Louisiana Transportation Research Center

Final Report 587

Evaluation of MIT-SCAN-T2 for Thickness Quality Control for PCC and HMA Pavements

by

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16. Abstract

Thickness is currently a pay item for PCC pavements and a quality control item for both PCC and HMA pavements. A change in pavement thickness of 0.5 in. can result in a change of multiple years of service. Current thickness measurements are performed by destructively coring the finished pavement and measuring the thickness of the core. Many times this is performed at the end of the project construction and only five representative samples are collected for each lot. Devices such as the MIT-SCAN-T2 are excellent examples of non-destructive technology capable of accurately measuring the pavement thickness.

The objective was to evaluate the MIT-SCAN-T2 as a non-destructive pavement thickness measuring device for quality control and quality assurance purposes. A ruggedness study was performed in the laboratory to determine factors of influence on thickness measurements. Field evaluations were performed to test the device in actual production conditions.

The ruggedness test showed the presence of steel-toe boot, surface area, plate manufacturer, and depth as potentially significant factors. However, the influence of these factors on the measured depth was large, causing significant errors in the depth readings. An additional factorial was performed with a control sample and additional runs, varying only one factor at a time. The readings obtained with this factorial were significantly more accurate, with an error of 0.2 in. for the control sample. These results show that the device is capable of accurately measuring thickness if used within the parameters recommended by the manufacturer.

The field results support the finding of the ruggedness study. If all of the negative influencing factors are controlled the MIT-SCAN-T2 can accurately measure the in-place depth of pavement. If any of these factors are present, then results can be skewed heavily.

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ACKNOWLEDGMENTS

The U.S. Department of Transportation, Federal Highway Administration (FHWA), Louisiana Department of Transportation and Development (DOTD), and Louisiana Transportation Research Center (LTRC) financially supported this research project. The efforts of Greg Tullier, Norris Rosser, Leon Goudeau, Ryan White, and Austin Gueho in the concrete laboratory are greatly appreciated. The efforts of the Project Preview Committee are also appreciated.

IMPLEMENTATION STATEMENT

The authors recommend that the Department consider implementing the MIT-SCAN-T2 when the number of projects being constructed as full-depth replacements warrants the cost. Implementation would be one to two machines purchased and then loaned from the Materials Lab when conducting thickness verifications on specific projects.

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INTRODUCTION

Thickness is currently a pay item for PCC pavements and a quality control item for both PCC and HMA pavements. A change in pavement thickness of 0.5 in. can result in a change of multiple years of service. Current thickness measurements are performed by destructively coring the finished pavement and measuring the thickness of the core. Many times this is performed at the end of the project construction and only five representative samples are collected for each lot. Today, multiple non-destructive pavement evaluation tools are available and the accuracy of such devices has significantly increased in recent years. Non-destructive thickness measurements will allow the Department a more efficient and effective method of maintaining pavement quality without damaging the pavement.

Literature Review

The MIT-SCAN-T2 is based on magnetic imaging tomography. The device uses magnetic fields to induce eddy currents in a high strength steel reflective target, 11.8 in. diameter and 0.03 in. thick, placed at the base of the pavement layer. Most PCC and HMA pavements are have no effect on magnetic fields, thus the device is medium independent [*1*]. The MIT-SCAN-T2 is noted as quick, easy-to-use, and non-destructive. One measurement takes about five minutes and the device can measure thicknesses up to 20 in. with a resolution of 0.04 in. [*2*]. The device can be used on wet or dry concrete as soon as the concrete is able to be walked on. One limitation of the device is the presence of metallic or magnetic objects in close proximity; dowel bars, guardrails, and parked vehicles within 3 to 8 ft. have shown to impact the device readings [*1, 2*]. The manufacturer of the MIT-SCAN-T2 and many sources agree that the accuracy of the device is 0.5% + 0.04 in. or roughly 0.1 in. for 12 in. thickness [*1-5*].

