets the stringent requirements of ASTM E1890 (3) and is used in calibrating other locked-wheel skid devices. TTI personnel operated this unit during testing while the other locked-wheel skid trailer was operated by Mr. John Wirth of TxDOT. VTTI personnel operated the SCRIM.



**Figure 1. Skid Pad 1.**



**Figure 2. Skid Pad 2.**





**Figure 3. Skid Pad 2A.**



**Figure 4. Skid Pad 5.**



**Figure 5. Skid Pad 6.**



**Figure 6. Skid Pad 7.**





**Figure 7. SCRIM Continuous Friction Measurement Equipment.**



**Figure 8. TTI Locked-Wheel Skid Trailer.**



**Figure 9. TxDOT Locked-Wheel Skid Trailer (29-4382K).**

Skid measurements on the test sections identified in Table 1 were conducted over a two-day period. Prior to skid testing, VTTI made a dry run on each skid pad to collect macro-texture data using the texture laser installed on the SCRIM. Subsequently, friction measurements were collected at 3 test speeds (30, 40, and 50 mph) with 8 to 10 repeat runs made per test speed and friction tester.

After skid testing was completed, TTI personnel collected macro-texture and friction measurements on each skid pad with the circular track meter (CTM) and dynamic friction tester (DFT). TTI collected these measurements to compare the friction numbers from the different devices using the international friction index (IFI). For these measurements, CTM and DFT data were collected to cover the intervals of the wheel lock-up on the ASTM E 274 systems. In this way, comparisons can be made based on friction statistics determined over the same (or as close to the same) interval over which the skid numbers from the locked-wheel trailers were determined. Table 2 identifies the intervals of wheel lock-up on the ASTM E 274 systems for each skid pad and test speed. Since the SCRIM provides continuous friction measurements, the friction coefficients from this device were determined over the same intervals to compare with the corresponding skid numbers from the locked-wheel skid trailers.

**Table 2. Intervals of Wheel Lock-Up on ASTM E 274 Systems.**

Skid Pad	Test Speed (mph)	Limits of Wheel Lock-up (ft.)*	
		Start	End
1	30	136	180
	40	159	218
	50	177	250
2	30	223	267
	40	240	299
	50	266	339
2A	30	216	260
	40	241	300
	50	252	325
5	30	111	155
	40	127	186
	50	173	246
6	30	76	120
	40	101	160
	50	120	193
7	30	75	119
	40	96	155
	50	119	192

\* Limits referred from start (north end) of skid pad.

### COMPARISON OF BETWEEN SCRIM READINGS AND LOCKED-WHEEL SKID NUMBERS

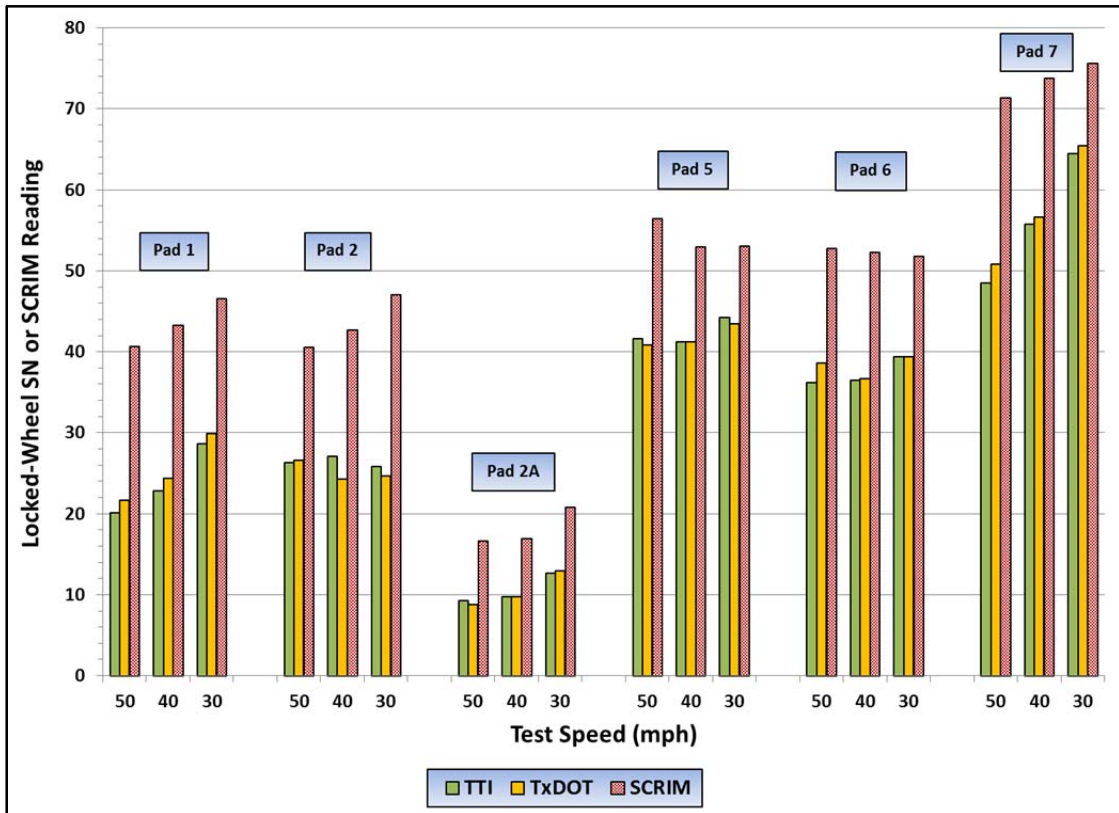
Table 3 gives averages of the friction measurements made with the locked-wheel skid trailers and the SCRIM on the skid pads tested in this comparative evaluation. The test readings from the runs made with these devices are given in Table A1 to Table A19 of the appendix. The locked-wheel skid numbers and SCRIM Readings in Table 3 are averages computed from corresponding quantities determined from repeat runs on each section. These statistics are also plotted in Figure 10 where it is observed that the SCRIM Readings are consistently higher than the skid numbers from the locked-wheel skid trailers. Figure 10 also shows that the test sections covered a good range of skid numbers from a low value of about 9 to a high value of about 65. In terms of the SCRIM, the readings range from 17 to 76.

On average, the SRs differ from the TTI locked-wheel skid numbers by +14.7 and from the TxDOT SNs by +14.3, with the differences being statistically significant at the 95% confidence level ( $\alpha = 0.05$ ) from paired *t*-tests conducted by the researchers. A similar finding was made in an earlier TxDOT project conducted by Zimmer and Fernando (4) where the locked-wheel skid trailer was compared with a Dynatest 6875H fixed-slip continuous friction measurement system owned by the Federal Highway Administration. In that project, the friction numbers from the Dynatest unit were found to be consistently higher than the skid numbers from TTI's locked-wheel skid-trailer, with an average difference of +14.5 on the TTI skid pads. The higher friction numbers from fixed-slip continuous friction measurement systems such as the SCRIM and the Dynatest 6875H reflect the differences between these systems and the locked-wheel skid trailer. In theory, fixed slip systems should give higher readings compared to locked-wheel units. From this perspective, it is perhaps of greater interest to check the correlation between the SCRIM Readings and the locked-wheel skid numbers.



**Table 3. Locked-Wheel Skid Numbers and SCRIM Readings from Tests.**

Skid Pad	Test Speed (mph)	Locked-Wheel Skid Number		SCRIM Reading
		TTI	TxDOT	
1	30	28.7	29.9	46.6
	40	22.9	24.4	43.3
	50	20.2	21.7	40.7
2	30	25.8	24.6	47.1
	40	27.1	24.3	42.7
	50	26.3	26.6	40.6
2A	30	12.6	12.9	20.8
	40	9.8	9.8	16.9
	50	9.2	8.7	16.7
5	30	44.3	43.4	53.1
	40	41.2	41.2	53.0
	50	41.6	40.8	56.5
6	30	39.4	39.4	51.8
	40	36.5	36.7	52.3
	50	36.2	38.6	52.8
7	30	64.4	65.4	75.6
	40	55.8	56.6	73.8
	50	48.5	50.9	71.4



**Figure 10. Locked-Wheel Skid Numbers and SCRIM Readings from Tests.**

Figure 11 and Figure 12 compare, respectively, the readings from the SCRIM with the skid numbers from the TTI and TxDOT locked-wheel skid trailers. These figures show good correlation between the locked-wheel skid numbers and the SCRIM Readings determined from the data collected on the skid pads tested. The goodness-of-fit statistics between each of the locked-wheel units and the SCRIM are very comparable, as readily seen in the coefficient of determination ( $R^2$ ) and standard error of the estimate (SEE) given in Figure 11 and Figure 12. The coefficients of the linear regression lines in these figures were also found to be statistically significant at the 95% confidence level. Note that the slope of each regression line is less than one consistent with the observation that the SCRIM Readings are consistently higher than the locked wheel skid numbers from the TTI and TxDOT units.

