New Mexico Department of Transportation

Research Bureau

Innovation in Transportation

Alternatives to Nuclear Densometer

Prepared by:
New Mexico Department of Transportation
State Materials Bureau
Santa Fe, NM

June 2013

Prepared for:
New Mexico
Department of Transportation
Research Bureau

In Cooperation with:
The US Department
of Transportation
Federal Highway Administration

Final Report NM11TT-02

JUNE 2013

USDOT FHWA SUMMARY PAGE

1. Report No. NM11TT-02	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Alternatives to Nuclear Densometer		5. Report Data 6. Performing Organization Code
7. Author(s): Bryce Simons, Project Advocate		8. Performing Organization Report No.
7. Performing Organization Name and Address New Mexico Department of Transportation State Materials Bureau Santa Fe, NM 87504		
12. Sponsoring Agency Name and Address NMDOT Research Bureau 7500B Pan American Freeway PO Box 94690 Albuquerque, NM 87199-4690		13. Type of Report and Period Covered Final Report: October 28, 2010 – June 30, 2013 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Non-nuclear Densometers are being considered to replace the nuclear Densometer to reduce the extreme cost of manpower, transportation, training, security and documentation to use and maintain them. This project seeks to find alternate technologies that could be used to provide an equal or better degree of reliability in determining the in-place density of unbound and bound materials. Ideally, this technology would be safe to use around other people, user-friendly for technicians to operate and sufficiently reliable that it could effectively be used to determine pay factors for large amounts of money, and if necessary, be credible enough for use in legal situations.

17. Key Words Non-nuclear densometer; PQI 380, SDG 200;	18. Distribution Statement Available from NMDOT Research Bureau

19.Security Classification Unclassified	20.Security Classification Unclassified	21. No. of pages 20	22. Price

Form DOT F 1700.7 (8-72)

THIS PAGE LEFT BLANK INTENTIONALLY

PROJECT NO. NM11TT-02

ALTERNATIVES TO NUCLEAR DENSOMETER

Final Report
October 28, 2010 – June 30, 2013

A Report on Research Sponsored by:

Research Bureau
New Mexico Department of Transportation
7500B Pan American Freeway NE
PO Box 94690
Albuquerque, NM 887199-4690
(505) 798-6730
Research.bureau@state.nm.us
http://NMDOTResearch.com

Prepared by:

Bryce Simons, P.E.
Materials Testing Engineer

New Mexico Department of Transportation
State Materials Bureau
PO Box 1149
Santa Fe, NM 87504

PREFACE

The objective of this research project is to investigate the feasibility and limitations of Non-Nuclear Densometers for replacing the current Nuclear Densometer in highway applications. A comprehensive literature and historical application review was completed to determine the characteristics and properties of Non-Nuclear Denometers currently being marketed.

NOTICE

The United States government and the State of New Mexico do not endorse products or manufacturers. Trade or manufactures' names appear herein solely because they are considered essential to the object of this report. This information is available in alternative accessible formats. To obtain an alternative format, contact the NMDOT Research Bureau, 7500B Pan American Freeway NE, PO Box 94690, Albuquerque, NM 87199-4690, (505) 798-6730.

DISCLAIMER

This report presents the results of research conducted by the authors and does not necessarily represent the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.

ABSTRACT

A comprehensive search of the state-of-the-art for measuring in-place density of bound and unbound materials showed that only one manufacturer appeared to have equipment that could be used in place of the Nuclear Densometers currently being used. The equipment tested consisted of the Pavement Quality Indicator 380 for Hot Mixed Asphalt and the Soil Density Gage 200 for unbound soils and base course materials. This equipment was purchased from TransTech Systems, Inc.

A comprehensive test program was set up to evaluate how this equipment works on actual projects and actual materials located throughout New Mexico. The results from the Soil Density Gage 200 indicated that it is extremely unreliable and inconsistent. Additionally it was found to be very difficult to use and to read the screen under natural daylight conditions. The Pavement Quality Indicator was more consistent, but also the screen was equally difficult to see under normal daylight conditions.