Yu showed the MIT-SCAN-T2 correlates very well (R2 = 0.9998) on a one-to-one scale with a step-frequency GPR and stated the application is well suited for production work and ready for pilot implementation for surface layer thickness [*3*]. CalTrans recommended MIT-SCAN-T2 for its ease of use and no calibration [*4*]. Wisconsin DOT ran a comparative study showing the MIT-SCAN-T2 and probing were acceptable quality tool that were more effective and efficient than coring [*5*]. Iowa DOT performed a comparative study on locally fabricated targets. The results of the study showed square targets of equal surface area to the circular manufacturer supplied targets resulted in minor changes in thickness readings, 1 to 2 mm. The device can be calibrated to account for the difference [*1*]. Iowa DOT and MnDOT have included MIT-SCAN-T2 in project proposals [*6, 7*].

OBJECTIVE

The objective of this research was to evaluate the MIT-SCAN-T2 as a non-destructive pavement thickness measuring device for quality control and quality assurance purposes. A ruggedness study was performed in the laboratory to determine factors of influence on thickness measurements. Field evaluations were performed to test the device in actual production conditions.

SCOPE

To meet the objectives of this project, a ruggedness study was completed. Factors considered included: measurement depth, plate size, geometry, orientation, skew, steel-toe boot influence, and plate manufacturer. Three field sites were used with varying thicknesses to validate the technology. The first site was a roller compacted concrete test section built at the Accelerated Pavement Testing Facility in Port Allen, LA, with thicknesses ranging from 4 to 8 in. The second site was a project located on I-49 north of Shreveport, LA, with a pavement thickness of about 11 in., and a third project was constructed at LTRC with thicknesses ranging from 8 in. to almost 13 in.

METHODOLOGY

Test Methods

MIT-SCAN-T2 Test Method

The MIT-SCAN-T2 test is conducted using stainless steel reflectors that secured to the base and then paved over. Ensure that reflector placement will not be near any metallic objects such as buried conduit or dowel bars. The two reflector shapes and two sizes are shown in Figure 1. Note the smaller reflectors are used for thicknesses up to 6 in. while the large reflectors can be used for pavement thicknesses up to 18 in.