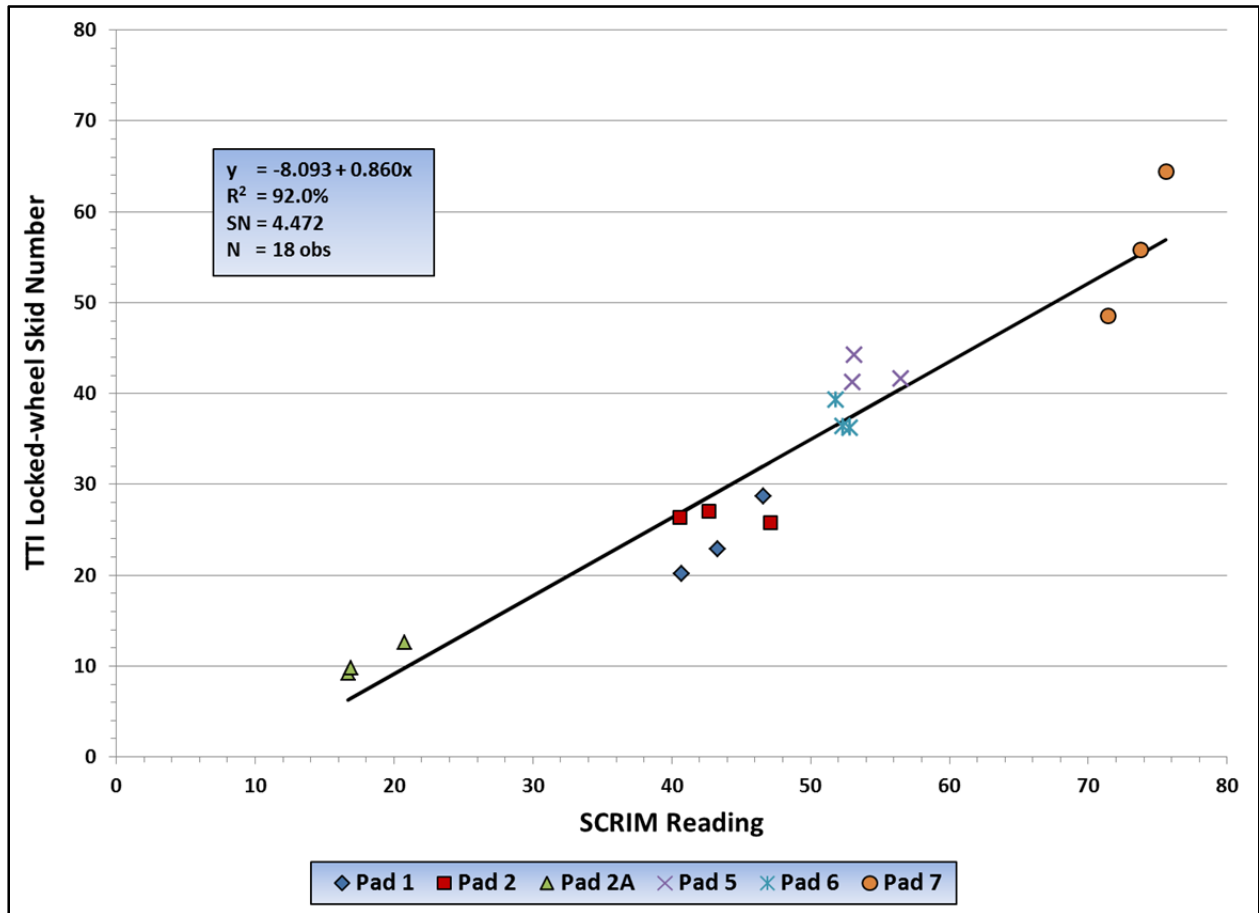
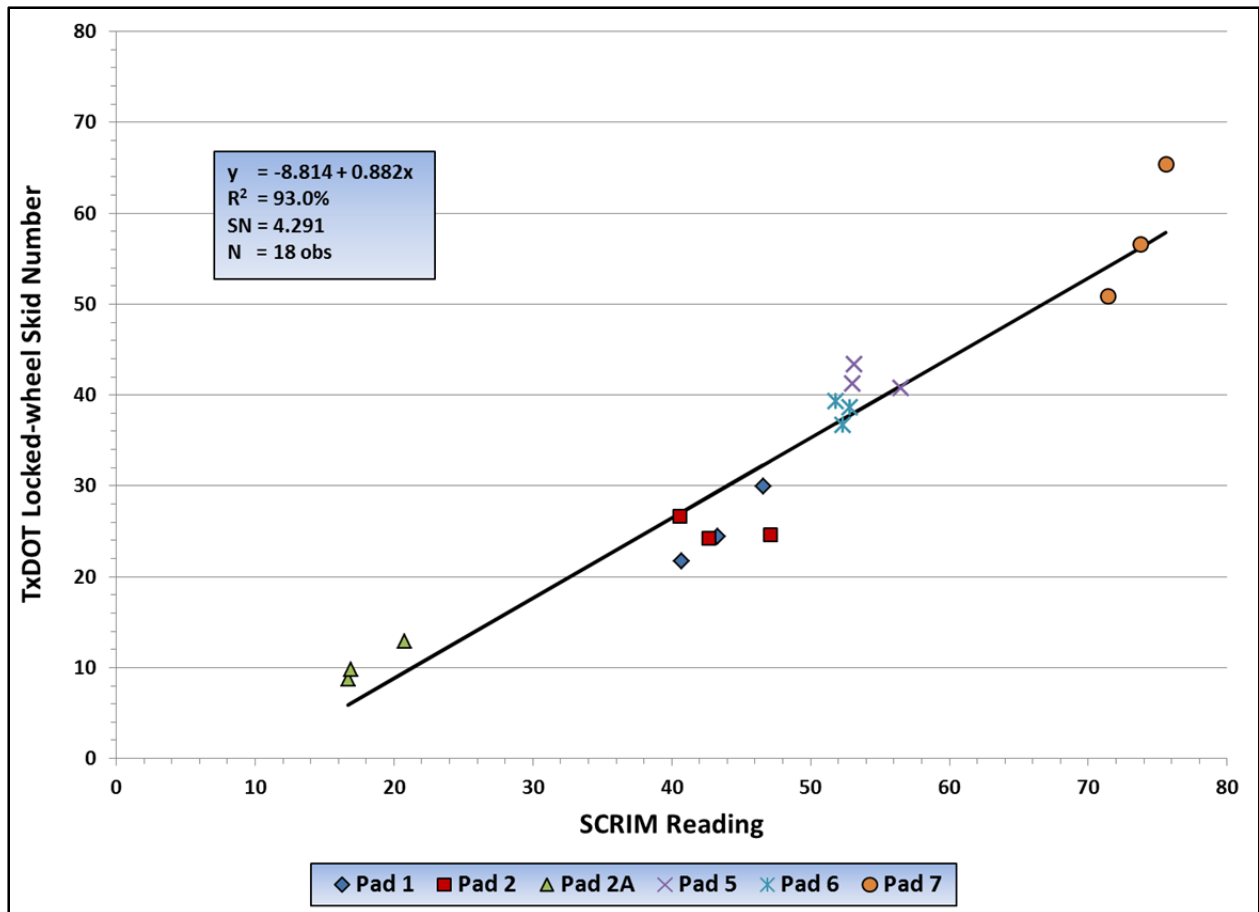


Figure 11. Comparison between TTI Locked-Wheel Skid Numbers and SCRIM Readings.



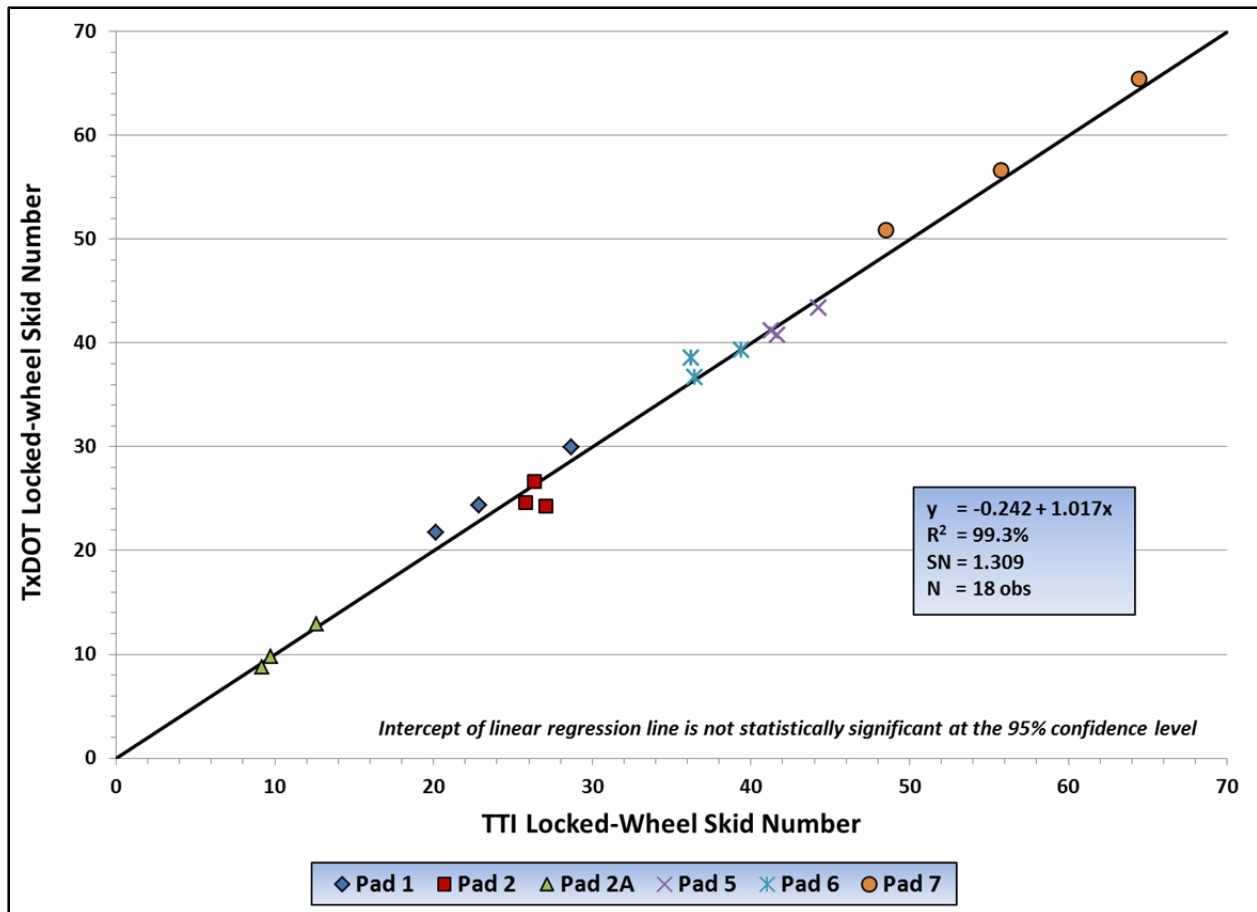
**Figure 12. Comparison between TxDOT Locked-wheel Skid Numbers and SCRIM Readings.**

Figure 13 compares the skid numbers between the TTI and TxDOT locked-wheel skid trailers. This figure shows a very high correlation between the skid numbers from both ASTM E 274 systems. Note that the slope of the linear regression line is close to unity, with an intercept that is not statistically significant at the 95% confidence level. On average, the difference between the skid numbers from the TTI and TxDOT locked-wheel trailers is 0.31. A paired *t*-test of the differences showed that the skid numbers from both units are not significantly different at the 95% confidence level.

### EVALUATION OF INTERNATIONAL FRICTION INDICES

TTI researchers also compared the friction measurement systems in terms of the international friction index. The IFI was developed from the *PIARC International Experiment to Compare and Harmonize Texture and Skid Resistance Measurements* (5). IFI permits harmonizing friction measurements collected with different devices to a common calibrated index. Researchers took the following steps to compare the locked-wheel and SCRIM friction measurement systems based on IFI:





**Figure 13. Comparison of TxDOT and TTI Locked-Wheel Skid Numbers.**

- Run tests with the circular track meter (CTM) and dynamic friction tester (DFT) on each skid pad.
- Determine IFI calibration coefficients following ASTM E1960 (6).
- Use the IFI calibration coefficients to compute the friction values at 60 kph (F60) for each friction measurement system.
- Compare the different systems based on calculated F60 values.

The methodology used to compare the SCRIM and locked-wheel units based on IFI followed the same procedure used by Fernando, Zimmer, and Mikhail (7) to compare locked-wheel and fixed-slip friction measurement systems. However, in the current project, the IFIs were determined over the range of test speeds at which friction measurements were collected. Since the previous comparisons are based on friction numbers over the interval of wheel lock-up at a given test speed, TTI researchers collected CTM and DFT measurements over the same intervals for the purpose of calculating international friction indices. The CTM and DFT data collected on the skid pads are presented in Table A20 to Table A21 of the appendix. From these measurements, researchers computed the averages of the mean profile depths (MPDs) and DFT friction coefficients corresponding to 20 kph (DFT<sub>20</sub>). Table 4 presents the averages determined from this step.

**Table 4. Mean Profile Depths and DFT Friction Coefficients used to Compute IFIs.**

Skid Pad	Test Speed (mph)	Limits of Wheel Lock-Up (ft.) <sup>a</sup>		Average MPD <sup>b</sup> (mm)	Average DFT <sub>20</sub> <sup>b</sup>
		Start	End		
1	30	136	180	0.642	0.360
	40	159	218	0.648	0.355
	50	177	250	0.659	0.336
2 <sup>c</sup>	30	223	267	1.372	0.317
	40	240	299	1.423	0.330
	50	266	339	1.289	0.326
2A <sup>c</sup>	30	216	260	0.821	0.197
	40	241	300	0.836	0.210
	50	252	325	0.835	0.226
5	30	111	155	2.354	0.353
	40	127	186	2.467	0.363
	50	173	246	2.757	0.370
6	30	76	120	1.911	0.337
	40	101	160	1.984	0.370
	50	120	193	1.921	0.366
7	30	75	119	1.359	0.710
	40	96	155	1.399	0.763
	50	119	192	1.464	0.746

<sup>a</sup> Limits referred from start (north end) of skid pad

<sup>b</sup> Determined over interval of wheel lock-up at given test speed

<sup>c</sup> Flush seals exhibit cracking along the test wheel paths

The average MPDs in Table 4 range from 0.64 to 2.76 mm, while the average DFT<sub>20</sub> range from about 0.2 to 0.76. According to ASTM E1960, pavement sections for calibrating friction testers should have profile depths for the range  $0.25 < \text{MPD} < 1.5\text{mm}$ , and friction values for the range  $0.30 < \text{DFT}_{20} < 0.90$ . The skid pads included in this evaluation exhibit macrotexture and friction characteristics that overlap with these ranges. Following ASTM E1960, researchers determined the IFI calibration constants using the MPD and DFT<sub>20</sub> values given in Table 4 with the following equations:

- Compute the speed constant  $S_p$  from the MPD (in mm):

$$S_p = 14.2 + 89.7 \text{MPD} \quad (1)$$

- Compute the calibrated friction value at 60 kph (F60) from DFT<sub>20</sub> and  $S_p$ :

$$F60 = 0.081 + 0.732 \times \text{DFT}_{20} \exp\left(\frac{-40}{S_p}\right) \quad (2)$$

- For a given friction measurement system, use the measured friction  $FRS$  for a given slip speed  $S$  with the speed constant  $S_p$  to compute the friction at 60 kph ( $FR60$ ):

$$FR60 = FRS \exp\left[\frac{(S - 60)}{S_p}\right] \quad (3)$$

- Determine the calibration constants  $A$  and  $B$  of the IFI equation from a linear regression of  $F60$  and  $FR60$ :

$$F60 = A + B \times FR60 \quad (4)$$

For locked-wheel skid trailers, the slip speed  $S$  in equation (3) is equal to the test speed  $V$  in kph, while for the SCRIM, the slip speed equals  $V$  multiplied by 34 percent ( $\sin 20^\circ$ ) where  $20^\circ$  is the test wheel angle of the SCRIM relative to the direction of travel. The above calculations are done using the corresponding data at each of the three test speeds used in this evaluation.

Using the data given in Table 3 and Table 4, researchers computed  $S_p$ ,  $F60$ , and  $FR60$  from equations (1) to (3). Researchers then used the  $F60$  and  $FR60$  values in a linear regression analysis to determine the calibration constants  $A$  and  $B$  of the IFI equation for each of the three friction measurement systems included in this evaluation. Table 5 summarizes the  $S_p$ ,  $F60$ , and  $FR60$  values used in the regression analysis while Table 6 presents the IFI calibration constants determined for each friction measurement system. The constants  $A$  and  $B$  were found to be statistically significant at the 95% confidence level for all three friction measurement systems.

**Table 5. Data for Determining IFI Calibration Constants.**

Skid Pad	Test Speed (mph)	Average MPD (mm)	Average DFT <sub>20</sub>	Average $S_p$	Average $F60$	Average $FR60$		
						SCRIM	TxDOT	TTI
1	30	0.642	0.360	71.807	0.23	0.254	0.254	0.243
2		1.372	0.317	137.288	0.25	0.343	0.226	0.237
2A		0.821	0.197	87.854	0.17	0.127	0.113	0.111
5		2.354	0.353	225.394	0.30	0.438	0.412	0.420
6		1.911	0.337	185.627	0.28	0.410	0.370	0.370
7		1.359	0.710	136.092	0.47	0.549	0.600	0.591
1		40	0.648	0.355	72.356	0.23	0.256	0.259
2	1.423		0.330	141.798	0.26	0.326	0.250	0.279
2A	0.836		0.210	89.174	0.18	0.110	0.102	0.102
5	2.467		0.363	235.460	0.30	0.451	0.420	0.420
6	1.984		0.370	192.180	0.30	0.429	0.375	0.373
7	1.399		0.763	139.705	0.50	0.562	0.584	0.576
1	50		0.659	0.336	73.282	0.22	0.261	0.287
2		1.289	0.326	129.793	0.26	0.316	0.312	0.308
2A		0.835	0.226	89.129	0.19	0.116	0.110	0.116
5		2.757	0.370	261.533	0.31	0.499	0.442	0.450
6		1.921	0.366	186.544	0.30	0.443	0.431	0.404
7		1.464	0.746	145.521	0.50	0.571	0.585	0.558

**Table 6. IFI Calibration Constants from Linear Regression Analysis.**

Friction Measurement System	Intercept A	Slope B	R <sup>2</sup> %	SEE
SCRIM	0.077	0.599	80.0	0.046
TxDOT locked-wheel trailer	0.088	0.598	87.8	0.036
TTI locked-wheel trailer	0.085	0.615	87.7	0.036



Given the calibration constants shown in Table 6, researchers determined the IFIs and compared the locked-wheel and SCRIM friction measurement systems based on the calibrated friction values at 60 kph (F60). Table 7 presents the IFIs on each section. Following ASTM E1960, the F60 and  $S_p$  values are reported for each skid measuring device.

**Table 7. Calculated IFI Values from Data Collected on Test Sections.**

Skid Pad	Test Speed (mph)	Average $S_p$	Calibrated F60 Value (IFI)		
			SCRIM	TxDOT	TTI
1	30	71.807	22.895	24.000	23.419
2	30	137.288	28.221	22.323	23.023
2A	30	87.854	15.269	15.563	15.250
5	30	225.394	33.897	33.455	34.281
6	30	185.627	32.217	30.910	31.178
7	30	136.092	40.557	44.669	44.784
1	40	72.356	22.998	24.293	23.372
2	40	141.798	27.231	23.771	25.610
2A	40	89.174	14.285	14.936	14.749
5	40	235.460	34.685	33.917	34.270
6	40	192.180	33.374	31.240	31.371
7	40	139.705	41.333	43.710	43.825
1	50	73.282	23.298	25.958	24.826
2	50	129.793	26.594	27.436	27.402
2A	50	89.129	14.619	15.383	15.582
5	50	261.533	37.555	35.202	36.123
6	50	186.544	34.232	34.566	33.292
7	50	145.521	41.857	43.787	42.760

Figure 14 compares the calibrated F60 values for the TTI locked-wheel skid trailer with the corresponding SCRIM values. Recall from the earlier comparisons that the SCRIM readings are higher than the locked-wheel skid numbers, with an average difference of +14.7, and with a regression line slope of 0.86 (see Figure 11). After harmonizing the measurements based on IFI, the data points are now observed to plot about the line of equality, thereby demonstrating that the IFI standard transforms the measurements to a comparable scale. Figure 15 shows a similar observation based on comparing the F60 values for the TxDOT locked-wheel skid trailer and the SCRIM. Figure 16 shows the comparison of F60 values for the two locked-wheel skid trailers.

Researchers performed a linear regression analysis on the data plotted in each of the comparisons shown in Figure 14 to Figure 16. This analysis found that the intercept term for each regression equation is not statistically significant at the 95 percent confidence level. Consequently, researchers re-did the analysis with the intercept term set to zero. The resulting relationships and goodness-of-fit statistics are shown in Figure 14 to Figure 16. It is observed that the slope of each relationship is close to unity indicating the agreement between the calibrated F60 values determined from the IFI equations for the three friction measurement systems compared in this study. Fernando, Zimmer, and Mikhail (7) reported similar findings in their comparative evaluation of fixed slip and ASTM E 274 systems based on IFI.

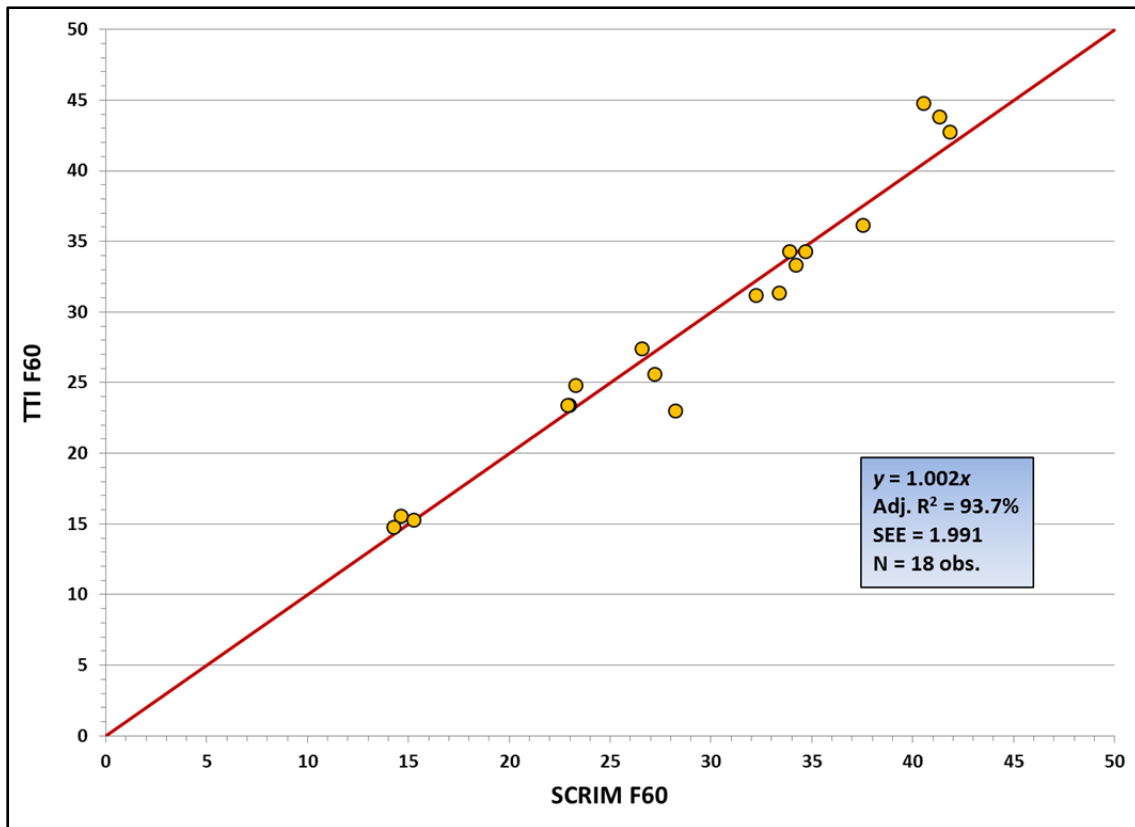


Figure 14. Comparison of Calibrated F60 Values (TTI Locked-Wheel vs. SCRIM).