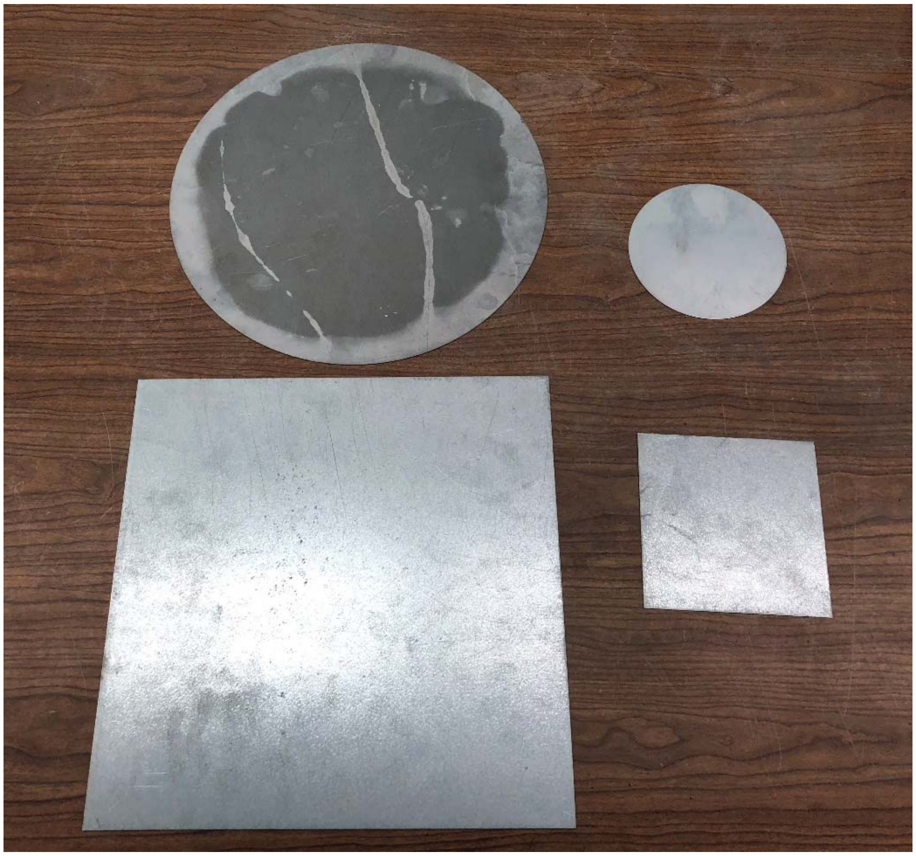

Figure 1
MIT-SCAN-T2 reflectors

Once the MIT-SCAN-T2 has been turned on and warmed up according to the manufacturer's recommendations, the operator inputs the correct calibration file to be used and uses the search function to locate disks. Once located, place the MIT-SCAN-T2, shown in Figure 2, approximately 12 in. away from the edge of the disk and move the device forward while pressing the "Measure" button. Ensure that the movement is at a steady and slow pace for a distance of about 5 ft. or until the device makes and audible “beep” sound indicating that the measurement is complete. Save the data to memory and a verification measurement is recommended to be taken. Before proceeding to the next disk, press the “Increment” key to record the location (i.e., station number, log mile, etc.). Turn off the machine after all measurements have been collected. Note that all data is transferrable to a personal computer using the supplied software.

Figure 2
MIT-SCAN-T2 device

Ruggedness Study Method

The factors included in the ruggedness study are shown in Table 1. The targets were placed to simulate two measurement depths, 8.5 and 12.5 in. Two sizes (small, large) and two shapes (square, circle) of targets were used. The factorial included targets procured from the manufacturer as well as from the DOTD sign shop. For the square targets, some were placed in-line with the direction of travel of the device (+ level), while others were placed diagonally in the path of travel (- level). The influence of skew was investigated by raising one of the edges of the targets. Finally, for some of the runs, a steel-toe boot was placed close to the travel path of the device. A partial factorial with foldover was setup using the Plackett-Burman design described in ASTM E1169 [*8*].

Figure 3
Example of a skewed reflector

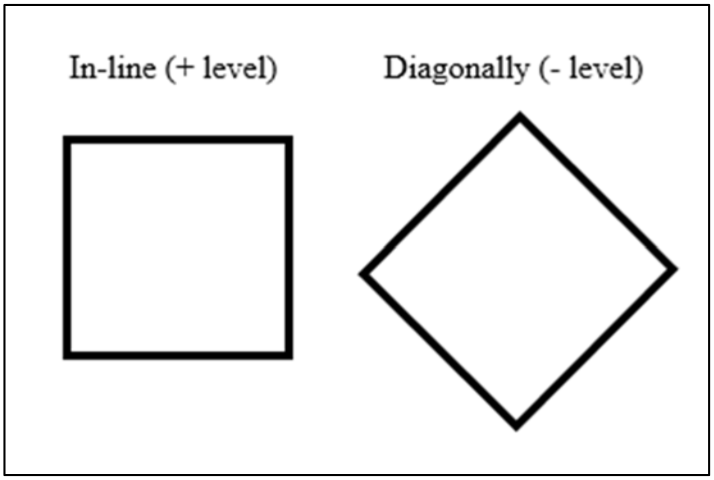

Figure 4
Positioning of square reflectors

Table 1
Factors included in the ruggedness study

Factor	Variable	Discussion	Level 1 (-)	Level 2 (+)
A	Depth	Depth of measurement	8.5”	12.5”
B	Surface area	Size of the target plate	Small	Large
C	Dimension	Shape of the target plate	Square	Circle
D	Source	Manufacturer-supplied or fabricated in the DOTD sign shop	Sign shop	Manufacturer
E	Orientation	Placement diagonal or perpendicular to the direction of travel (applies to square plate only)	Diagonal	Perpendicular
F	Skew	Skew introduced by raising one edge of plate	Skew	Flat
G	Steel-toe boot	Influence of the presence of a steel-toe boot	Yes	No