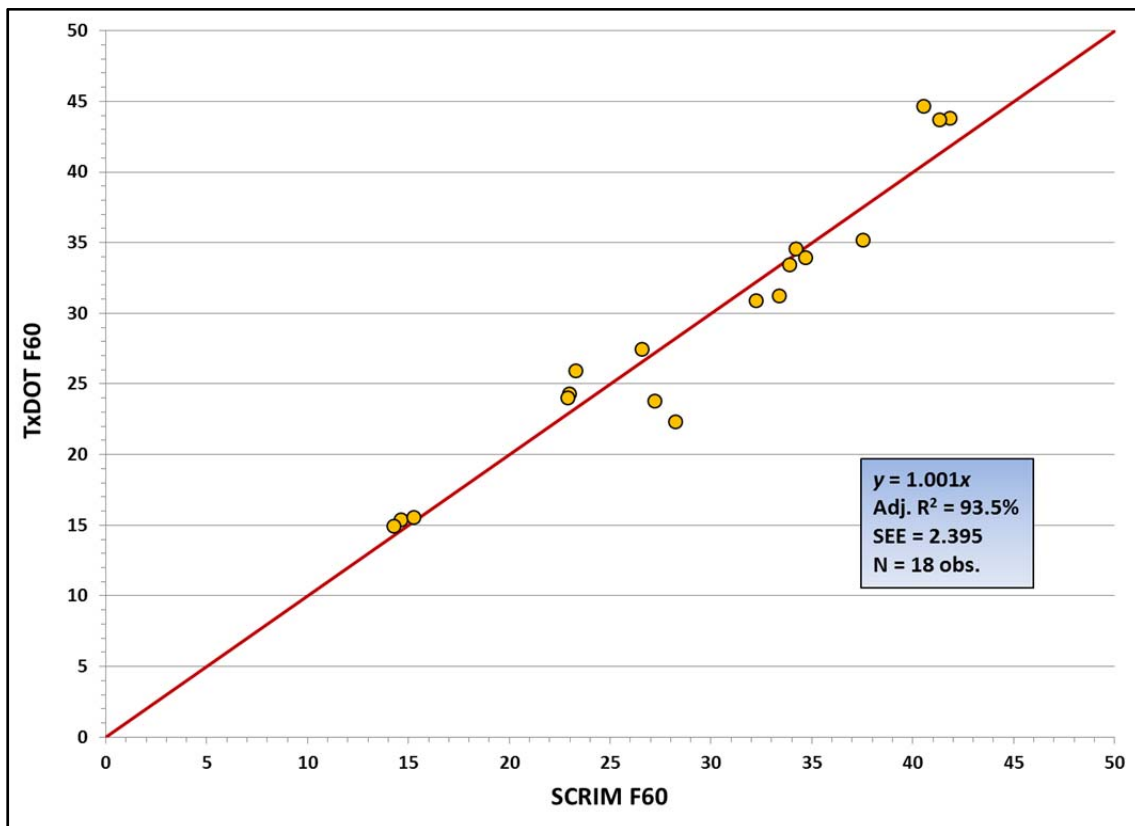
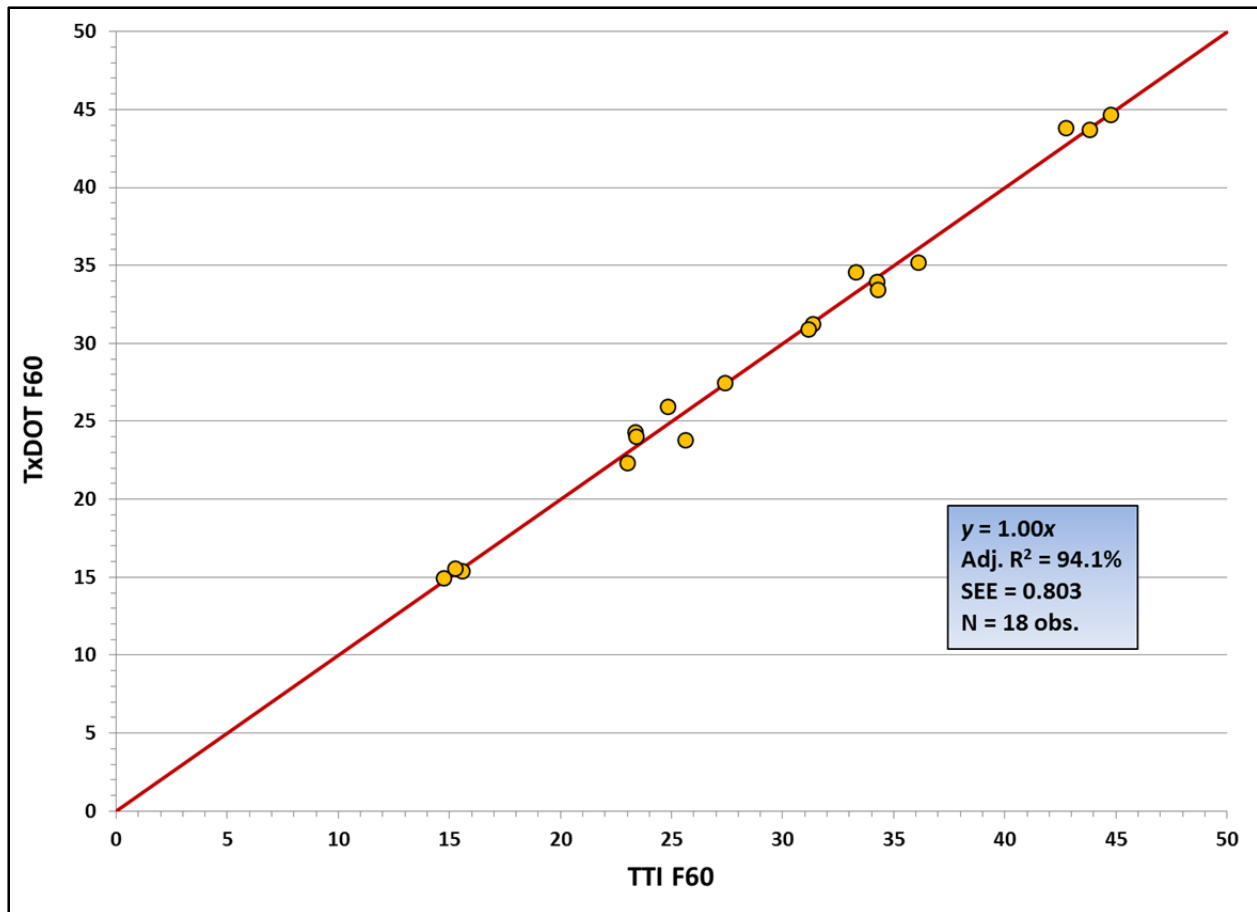


Figure 15. Comparison of Calibrated F60 Values (TxDOT Locked-Wheel vs. SCRIM).



**Figure 16. Comparison of Calibrated F60 Values (TxDOT vs. TTI Locked-Wheel Trailer).**

### SCRIM Tire Percent Slip Verification

As part of the comparison an attempt was made to visually verify the percent slip of the SCRIM test tire. To accomplish this verification, a high-speed camera was setup perpendicular to the path of the test wheel. The camera was setup to view the test wheel as it traversed a measured distance. In this regard, the test wheel cabinet door was removed to get a clear view of the test wheel. The wheel was then marked using a marking paint for reference. This allowed the analyst to count the number of rotations of the test tire over the measured distance. An image from the high speed video is shown in Figure 17. By knowing the measured distance, the number of rotations, and the rolling radius of the tire, the percent slip could be calculated.

To keep the test tire within view of the high speed camera at a reasonable resolution, the measured distance was restricted to 20 feet. After review of the video, it was determined that this distance was not long enough to accurately measure the percent slip due to the small skew angle of the test tire. The small skew angle meant that the number of rotations of the test tire was only slightly affected. Since the number of rotations was only slightly affected, a small percent of rotation variance could greatly affect the calculated percent slip. This possible error was considered unacceptable to make a judgment on verifying the percent slip.

The procedure did show that the method would work, but the standard distance needs to be increased significantly to reduce the error in the measurement. This observation was determined after testing was completed. Therefore, researchers were not able to perform another test as the SCRIM was no longer at the TTI facility. For future testing, the researchers recommend mounting a GoPro style camera to video the side of the SCRIM vehicle and test tire.



The SCRIM should then be driven over a measured test distance in excess of 200 feet. This longer distance should minimize the error associated with counting the number of rotations of the test tire and allow for a more accurate measurement of the percent slip.



**Figure 17. SCRIM Percent Slip Verification Test Setup.**

## **SUMMARY OF FINDINGS**

The following findings are noted from the results presented in this technical memorandum:

- The SCRIM Readings are consistently higher than the skid numbers from the locked-wheel skid trailers. This observation is to be expected from theory, and is also supported by the statistical test of the differences that showed the SCRIM Readings to be significantly higher than the locked-wheel skid numbers at the 95% confidence level.
- Notwithstanding the higher SCRIM Readings relative to the locked-wheel skid trailer, the results from this comparative evaluation showed good correlation between the locked-wheel skid numbers and SCRIM Readings on skid pads that covered a good range of friction values.
- The skid numbers from the TTI and TxDOT locked-wheel skid trailers were found to be highly correlated. The slope of the linear regression line fitted to the data is close to unity, with an intercept that is not statistically significant. In addition, the average difference of 0.31 between the skid numbers from the TTI and TxDOT locked-wheel friction measurement systems is not statistically significant at the 95% confidence level.
- Evaluation of international friction indices demonstrated that the IFI standard transforms the friction values from the SCRIM and locked-wheel systems to a comparable scale. Linear regression analyses where the intercept term was set to zero showed that, for any two friction measurement systems, the slope of the relationship between the calibrated F60 values is close to unity.

- The percent slip of the test tire could not be conclusively verified from the test conducted in this study but the experience gained provided recommendations on how this verification might be conducted in the future.

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## **APPENDIX**

# **DATA FROM COMPARATIVE TESTING OF SCRIM AND LOCKED-WHEEL FRICTION MEASUREMENT SYSTEMS**



**Table A1. Skid Numbers from TxDOT/TTI Locked-Wheel Skid Trailer Tests.**

Skid Pad	Run No.	Skid Number (SN)					
		TTI			TxDOT		
		50 mph	40 mph	30 mph	50 mph	40 mph	30 mph
1	1	23.9	23.6	29.5	24.4	23.0	29.5
	2	20.1	23.9	29.6	23.0	25.1	31.5
	3	20.0	22.6	28.3	21.3	24.6	29.9
	4	20.3	22.8	29.1	21.8	25.2	30.2
	5	19.8	23.0	28.5	20.8	24.0	29.3
	6	19.6	22.5	28.9	21.5	24.3	31.1
	7	20.6	23.0	28.4	21.8	24.1	30.0
	8	20.1	23.2	28.8	21.5	24.2	30.6
	<b>Average*</b>	<b>20.2</b>	<b>22.9</b>	<b>28.7</b>	<b>21.7</b>	<b>24.4</b>	<b>29.9</b>
2	1	32.7	30.1	27.6	29.0	24.4	24.9
	2	26.1	27.8	25.4	27.5	24.0	24.9
	3	27.7	28.6	26.9	27.3	24.0	24.4
	4	27.7	27.1	25.1	26.2	25.3	24.2
	5	27.5	25.6	24.8	27.8	24.5	24.2
	6	24.5	26.3	25.6	26.0	23.4	22.0
	7	24.5	26.5	23.0	24.9	22.7	25.2
	8	24.1	26.1	27.1	24.2	22.7	25.1
	<b>Average*</b>	<b>26.3</b>	<b>27.1</b>	<b>25.8</b>	<b>26.6</b>	<b>24.3</b>	<b>24.6</b>
2A	1	4.8	9.8	13.4	9.0	9.7	12.2
	2	9.7	9.6	13.0	8.9	10.1	12.4
	3	9.4	9.5	13.0	8.5	9.8	12.3
	4	9.1	10.0	12.3	8.9	11.2	12.8
	5	8.9	10.2	12.9	8.6	9.6	13.8
	6	9.2	9.9	11.7	8.4	8.8	12.9
	7	9.8	9.5	12.9	8.5	8.4	13.2
	8	9.0	9.7	11.4	9.7	10.5	11.1
	<b>Average*</b>	<b>9.2</b>	<b>9.8</b>	<b>12.6</b>	<b>8.7</b>	<b>9.8</b>	<b>12.9</b>
5	1	49.4	43.9	45.3	43.6	40.7	44.4
	2	44.0	41.6	45.2	44.3	41.2	43.8
	3	43.2	41.1	42.7	40.4	39.7	43.9
	4	40.8	41.1	43.6	40.9	40.3	43.0
	5	41.2	41.9	44.2	40.2	42.8	44.2
	6	41.7	40.9	43.6	38.1	41.4	42.7
	7	38.9	40.8	45.4	39.0	42.5	43.0
	8	37.8	40.4	43.7	40.9	41.3	42.2
	<b>Average*</b>	<b>41.6</b>	<b>41.2</b>	<b>44.3</b>	<b>40.8</b>	<b>41.2</b>	<b>43.4</b>

\*Average computed taking out high and low values except for cases where there are 2 high or 2 low values.

**Table A1. Skid Numbers from TxDOT/TTI Locked-Wheel Skid Trailer Tests (continued).**

Skid Pad	Run No.	Skid Number (SN)					
		TTI			TxDOT		
		50 mph	40 mph	30 mph	50 mph	40 mph	30 mph
6	1	45.1	38.0	39.9	39.3	37.0	39.9
	2	38.5	36.1	39.5	39.9	36.3	39.5
	3	37.8	35.8	40.0	38.4	37.9	40.0
	4	34.8	36.3	39.6	38.1	40.0	39.6
	5	35.1	35.1	40.2	38.7	35.8	40.2
	6	36.3	36.7	38.8	39.5	35.1	38.8
	7	34.8	37.7	38.5	37.7	35.8	38.5
	8	34.4	36.1	37.9	37.3	37.3	37.9
	<b>Average*</b>	<b>36.2</b>	<b>36.5</b>	<b>39.4</b>	<b>38.6</b>	<b>36.7</b>	<b>39.4</b>
7	1	52.1	57.9	65.7	54.1	53.8	66.1
	2	48.8	56.2	64.8	50.5	55.0	65.5
	3	45.9	55.9	63.0	52.1	55.8	64.5
	4	48.0	56.7	63.8	48.6	58.4	66.5
	5	48.8	54.2	63.3	50.8	56.5	66.0
	6	48.8	55.3	64.4	52.5	55.5	63.3
	7	48.2	56.0	67.5	48.8	58.4	64.2
	8	48.4	54.6	64.6	50.4	58.4	66.1
	<b>Average*</b>	<b>48.5</b>	<b>55.8</b>	<b>64.4</b>	<b>50.9</b>	<b>56.6</b>	<b>65.4</b>

\*Average computed taking out high and low values except for cases where there are 2 high or 2 low values.

**Table A2. Friction Numbers from SCRIM Tests on Pad 1 (50 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
341	36.1	34.1	33.1	36.0	33.1	34.1	31.8	35.1
344	47.1	44.1	44.1	43.1	45.1	46.1	40.8	46.2
348	40.1	40.1	38.1	39.1	37.1	38.1	36.8	38.1
351	43.1	41.1	39.1	42.1	40.1	38.1	39.8	37.1
354	36.1	40.1	40.1	39.1	35.1	39.1	39.8	38.1
358	38.1	40.1	37.1	43.1	38.1	38.1	36.8	36.1
361	47.1	49.1	51.1	53.1	47.1	49.2	45.8	47.2
364	41.1	41.1	40.1	39.1	41.1	39.1	36.8	40.2
367	45.1	46.1	47.1	45.0	42.0	44.1	43.8	42.1
371	44.1	40.1	42.1	47.0	43.0	46.1	42.8	43.1
374	40.1	42.1	40.1	43.0	40.1	40.1	41.8	42.1
377	39.1	36.1	39.1	43.1	42.1	38.1	40.8	42.1
380	39.1	41.1	40.1	44.1	39.1	38.1	39.8	36.1
384	38.1	38.1	40.1	42.1	36.1	40.2	39.8	35.1
387	40.1	40.1	39.1	42.1	39.1	38.1	38.8	36.1
390	40.1	42.1	42.1	40.1	41.1	45.1	40.8	43.2
394	42.1	43.1	42.1	38.1	41.1	41.1	40.8	40.1
397	39.1	45.1	43.1	43.1	37.1	41.1	40.8	39.1
400	42.1	46.1	42.1	44.1	43.1	45.1	43.8	40.1
403	41.1	40.1	40.1	40.1	40.1	40.1	40.8	41.1
407	39.1	37.1	35.1	43.1	35.1	33.1	36.8	32.1
410	41.1	43.1	40.1	42.1	38.1	38.1	43.8	38.1
413	41.1	44.1	43.1	45.1	44.0	40.1	41.8	40.1
Average	40.9	41.5	40.8	42.4	39.9	40.4	40.2	39.5
<b>Overall Average</b>		<b>40.7</b>						

**Table A3. Friction Numbers from SCRIM Tests on Pad 1 (40 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
325	47.5	45.5	45.1	47.2	45.0	47.5	47.1	43.3
328	43.4	42.4	45.1	42.2	44.1	42.4	44.1	43.3
331	46.5	44.4	44.1	46.2	43.1	44.4	46.1	42.3
335	42.4	42.3	44.1	42.2	44.1	42.3	43.0	43.3
338	40.4	41.3	41.1	41.2	41.0	40.3	42.0	41.3
341	38.3	39.3	40.1	37.2	40.0	38.3	39.1	41.3
344	49.4	49.4	46.1	47.2	46.1	47.4	48.1	45.3
348	40.4	38.4	40.1	40.2	39.1	41.4	38.1	40.3
351	44.4	43.4	41.1	40.2	40.1	42.4	42.1	40.3
354	41.4	40.4	44.1	42.2	44.1	42.4	44.1	44.3
358	40.4	41.4	46.1	39.2	44.1	42.4	44.1	44.3
361	43.4	42.3	42.1	44.2	44.1	40.4	44.1	43.3
364	45.3	45.3	46.1	43.2	43.1	46.3	43.1	43.3
367	45.3	45.3	45.2	46.2	45.0	44.3	46.0	45.2
371	47.4	46.3	44.1	44.2	42.1	46.3	43.0	43.2
374	42.3	42.3	42.0	42.2	41.0	41.3	43.0	41.2
377	46.3	47.4	48.0	45.2	47.1	47.4	46.1	46.3
380	42.3	41.4	42.1	42.2	42.1	40.4	43.1	42.3
Average	43.7	43.3	43.7	42.9	43.1	43.2	43.7	43.0
<b>Overall Average</b>		<b>43.3</b>						



**Table A4. Friction Numbers from SCRIM Tests on Pad 1 (30 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
302	48.0	47.8	47.8	47.0	46.8	47.8	49.0	48.0
305	47.0	44.0	44.8	47.0	45.0	43.8	46.0	43.0
308	46.0	48.0	46.8	46.0	45.8	46.8	47.0	49.0
312	44.0	42.8	42.8	43.0	41.8	42.0	44.8	41.0
315	49.0	47.0	48.0	47.0	47.8	48.0	46.8	47.0
318	43.0	45.0	45.0	46.0	43.8	43.0	44.8	44.0
321	47.0	42.0	40.8	43.0	42.0	42.0	41.8	41.0
325	47.0	48.0	47.8	49.0	46.0	48.0	48.0	48.0
328	50.0	50.0	49.0	49.0	49.0	50.0	50.8	48.0
331	49.0	49.0	50.0	50.0	48.8	49.0	50.8	49.0
335	48.8	49.8	48.8	49.0	49.8	49.0	48.8	48.0
338	43.8	47.0	47.0	46.0	45.0	45.8	42.8	46.0
341	45.8	44.0	43.0	43.0	44.0	44.0	42.0	43.0
344	49.0	52.0	52.0	51.0	51.0	50.0	50.0	50.0
Average	46.9	46.9	46.7	46.8	46.2	46.4	46.7	46.0
<b>Overall Average</b>	<b>46.6</b>							

**Table A5. Friction Numbers from SCRIM Tests on Pad 2 (50 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
430	66.1	61.1	57.1	54.1	44.2	39.1	42.1	39.1	39.1
433	60.2	59.1	44.1	46.1	48.1	36.0	37.1	41.2	43.2
436	55.2	54.1	49.1	59.1	52.1	39.1	42.1	43.1	44.2
440	58.2	64.1	49.1	55.1	56.1	45.2	42.0	45.1	50.2
443	60.3	53.1	49.1	38.1	46.1	38.1	37.1	37.1	40.2
446	52.4	52.1	33.1	44.1	46.1	42.1	34.1	39.1	37.1
449	65.2	58.1	48.2	48.1	50.1	37.1	45.1	42.2	44.2
453	53.4	60.2	43.2	48.1	54.1	43.2	39.1	48.2	44.2
456	59.3	62.1	45.2	46.1	60.2	46.2	39.1	46.2	47.2
459	50.4	54.1	48.1	49.1	55.2	46.2	42.1	46.2	44.2
462	59.3	57.1	37.1	41.1	54.2	46.2	35.1	41.2	39.1
466	52.4	53.1	47.2	47.1	45.1	33.1	43.1	36.1	33.1
469	65.2	67.1	49.2	48.1	56.0	51.1	41.1	48.2	46.2
472	53.4	52.2	52.2	45.1	52.2	44.2	47.1	42.2	40.2
476	54.5	60.1	45.2	43.1	49.3	39.1	37.1	37.1	36.1
479	66.2	56.1	46.2	41.1	43.1	31.1	40.1	35.1	34.1
482	54.4	64.1	46.2	47.1	48.1	37.1	44.1	39.1	40.2
485	57.5	52.1	37.1	38.1	45.2	34.1	38.1	32.1	32.1
489	51.5	66.2	46.2	48.1	47.1	47.2	39.1	43.2	35.1
492	72.3	56.2	41.2	37.1	44.1	37.1	35.1	35.1	37.1
495	52.5	63.2	50.2	48.1	44.1	42.1	44.1	44.2	38.1
499	55.5	56.1	45.2	42.1	51.1	48.1	38.1	41.2	41.2
502	59.4	53.1	51.2	49.1	47.1	40.1	43.1	39.1	37.1
Average	<b>58.0</b>	<b>58.0</b>	<b>46.1</b>	<b>46.2</b>	<b>49.5</b>	41.0	40.2	40.9	40.2
<b>Overall Average</b>	<b>40.6</b>		Removed runs 1 to 5 from calculation of overall average as excessive dust affected the friction measurements during the first passes made at 50 mph on skid pad. The friction stabilized after several passes cleared the dust.						