Analysis Techniques

ASTM E1169 was used to analyze the data for the ruggedness study [*8*]. Student t-tests were performed on the additional factorial to compare the effects of changing one of the factor levels against a control. The ruggedness factorial included 16 combinations of factors and the extra factorial included 8 additional combinations for a total of 24 unique combinations of factors, shown in Table 2. The average result of three specimens was considered a sample.

Table 2
Ruggedness factorial combinations

	Depth	Area	Dimen.	Source	Orient.	Skew	Steel-toe
R1	1	1	1	-1	1	-1	-1
R2	-1	1	1	1	-1	1	-1
R3	-1	-1	1	1	1	-1	1
R4	1	-1	-1	1	1	1	-1
R5	-1	1	-1	-1	1	1	1
R6	1	-1	1	-1	-1	1	1
R7	1	1	-1	1	-1	-1	1
R8	-1	-1	-1	-1	-1	-1	-1
F1	-1	-1	-1	1	-1	1	1
F2	1	-1	-1	-1	1	-1	1
F3	1	1	-1	-1	-1	1	-1
F4	-1	1	1	-1	-1	-1	1
F5	1	-1	1	1	-1	-1	-1
F6	-1	1	-1	1	1	-1	-1
F7	-1	-1	1	-1	1	1	-1
F8	1	1	1	1	1	1	1
X1	1	1	1	1	1	1	1
X2	-1	1	1	1	1	1	1
X3	1	-1	1	1	1	1	1
X4	1	1	-1	1	1	1	1
X5	1	1	1	-1	1	1	1
X6	1	1	1	1	-1	1	1
X7	1	1	1	1	1	-1	1
X8	1	1	1	1	1	1	-1

R = Ruggedness factorial, F = Foldover, X = Additional factorial, -1 = Level 1 factor, 1 = Level 2 factor

DISCUSSION OF RESULTS

This section is divided into the results of the ruggedness study and the field thickness comparisons.

Ruggedness Study

Table 3 shows the average test result for each combination of the ruggedness and foldover factorial. The analysis procedure from ASTM E1169 computes the main effect values for each factor as well as estimated effects of interactions [*8*]. The main effects are ordered by absolute value and plotted as a half-normal plot; see Figure 5.

A line is drawn through the smaller effect estimates, which appear to lie approximately in a straight line. The line represents the standard error for the main effects and interaction estimates. Values falling furthest to the right of the line are potentially significant effects. As shown in Figure 5, the ruggedness test shows the presence of a steel-toe boot, surface area, plate manufacturer, and depth as potentially significant factors. The suffix –I, added to a factor label, indicates the interactions confounded with the factor. The determination of measurement depth as an influencing factor was expected as the device is being used to measure the depth. The influence of these factors was large enough to cause significant errors in the depth reading.

The additional factorial shown in Table 4 represents a control sample using all factors at level 2 (+) and varying only one factor at a time to level 1 (-). The readings obtained were significantly more accurate, with an error of 0.2 in. for the control sample.
For the additional factorial, student t-tests ($\alpha = 0.05$) were also performed between the control sample and each additional run. The results showed that all the additional runs except one with the orientation factor were significantly different from the control. The readings obtained for the perpendicular and diagonal orientations were identical.

The results showed four major interactions including: plate surface area (B-I), plate dimension (C-I), late orientation (E-I), and plate skew (F-I). Note that dimension and orientation will not be an issue since the Department will only implement manufacturer recommended circular plates if implementation is desired.