**Table A6. Friction Numbers from SCRIM Tests on Pad 2 (40 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
407	47.2	41.2	41.2	47.2	46.2	50.2	42.2	41.2	41.2
410	48.1	47.2	44.2	46.2	45.2	46.2	46.2	46.2	43.2
413	46.0	47.2	45.2	44.2	42.2	50.2	44.2	44.2	44.2
417	47.1	46.2	46.2	43.2	45.2	42.2	42.2	44.2	43.2
420	51.1	48.2	41.2	46.2	44.2	47.2	44.2	42.2	41.2
423	53.1	41.2	42.2	45.2	53.3	40.2	40.2	40.2	37.2
426	54.1	44.2	46.2	57.3	49.2	54.3	45.2	42.2	45.2
430	46.1	45.2	46.2	43.2	46.2	45.2	44.2	44.2	45.2
433	49.1	41.2	38.2	42.2	44.2	39.2	38.2	36.2	39.2
436	49.1	40.2	41.2	42.2	47.2	42.2	37.2	39.2	40.2
440	50.1	40.2	40.2	46.2	45.2	41.2	41.2	39.2	40.2
443	51.1	44.2	42.2	43.2	44.2	45.2	40.2	39.2	42.2
446	54.1	44.2	42.2	47.2	49.2	40.2	40.2	40.2	42.2
449	48.1	45.2	42.2	43.2	43.2	46.2	38.2	38.2	39.2
453	45.1	42.2	41.2	46.2	48.2	38.2	38.2	38.2	42.2
456	45.1	40.2	33.2	41.2	38.2	37.2	34.2	32.2	37.2
459	48.1	40.2	41.2	41.2	41.2	39.2	39.2	41.2	41.2
462	45.1	43.2	35.2	44.2	38.2	40.2	40.2	36.2	40.2
Average	<b>48.8</b>	43.4	41.6	45.0	45.1	43.6	40.9	40.3	41.4
<b>Overall Average</b>		<b>42.7</b>	Removed run 1 from calculation of overall average.						

**Table A7. Friction Numbers from SCRIM Tests on Pad 2 (30 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
387	43.1	42.2	44.3	45.3	42.1	47.3	45.3	42.1	46.3
390	47.1	46.3	44.3	44.3	48.1	41.2	43.3	46.3	44.3
394	53.1	51.3	49.3	48.3	49.1	49.3	48.3	45.3	47.1
397	44.1	43.3	50.3	45.3	45.1	49.3	48.3	44.1	44.3
400	45.1	44.3	42.2	42.2	44.1	43.3	48.4	42.2	43.3
403	42.1	42.2	45.3	40.2	43.3	44.3	47.4	38.2	40.2
407	50.1	45.3	47.3	48.3	46.3	47.3	48.3	43.3	50.3
410	50.1	50.3	47.3	47.3	48.1	48.3	49.3	46.3	45.3
413	48.1	44.3	44.3	47.3	46.1	44.3	48.3	43.3	45.1
417	48.1	47.3	44.3	43.3	48.1	45.3	47.3	46.3	44.3
420	50.1	46.3	49.3	49.3	53.1	43.3	47.3	51.3	49.3
423	54.1	50.3	50.3	51.3	53.1	52.3	57.5	54.3	51.3
426	50.1	51.3	52.3	51.3	47.1	49.3	47.3	47.3	50.3
430	50.1	49.3	47.3	49.3	52.3	48.3	61.4	51.3	50.3
Average	48.3	46.7	47.0	46.6	47.6	46.6	49.1	45.8	46.5
<b>Overall Average</b>		<b>47.1</b>							

**Table A8. Friction Numbers from SCRIM Tests on Pad 2A (50 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
417	11.0	16.0	3.0	17.0	17.0	14.0	5.0	12.0
420	28.0	26.0	26.0	24.0	16.0	23.0	21.0	15.0
423	25.0	19.0	20.0	19.0	19.0	17.0	18.0	17.0
426	31.1	23.0	10.0	22.1	9.0	21.0	10.0	13.0
430	21.0	21.0	17.0	19.0	12.0	16.0	11.0	10.0
433	12.0	15.0	17.0	14.0	17.0	16.0	15.0	14.0
436	18.0	14.0	15.0	14.0	14.0	10.0	14.0	11.0
440	29.0	18.0	17.0	19.0	15.0	20.0	14.0	14.0
443	27.0	26.0	18.0	24.0	17.0	20.0	17.0	16.0
446	28.0	17.0	16.0	18.0	19.0	15.0	15.0	17.0
449	28.0	20.0	23.0	16.0	16.0	16.0	18.0	15.0
453	18.0	15.0	7.0	22.0	10.0	16.0	7.0	11.0
456	12.0	15.0	24.0	13.0	12.0	8.0	13.0	13.0
459	22.0	20.0	21.0	19.0	16.0	15.0	16.0	13.0
462	21.0	19.0	16.0	18.0	18.0	20.0	17.0	20.0
466	17.0	18.0	11.0	27.0	16.0	16.0	13.0	16.0
469	36.1	27.0	26.0	25.0	21.0	22.0	19.0	18.0
472	38.1	27.0	24.0	30.0	25.0	24.0	26.0	25.0
476	34.1	27.0	28.0	24.0	22.0	22.0	20.0	21.0
479	44.1	32.0	30.0	29.0	24.0	24.0	25.0	22.0
482	42.1	33.0	29.0	33.1	34.1	31.1	28.0	25.0
485	26.0	26.0	24.0	23.0	23.0	24.0	20.0	24.0
489	27.0	28.0	28.0	17.0	15.0	19.0	22.0	20.0
Average	<b>25.9</b>	<b>21.8</b>	<b>19.6</b>	<b>21.2</b>	<b>17.7</b>	<b>18.7</b>	16.7	16.6
<b>Overall Average</b>	<b>16.7</b>		Removed runs 1 to 6 from calculation of overall average as excessive dust affected the friction measurements during the first passes made at 50 mph on skid pad. The friction stabilized after several passes cleared the dust.					



**Table A9. Friction Numbers from SCRIM Tests on Pad 2A (40 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
407	17.1	17.1	15.1	16.1	16.1	17.1	13.1	13.1
410	14.1	18.1	15.1	17.1	15.1	14.1	15.1	16.1
413	13.0	10.0	11.1	13.1	11.1	12.1	15.1	17.1
417	19.0	21.1	19.1	17.1	20.1	18.1	21.1	22.2
420	22.1	22.1	23.1	25.1	23.1	24.1	23.1	23.2
423	14.1	17.1	16.1	13.1	17.1	15.1	15.1	16.1
426	16.0	17.1	16.1	19.1	15.1	16.1	21.1	21.2
430	13.0	13.1	11.1	14.1	12.1	12.1	18.1	17.1
433	17.0	17.1	15.1	14.1	14.1	14.1	16.1	16.1
436	18.0	16.1	15.1	18.1	17.1	18.1	17.1	17.1
440	18.0	17.1	17.1	14.1	17.1	18.1	16.1	16.1
443	14.0	16.1	16.1	18.1	16.1	15.1	19.1	18.1
446	19.0	20.1	21.1	20.1	21.1	18.1	22.1	23.2
449	15.0	18.1	16.1	17.1	17.1	19.1	17.1	16.1
453	16.0	13.1	17.1	15.1	17.1	15.1	16.1	15.1
456	20.0	21.1	21.1	19.1	19.1	20.1	17.1	18.1
459	15.0	19.1	13.1	13.1	13.1	19.1	15.1	14.1
462	15.0	21.1	17.1	14.1	16.1	17.1	15.1	15.1
Average	16.4	17.5	16.4	16.5	16.5	16.8	17.4	17.5
<b>Overall Average</b>	<b>16.9</b>							

**Table A10. Friction Numbers from SCRIM Tests on Pad 2A (30 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
380	21.1	21.1	21.1	26.1	20.1	23.1	20.1	19.1
384	23.1	21.1	22.1	24.1	22.1	24.1	24.1	20.1
387	20.0	20.1	20.1	24.1	20.1	22.1	20.1	19.1
390	28.1	28.1	28.1	26.1	26.1	24.1	25.1	25.1
394	20.0	17.0	21.1	31.1	22.1	25.1	18.0	19.1
397	18.0	18.0	17.0	24.1	19.1	21.1	18.0	17.0
400	14.0	13.0	13.0	24.1	13.0	17.0	17.0	11.0
403	25.1	26.1	22.1	25.1	20.1	21.1	23.1	21.1
407	22.1	22.1	21.1	28.1	20.1	20.1	23.1	20.1
410	20.1	18.0	20.1	21.1	23.1	18.0	20.1	19.1
413	20.0	20.1	20.1	34.1	21.1	26.1	20.1	20.1
417	18.0	16.0	16.0	25.1	20.1	20.1	19.1	18.0
420	21.1	21.1	21.1	31.1	22.1	22.1	21.1	20.1
423	26.1	25.1	24.1	27.1	23.1	25.1	26.1	23.1
Average	21.2	20.5	20.5	<b>26.5</b>	20.8	22.1	21.1	19.4
<b>Overall Average</b>	<b>20.8</b>		Run 4 considered an outlier (not included in calculating the overall average).					

**Table A11. Friction Numbers from SCRIM Tests on Pad 5 (50 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
938	62.2	66.2	58.1	61.2	55.1	53.2	55.2	59.2
941	61.2	54.1	56.1	49.2	57.1	55.2	51.2	52.2
945	58.2	62.2	49.1	55.2	47.1	48.2	48.2	49.2
948	60.2	54.2	59.1	50.2	55.1	56.2	55.2	54.2
951	58.2	54.1	50.1	52.2	50.1	48.2	48.2	57.2
954	66.2	63.2	63.1	52.2	52.1	57.2	62.4	45.2
958	59.2	55.2	59.1	58.2	57.2	58.2	53.2	54.2
961	58.2	58.2	53.1	45.2	42.2	43.2	56.2	51.2
964	65.2	58.2	58.1	63.2	61.1	59.2	57.2	51.1
968	51.2	55.1	53.1	52.2	51.1	48.2	49.2	56.2
971	58.2	46.2	50.1	48.2	49.2	49.2	51.2	47.2
974	65.2	67.3	61.1	62.2	60.2	59.2	60.2	55.2
977	53.2	52.2	52.1	46.2	57.2	51.2	48.3	57.2
981	64.2	61.2	57.1	59.2	49.2	55.2	58.3	55.2
984	76.3	67.3	73.1	63.2	70.3	68.3	68.3	56.2
987	62.2	67.3	57.1	64.2	60.2	58.2	56.3	64.2
991	74.3	65.2	66.1	59.2	61.2	64.2	67.3	60.2
994	65.2	71.3	59.1	64.2	59.2	56.2	60.2	57.2
997	62.2	66.1	61.1	56.2	58.1	57.2	67.3	62.1
1,000	68.3	54.2	66.1	68.3	66.2	66.2	54.2	61.2
1,004	69.3	68.3	69.1	65.2	64.2	65.2	63.2	66.2
1,007	70.3	64.2	61.1	62.2	59.2	60.2	65.2	54.1
1,010	61.2	67.3	59.1	57.2	59.2	56.2	62.2	59.1
Average	<b>63.1</b>	<b>60.8</b>	<b>58.7</b>	<b>57.2</b>	<b>56.6</b>	56.3	57.3	55.9
<b>Overall Average</b>	<b>56.5</b>		Removed runs 1 to 5 from calculation of overall average as excessive dust affected the friction measurements during the first passes made at 50 mph on skid pad. The friction stabilized after several passes cleared the dust.					