These results show that the device is capable of accurately measuring thickness if used within the parameters recommended by the manufacturer.

Table 3
Ruggedness factorial and foldover average test results

ID	Depth (in.)	ID	Depth (in.)
R1	10.5	F1	13.6
R2	8.6	F2	18.0
R3	14.6	F3	10.5
R4	7.3	F4	8.0
R5	8.1	F5	6.8
R6	20.0	F6	7.2
R7	18.8	F7	9.7
R8	12.2	F8	12.3

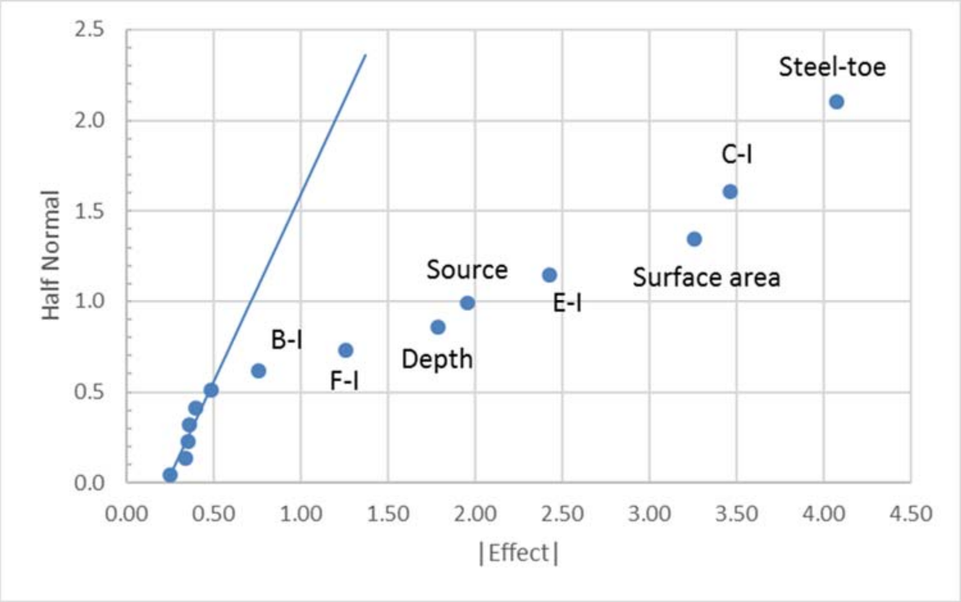

Figure 5
Half-normal plot

Table 4
Additional factorial data (averages)

ID	Factor	Measured depth (inch)	Error (inch)
X1	Control	12.3	-0.2
X2	Depth	8.6	0.1
X3	Area	17.3	4.8
X4	Dimension	11.3	-1.2
X5	Source	12.0	-0.5
X6	Orientation	12.3	-0.2
X7	Skew	11.7	-0.8
X8	Steel-toe	9.3	-3.2

Field Thickness Comparisons

Accelerated Loading Facility Roller Compacted Concrete

The first site used to field test the MIT-SCAN-T2 was the Accelerated Pavement Testing Facility in Port Allen, LA. During the placement of a test section of roller compacted concrete (RCC) a total of 18 manufacturer plates were placed along the section. The test section design included a 4 in., 6 in., and 8 in. thick RCC. The manufacturers small round plates were used on the 4 in. and one area of the 6 in. design while the manufacturers large round plates were used for one area of the 6 in. and the 8 in. RCC. Cores were taken on a randomly selected number of placements and then measured, the results of the readings and core measurements can be seen in Table 5 and Table 6.

Table 5
RCC large plate diameter data

	Location				Average
Readings (in.)	**1**	7.0	7.0	7.0	7.0
Core (in.)		6.83	6.79	6.79	6.8
		Difference (in.)			0.2
		Error (%)			2.8
Readings (in.)	**2**	8.6	8.6	8.6	8.6
Core (in.)		8.43	8.29	8.27	8.3
		Difference (in.)			0.3
		Error (%)			3.1
Readings (in.)	**3**	9.8	9.8	9.8	9.8
Core (in.)		9.56	9.68	9.67	9.6
		Difference (in.)			0.2
		Error (%)			1.7
Readings (in.)	**4**	6.5	6.5	6.5	6.5
Core (in.)		6.36	6.42	6.29	6.4
		Difference (in.)			0.1
		Error (%)			2.2
Readings (in.)	**5**	6.3	6.3	6.3	6.3
Core (in.)		6.05	6.08	6.02	6.1
		Difference (in.)			0.3
		Error (%)			4.0

The results show that the MIT-SCAN-T2 performs much better when using the manufacturers large plates. The average percentage error for the group using the small plates is 9.4 percent while the group using the large plates only averages 2.8 percent.

Table 6
RCC small diameter plate data

	Location				Average
Readings (in.)	**1**	5.2	5.2	5.2	5.2
Core (in.)		4.54	4.71	4.68	4.6
		Difference (in.)			0.6
		Error (%)			10.7
Readings (in.)	**2**	5.7	5.6	5.6	5.6
Core (in.)		5.12	5.01	5.09	5.1
		Difference (in.)			0.6
		Error (%)			9.9
Readings (in.)	**3**	4.5	4.6	4.5	4.5
Core (in.)		4.12	4.02	4.19	4.1
		Difference (in.)			0.4
		Error (%)			9.3
Readings (in.)	**4**	5.3	5.4	5.3	5.3
Core (in.)		4.83	5.04	4.90	4.9
		Difference (in.)			0.4
		Error (%)			7.7

I -49 Concrete Pavement

A section of I-49 in north Louisiana was used as a field test site for the MIT-SCAN-T2 device. The pavement design is 11-in jointed plane concrete placed by a slipform concrete paver. Six of the manufacturers large round plates were secured in two transverse rows to the roadway base, seen in Figure 6. Station numbers indicate the two nearest marked stations on the roadway and the numbered plates indicate the randomly selected coring locations, as it would be done under actual field implementation. The three randomly selected locations were measured with the device cored for comparison measurements, these results can be seen in Table 7.

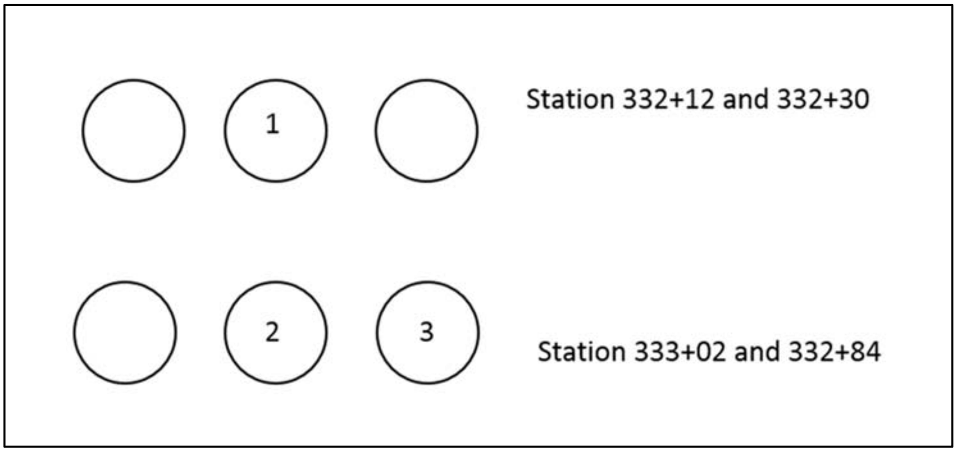

Figure 6
I-49 plate layout

Table 7
I-49 testing data

I-49	1	2	3
Readings (in.)	11.2	11.3	11.2
Core measurements (in.)	11.20	11.21	11.23
	11.18	11.27	11.23
	11.24	11.20	11.17
Core Average (in.)	11.2	11.2	11.2
Error (%)	0.0	0.7	0.1

The MIT-SCAN-T2 performed very well in this set of tests. The error for the three test results is almost negligible. The very low percentage of error can be contributed to the flatness of the road base and finished concrete surface.