**Table A12. Friction Numbers from SCRIM Tests on Pad 5 (40 mph).**

SCRIM Distance (ft.)	Run No.									
	1	2	3	4	5	6	7	8	9	
892	57.3	56.3	53.3	55.3	55.3	54.3	54.3	51.2	51.2	
895	59.1	50.2	53.3	50.2	55.3	53.3	58.3	54.3	56.3	
899	59.1	55.3	51.2	55.3	56.3	54.3	56.3	51.2	53.3	
902	60.1	55.3	58.3	53.3	59.3	55.3	55.3	54.3	53.3	
905	57.1	59.3	56.3	57.3	51.2	57.3	56.3	53.3	52.3	
909	61.1	53.3	55.3	53.3	57.3	52.3	57.3	55.3	55.3	
912	56.1	56.3	56.3	55.3	53.3	57.3	56.3	56.3	54.3	
915	60.1	52.3	54.3	51.2	54.3	50.2	54.3	50.2	53.3	
918	53.1	53.3	57.3	52.3	50.2	52.3	55.3	53.3	51.2	
922	62.1	52.3	54.3	48.2	52.3	49.2	55.3	48.2	55.3	
925	55.1	54.3	55.3	51.2	53.3	56.3	56.3	54.3	53.3	
928	55.1	56.3	51.2	48.2	54.3	51.2	54.3	49.2	48.2	
932	58.1	50.2	51.2	57.3	52.3	52.3	59.3	55.3	58.3	
935	57.1	52.3	54.3	53.3	48.2	50.2	58.3	50.2	56.3	
938	55.1	51.2	57.3	49.2	54.3	53.3	60.3	53.3	53.3	
941	48.1	50.2	53.3	50.2	45.2	48.2	54.3	46.2	47.2	
945	57.1	52.3	55.3	44.2	52.3	50.2	59.3	50.2	56.3	
948	51.1	53.3	51.2	53.3	48.2	52.3	56.3	49.2	53.3	
Average	<b>56.8</b>	53.5	54.4	52.1	52.9	52.8	<b>56.5</b>	52.0	53.4	
<b>Overall Average</b>	<b>53.0</b>		Runs 1 & 7 considered outliers (not included in calculating the overall average).							

**Table A13. Friction Numbers from SCRIM Tests on Pad 5 (30 mph).**

SCRIM Distance (ft.)	Run No.									
	1	2	3	4	5	6	7	8	9	10
876	55.2	53.0	53.1	55.2	49.1	51.0	46.1	51.1	53.0	54.1
879	50.1	59.2	54.1	55.2	57.2	55.2	58.2	56.2	55.2	59.2
882	56.2	53.1	52.1	56.2	48.1	50.1	47.1	52.1	50.1	53.1
886	49.1	53.1	49.1	51.1	51.1	53.1	50.1	47.1	53.1	52.1
889	55.2	55.2	52.1	56.2	50.1	48.1	49.1	54.1	55.2	55.2
892	54.1	52.1	52.1	56.2	53.1	54.1	52.1	49.1	53.1	56.2
895	52.1	55.2	52.1	54.1	50.1	48.1	48.1	54.1	51.1	55.2
899	54.1	55.2	53.1	58.2	56.2	56.2	53.1	53.1	56.2	57.2
902	58.2	58.2	56.2	53.1	53.1	53.1	54.1	56.2	56.2	60.2
905	51.1	49.1	50.1	53.1	50.1	53.1	52.1	48.1	53.1	54.1
909	54.1	53.1	50.1	51.1	51.1	53.1	50.1	52.1	54.1	57.2
912	57.2	54.1	55.2	55.2	52.1	55.2	51.1	52.1	57.2	57.2
915	50.1	52.1	49.1	53.1	53.1	53.1	52.1	52.1	53.1	54.1
918	54.1	49.1	52.1	54.1	47.1	53.1	47.1	48.1	55.2	55.2
Average	53.6	53.7	52.2	54.4	51.6	52.6	50.8	51.9	54.0	55.7
<b>Overall Average</b>	<b>53.1</b>									

**Table A14. Friction Numbers from SCRIM Tests on Pad 6 (50 mph).**

SCRIM Distance (ft.)	Run No.							
	1	2	3	4	5	6	7	8
1,486	55.1	48.1	50.1	53.1	51.1	49.1	46.1	49.1
1,489	55.1	57.1	55.1	53.1	48.1	50.1	56.1	56.1
1,492	62.1	53.1	54.1	54.1	53.1	52.1	54.1	52.1
1,496	51.1	56.1	53.1	53.1	46.1	48.1	53.1	58.1
1,499	59.1	48.1	58.1	49.1	55.1	56.1	53.1	47.1
1,502	54.1	58.1	54.1	58.1	54.1	50.1	53.1	61.1
1,506	59.1	51.1	57.1	46.1	55.1	54.1	51.1	46.1
1,509	60.1	60.1	54.1	57.1	53.1	53.1	56.1	57.1
1,512	61.1	58.1	68.1	53.1	62.1	63.1	60.1	54.1
1,515	58.1	54.1	50.1	53.1	50.1	47.1	49.1	60.1
1,519	61.1	59.1	58.1	50.1	52.1	52.1	57.1	51.1
1,522	61.1	54.1	54.1	57.1	53.1	53.1	53.1	57.1
1,525	58.1	59.1	60.1	51.1	48.1	51.1	57.1	48.1
1,528	57.1	53.1	55.1	58.1	58.1	55.1	51.1	54.1
1,532	55.1	59.1	52.1	52.1	48.1	50.1	58.1	53.1
1,535	60.1	50.1	55.1	52.1	54.1	53.1	52.1	49.1
1,538	51.1	56.1	52.1	52.1	47.1	47.1	52.1	54.1
1,542	62.1	53.1	55.1	52.1	59.1	56.1	57.1	52.1
1,545	55.1	57.1	52.1	55.1	50.1	49.1	53.1	54.1
1,548	62.1	55.1	59.1	50.1	55.1	57.1	57.1	51.1
1,551	57.1	55.1	52.1	55.1	52.1	49.1	49.1	55.1
1,555	57.1	53.1	59.1	45.1	50.1	51.1	54.1	47.1
Average	<b>57.8</b>	<b>54.9</b>	<b>55.4</b>	52.7	52.5	52.1	53.8	53.0
<b>Overall Average</b>	<b>52.8</b>		Removed runs 1 to 3 from calculation of overall average as excessive dust affected the friction measurements during the first passes made at 50 mph on skid pad. The friction stabilized after several passes cleared the dust.					

**Table A15. Friction Numbers from SCRIM Tests on Pad 6 (40 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
1,466	51.2	46.2	51.2	53.3	49.2	51.2	50.2	47.2	49.2
1,469	50.2	52.3	48.2	48.2	49.2	48.2	46.2	49.2	46.2
1,473	53.3	48.2	51.2	50.2	51.2	50.2	51.2	49.2	48.2
1,476	50.2	53.3	51.2	53.3	48.2	50.2	47.2	53.3	45.2
1,479	57.3	51.2	55.3	47.2	58.3	53.3	54.3	49.2	52.3
1,483	50.2	52.3	50.2	54.3	45.2	52.3	47.2	54.3	46.2
1,486	57.3	52.3	54.3	54.3	55.3	51.2	54.3	55.3	52.3
1,489	53.3	54.3	56.3	51.2	49.2	51.2	55.3	49.2	51.2
1,492	53.3	53.3	50.2	48.2	54.3	47.2	49.2	53.3	50.2
1,496	53.3	52.3	54.3	54.3	50.2	56.3	53.3	50.2	49.2
1,499	57.3	57.3	53.3	50.2	59.3	53.3	54.3	52.3	52.3
1,502	53.3	51.2	54.3	56.3	49.2	58.3	54.3	54.3	51.2
1,506	55.3	56.3	53.3	53.3	53.3	51.2	55.3	58.3	49.2
1,509	58.3	54.3	58.3	54.3	55.3	60.3	60.3	49.2	55.3
1,512	53.3	56.3	54.3	54.3	53.3	51.2	53.3	56.3	50.2
1,515	58.3	51.2	55.3	51.2	53.3	55.3	60.3	52.3	53.3
1,519	50.2	54.3	51.2	55.3	50.2	52.3	54.3	51.2	46.2
1,522	53.3	47.2	51.2	47.2	51.2	49.2	56.3	53.3	50.2
Average	53.8	52.4	53.0	52.0	52.0	52.4	53.1	52.1	49.9
<b>Overall Average</b>		<b>52.3</b>							

**Table A16. Friction Numbers from SCRIM Tests on Pad 6 (30 mph).**

SCRIM Distance (ft.)	Run No.									
	1	2	3	4	5	6	7	8	9	10
1,440	52.1	54.1	53.1	50.1	55.2	56.2	55.2	27.1	50.1	52.1
1,443	53.1	49.1	48.1	52.1	46.1	45.1	46.1	26.1	43.1	46.1
1,446	56.2	52.1	53.1	53.1	51.1	52.1	49.1	26.1	47.1	51.1
1,450	59.2	58.2	54.1	53.1	48.1	51.1	52.1	27.1	50.1	52.1
1,453	51.1	53.1	53.1	51.1	50.1	50.1	49.1	28.1	46.1	49.1
1,456	54.1	53.1	51.1	53.1	50.1	52.1	52.1	22.1	47.1	49.1
1,460	53.1	54.1	56.2	54.1	53.1	55.2	53.1	26.1	49.1	51.1
1,463	59.2	55.2	47.1	52.1	48.1	47.1	49.1	5.0	45.1	49.1
1,466	52.1	55.2	56.2	54.1	55.2	52.1	51.1	22.1	49.1	51.1
1,469	51.1	50.1	46.1	46.1	48.1	50.1	50.1	33.1	44.1	46.1
1,473	51.1	52.1	52.1	53.1	47.1	47.1	47.1	20.1	45.1	49.1
1,476	57.2	54.1	51.1	52.1	54.1	55.2	55.2	22.1	49.1	52.1
1,479	52.1	60.2	57.2	55.2	52.1	54.1	53.1	23.1	52.1	55.2
1,483	54.1	47.1	45.1	52.1	51.1	48.1	50.1	19.1	43.1	46.1
1,440	52.1	54.1	53.1	50.1	55.2	56.2	55.2	27.1	50.1	52.1
Average	54.0	53.4	51.7	52.3	50.7	51.1	50.9	<b>23.3</b>	<b>47.2</b>	50.0
<b>Overall Average</b>		<b>51.8</b>	Tire blew on run 8. Runs 8 & 9 removed from calc. of overall avg.							