LTRC Field Placement

A third field test was done at LTRC. A slab was constructed with three lanes that measures 4 ft. by 10.5 ft. The three lanes were 8 in., 10 in., and 12 in. cast-in-place portland cement concrete. In each lane, three manufacturers round plates were placed 2 ft. apart from one another, shown in Figure 7. The nine plates were measured with the MIT-SCAN-T2 and then cored to check the measurements, this data can be seen in Table 8 to Table 10.

Figure 7
Plate layout for LTRC slab

Table 8
Results for LTRC 12-in. lane

	Mit-Scan (in.)	**Core Average (in.)**		
1	13.4	12.8	**Difference (in.)**	**Error (%)**
	13.3			
	13.3			
Avg.	13.3		0.5	3.9
2	13.4	12.9	**Difference (in.)**	**Error (%)**
	13.3			
	13.3			
Avg.	13.3		0.4	3.1
3	12.8	12.3	**Difference (in.)**	**Error (%)**
	12.8			
	12.7			
Avg.	12.8		0.5	4.0

Table 9
Results for LTRC 10-in. lane

	Mit-Scan (in.)	Core Average (in.)		
1	10.8	10.5	**Difference (in.)**	**Error (%)**
	10.8			
	10.8			
Avg.	10.8		0.3	2.9
2	11.0	10.7	**Difference (in.)**	**Error (%)**
	11.1			
	11.1			
Avg.	11.1		0.4	3.7
3	10.8	10.4	**Difference (in.)**	**Error (%)**
	10.8			
	10.8			
Avg.	10.8		0.4	3.8

Table 10
Results for LTRC 8-in. lane

	Mit-Scan (in.)	Core Average (in.)		
1	8.1	8.1	**Difference (in.)**	**Error (%)**
	8.1			
	8.0			
Avg.	8.1		0.0	0.0
2	8.5	8.5	**Difference (in.)**	**Error (%)**
	8.6			
	8.6			
Avg.	8.6		0.1	1.2
3	8.3	7.9	**Difference (in.)**	**Error (%)**
	8.3			
	8.3			
Avg.	8.3		0.4	5.1

For the field trial, the error increased as the thickness of the slab increased. Some of the error in this trail can be attributed to localized unevenness of the base causing skew and localized unevenness on the finished concrete surface.

CONCLUSIONS

The results of this study warrant the following conclusions. The ruggedness test showed the presence of steel-toe boot, surface area, plate manufacturer, and depth as potentially significant factors. However, the influence of these factors on the measured depth was large, causing significant errors in the depth readings. An additional factorial was performed with a control sample and additional runs, varying only one factor at a time. The readings obtained with this factorial were significantly more accurate, with an error of 0.2 in. for the control sample. These results show that the device is capable of accurately measuring thickness if used within the parameters recommended by the manufacturer.

The field results support the finding of the ruggedness study. If all of the negative influencing factors are controlled the MIT-SCAN-T2 can accurately measure the in place depth of pavement. If any of these factors are present, then results can be skewed heavily.

RECOMMENDATIONS

The authors recommend that the Department consider implementing the MIT-SCAN-T2 when the number of projects being constructed as full-depth replacements warrants the cost. Implementation would be one to two machines purchased and then loaned from the Materials Lab when conducting thickness verifications on specific projects.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ASTM	American Society of Testing and Materials
DOTD	Louisiana Department of Transportation and Development
FHWA	Federal Highway Administration
ft.	feet
in.	inch(es)
LTRC	Louisiana Transportation Research Center

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