**Table A17. Friction Numbers from SCRIM Tests on Pad 7 (50 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
1483	67.1	68.1	74.1	70.1	68.1	79.1	69.1	71.1	68.1
1486	77.1	81.1	77.1	76.1	73.1	76.1	69.1	70.1	72.1
1489	81.1	75.1	87.1	77.1	72.1	72.1	81.1	79.1	72.1
1492	78.1	77.1	76.1	76.1	79.1	81.1	70.1	70.1	75.1
1496	71.1	67.1	79.1	67.1	66.1	72.1	73.1	68.1	66.1
1499	76.1	78.1	75.1	73.0	74.1	75.1	68.1	73.1	72.1
1502	78.1	71.1	77.0	67.1	71.1	71.1	75.1	70.1	71.1
1506	71.1	71.1	78.1	71.1	75.1	80.1	71.1	77.1	78.1
1509	75.1	78.1	76.1	72.1	72.1	73.1	73.1	65.1	67.1
1512	74.1	70.1	83.1	77.1	72.1	78.1	75.1	75.1	74.1
1515	76.1	72.1	73.1	66.1	73.1	73.1	68.1	66.1	71.1
1519	66.1	64.1	79.1	72.1	65.1	71.1	71.1	71.1	69.1
1522	76.1	70.1	71.1	69.1	73.1	73.1	65.1	71.1	73.1
1525	71.1	69.1	79.1	72.1	67.1	72.1	73.1	71.1	67.1
1528	78.1	77.1	78.1	76.1	76.1	74.1	71.1	74.1	74.1
1532	75.1	68.1	77.1	67.1	71.1	74.1	74.1	73.1	72.1
1535	73.1	77.1	73.1	74.1	71.1	75.1	68.1	72.1	72.1
1538	75.1	69.1	79.1	66.1	67.1	66.1	73.1	66.1	64.1
1542	74.1	73.1	78.1	75.1	74.1	74.1	71.1	75.1	76.1
1545	75.1	73.1	71.1	67.1	71.1	71.1	73.1	67.1	70.1
1548	68.1	73.1	79.1	73.1	69.1	74.1	72.1	73.1	72.1
1551	74.1	74.1	74.1	69.1	69.1	72.1	70.1	68.1	70.1
1555	68.1	71.1	77.1	74.1	69.1	73.1	73.1	72.1	70.1
Average	<b>73.9</b>	<b>72.6</b>	<b>77.1</b>	71.7	71.3	<b>74.0</b>	71.7	71.3	71.2
<b>Overall Average</b>	<b>71.4</b>		Removed runs 1 to 3 from calculation of overall average as excessive dust affected the friction measurements during the first passes made at 50 mph on skid pad. The friction stabilized after several passes cleared the dust. In addition, run 6 considered an outlier (not included in calculating the overall average).						

**Table A18. Friction Numbers from SCRIM Tests on Pad 7 (40 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
1,460	75.4	74.4	71.3	79.4	72.4	75.4	70.3	74.4	71.3
1,463	74.4	73.4	75.4	77.4	77.4	71.3	76.4	74.4	76.4
1,466	73.4	72.4	68.3	76.4	68.3	73.4	70.3	72.4	67.3
1,469	69.3	71.3	74.4	76.4	75.4	69.3	74.4	75.4	75.4
1,473	75.4	74.4	72.4	80.4	73.4	77.4	74.4	69.3	72.4
1,476	73.4	72.4	75.4	74.4	74.4	70.3	73.4	76.4	73.4
1,479	75.4	79.4	75.4	80.4	73.4	75.4	77.4	74.4	73.4
1,483	79.4	75.4	77.4	76.4	77.4	76.4	73.4	76.4	76.4
1,486	72.4	77.4	76.4	82.4	73.4	72.4	78.4	73.4	72.4
1,489	72.4	72.4	70.3	72.4	70.3	72.4	67.3	69.3	70.3
1,492	71.3	75.4	74.4	78.4	75.4	70.3	75.4	78.4	75.4
1,496	77.4	75.4	75.4	76.4	74.4	77.4	74.4	72.4	73.4
1,499	72.4	73.4	77.4	74.4	77.4	73.4	77.4	75.4	77.4
1,502	78.4	80.4	75.4	81.4	73.4	77.4	75.4	72.4	72.4
1,506	74.4	72.4	76.4	72.4	73.4	71.3	74.4	73.4	72.4
1,509	74.4	75.4	71.3	77.4	66.3	73.4	71.3	66.3	66.3
1,512	73.4	73.4	77.4	76.4	73.4	71.3	73.4	73.4	73.4
1,515	76.4	76.4	74.4	78.4	69.3	75.4	73.4	70.3	68.3
1,519	74.4	72.4	75.4	74.4	76.4	74.4	73.4	74.4	76.4
Average	74.4	74.6	74.4	77.1	73.4	73.6	73.9	73.3	72.8
<b>Overall Average</b>	<b>73.8</b>		Run 4 considered an outlier (not included in calculating overall average).						

**Table A19. Friction Numbers from SCRIM Tests on Pad 7 (30 mph).**

SCRIM Distance (ft.)	Run No.								
	1	2	3	4	5	6	7	8	9
1,440	72.4	72.4	72.4	74.4	75.4	70.4	70.4	71.4	73.4
1,443	75.4	75.4	75.4	82.5	72.4	76.5	79.5	75.4	74.4
1,446	80.5	78.5	76.5	77.5	81.5	77.5	73.4	77.5	77.5
1,450	73.4	73.4	75.4	79.5	74.4	77.5	78.5	75.4	75.4
1,453	83.5	83.5	80.5	76.5	81.5	77.5	77.5	80.5	78.5
1,456	70.4	70.4	73.4	78.5	75.4	78.5	76.5	71.4	75.4
1,460	78.5	76.5	75.4	74.4	77.5	75.4	76.5	77.5	73.4
1,463	72.4	72.4	74.4	81.5	75.4	70.4	71.4	74.4	77.5
1,466	76.5	74.4	71.4	73.4	76.5	79.5	76.5	73.4	70.4
1,469	72.4	71.4	73.4	76.5	72.4	68.4	72.4	71.4	72.4
1,473	78.5	78.5	75.4	78.5	75.4	76.5	78.5	76.5	71.4
1,476	75.4	75.4	76.5	80.5	77.5	75.4	76.5	73.4	77.5
1,479	76.5	75.4	74.4	79.5	74.4	74.4	75.4	73.4	73.4
1,483	76.5	76.5	74.4	77.5	78.5	75.4	74.4	75.4	74.4
Average	75.9	75.3	74.9	77.9	76.3	75.2	75.5	74.8	74.7
<b>Overall Average</b>	<b>75.6</b>								

**Table A20. CTM Measurements on Skid Pads.**

Skid Pad	Station ID	Distance (ft.)	Mean Profile Depth (mm)		
			Run 1	Run 2	Run 3
1	A	148	0.65	0.64	0.63
	B	162	0.62	0.62	0.70
	C	178	0.68	0.61	0.63
	D	196	0.70	0.58	0.61
	E	216	0.71	0.71	0.61
	F	230	0.80	0.78	0.77
	G	244	0.57	0.56	0.56
2	A	230	0.96	1.35	1.02
	B	245	1.59	1.78	1.11
	C	260	1.62	1.45	1.47
	D	275	1.36	1.31	1.35
	E	295	1.29	1.39	1.35
	F	310	1.54	1.01	1.76
	G	325	1.05	1.28	0.81
	H	335	1.32	1.11	1.40
2A	A	230	0.88	0.73	0.87
	B	244	0.90	0.87	0.88
	C	258	0.71	0.80	0.75
	D	278	0.94	1.00	0.93
	E	298	0.83	0.83	0.59
	F	310	1.13	0.86	0.96
	G	320	0.59	0.84	0.77
5	A	115	2.37	2.39	2.28
	B	130	2.06	2.41	2.46
	C	145	2.49	2.36	2.37
	D	160	2.32	2.66	2.41
	E	180	2.93	2.63	2.50
	F	195	3.32	3.35	2.83
	G	210	3.05	2.87	3.05
	H	225	2.33	2.75	2.43
	I	240	2.42	2.47	2.43
6	A	80	2.07	1.86	1.84
	B	96	1.65	1.82	2.24
	C	112	1.99	1.70	2.03
	D	128	1.72	1.66	1.80
	E	144	2.75	2.62	2.69
	F	158	1.54	1.76	1.55
	G	174	1.90	1.85	1.86
	H	190	1.88	1.63	1.61

**Table A20. CTM Measurements on Skid Pads (continued).**

Skid Pad	Station ID	Distance (ft.)	Mean Profile Depth (mm)		
			Run 1	Run 2	Run 3
7	A	80	1.37	1.40	1.40
	B	95	1.42	1.47	1.33
	C	110	1.34	1.18	1.32
	D	125	1.48	1.32	1.74
	E	140	1.38	1.47	1.22
	F	150	1.40	1.37	1.57
	G	170	1.45	1.58	1.29
	H	190	1.40	1.76	1.53

**Table A21. DFT Measurements on Skid Pads.**

Skid Pad	Station ID	Distance (ft.)	Speed (kph)			
			20	48	64	80
1	A	148	0.38	0.41	0.44	0.10
	B	162	0.36	0.39	0.42	0.12
	C	178	0.34	0.37	0.40	0.10
	D	196	0.37	0.40	0.43	0.11
	E	216	0.35	0.38	0.41	0.09
	F	230	0.34	0.38	0.41	0.07
	G	244	0.28	0.32	0.34	0.05
2	A	230	0.31	0.31	0.31	0.09
	B	245	0.32	0.27	0.28	0.09
	C	260	0.32	0.29	0.31	0.11
	D	275	0.35	0.29	0.29	0.12
	E	295	0.33	0.29	0.30	0.12
	F	310	0.29	0.24	0.24	0.07
	G	325	0.31	0.25	0.27	0.10
	H	335	0.35	0.29	0.30	0.11
2A	A	230	0.19	0.14	0.14	0.05
	B	244	0.19	0.12	0.12	0.08
	C	258	0.21	0.15	0.15	0.06
	D	278	0.24	0.16	0.16	0.09
	E	298	0.20	0.14	0.14	0.07
	F	310	0.24	0.20	0.22	0.08
	G	320	0.24	0.18	0.18	0.11
5	A	115	0.34	0.39	0.45	0.14
	B	130	0.35	0.41	0.42	0.09
	C	145	0.37	0.43	0.48	0.09
	D	160	0.35	0.44	0.46	0.11
	E	180	0.38	0.47	0.50	0.19
	F	195	0.41	0.48	0.51	0.17
	G	210	0.40	0.54	0.50	0.19
	H	225	0.37	0.59	0.54	0.15
	I	240	0.29	0.45	0.37	0.18

**Table A21. DFT Measurements on Skid Pads (continued).**

Skid Pad	Station ID	Distance (ft.)	Speed (kph)			
			20	48	64	80
6	A	80	0.32	0.36	0.38	0.11
	B	96	0.33	0.38	0.40	0.11
	C	112	0.36	0.37	0.43	0.09
	D	128	0.35	0.38	0.41	0.12
	E	144	0.40	0.57	0.51	0.09
	F	158	0.37	0.43	0.42	0.13
	G	174	0.35	0.40	0.49	0.16
	H	190	0.36	0.39	0.38	0.11
7	A	80	0.68	0.64	0.60	0.09
	B	95	0.69	0.60	0.62	0.08
	C	110	0.76	0.69	0.68	0.11
	D	125	0.77	0.68	0.69	0.10
	E	140	0.75	0.69	0.69	0.08
	F	150	0.77	0.70	0.67	0.11
	G	170	0.72	0.66	0.68	0.09
	H	190	0.72	0.66	0.68	0.11