However, neither of these technologies allowed the elimination of the current Nuclear Densometer in use by the department. It is still necessary to utilize the Nuclear Densometer on a daily basis along with the both the Pavement Quality Indicator 380 and the Soil Density Gage 200 density gage in order to determine a daily correction factor by which the remaining results from the days measurements could be determined.

Due to the extreme lack of reliability of the Soil Density Gage and the inability to replace the Nuclear Densometer with either of these technologies, it was the unanimous conclusion of the Technical Panel that at this time as this technology is not appropriate for use in any application that involves project or material acceptance or the determination of pay factors.

ACKNOWLEDGEMENTS

The author would like to thank the Technical Panel: Cliff Lucas, Ken Murphy, Jessica Sena, Joe DeHerrera, Brian Legan, Robert McCoy and FHWA members Frank Lozano, Steve Von Stein and Monica Jurado for their guidance and support throughout the project.

This project also recognizes the efforts of Jennifer Crooker, Joseph Leger, Lawrence Lujan, Jeremiah Herrera, Jeremy Madrid, Derek Martinez (AMEC), William Fulkrod, Ray Polanco, and Dee Billingsley – research project manager.

TABLE OF CONTENTS

TABLES

Acronyms

AASHTO – American Association of Highway Transportation Officials
ASTM – American Society for Testing and Materials
FHWA – Federal Highway Administration
ND – Nuclear Densometer
NMDOT – New Mexico Department of Transportation
PQI – Pavement Quality Indicator
SDG – Soil Density Gage
TTCP – Technician Training Certification Program

THIS PAGE LEFT BLANK INTENTIONALLY

1 INTRODUCTION

This report describes an evaluation of the evolving state-of-the-art for measurement of in-place density of bound and unbound materials. Currently, the only acceptable methods of measuring the in-place density of these materials is to use relatively labor intensive methods such as the Sand Cone Method or the Balloon Method or the more automated method using Nuclear Densometers (ND). The current specifications in New Mexico call for the use of the ND for both unbound materials (such as base course, subgrade soils, trench backfill, etc.) or bound materials (such as Hot Mix Asphalt). Although this technology has worked well over the years, and is well accepted by the industry, it is both cumbersome to carry this equipment around in the field, extremely cumbersome to transport this equipment to and from projects, extremely problematic to store the equipment in properly prepared, maintained and secured facilities when not in use and very expensive to properly maintain and document this equipment to remain in full compliance with the Nuclear Regulatory requirements for any equipment using radioactive materials.

Due to the extreme cost of manpower, transportation, training, security and documentation to use and maintain the NDs, there is a significant desire to find alternate technologies that could be used to provide an equal or better degree of reliability in determining the in-place density of unbound and bound materials. Ideally, this technology would be safe to use around other people, user-friendly for technicians to operate and sufficiently reliable that it could effectively be used to determine pay factors for large amounts of money, and if necessary, be credible enough for use in legal situations.

THIS PAGE LEFT BLANK INTENTIONALLY

2 LITERATURE REVIEW

INTRODUCTION AND BACKGROUND

A comprehensive search for appropriate technologies indicated that although a significant amount of research and development is underway by several companies, only one had a product that was sufficiently developed to be considered at this time.

TransTech Systems, Inc. from Schenectady, New York has a device called the Pavement Quality Indicator (PQI) that has been developed to measure the in-place density of Hot Mix Asphalt. The latest version of this model is the PQI 380. PQI density gages are currently being used in New Mexico by Fisher Industries and James Hamilton Construction Company for process control on hot mix asphalt, and appear to be relatively consistent and dependable. The units are very light and easily transported, so ease of handling was a benefit. Additionally, it did not use any radioactive sources or procedures, and did not require any of the same documentation and support required by Nuclear Densometers (ND).

TransTech Systems also had a recently developed unit called the Soil Density Gage that has been designed to measure the in-place density of unbound materials such as base course, subgrade soil, trench backfill, etc. The latest version of this unit is the SDG 200. Information provided by TransTech Systems indicated that the following descriptions of how this equipment works.

The PQI uses Impedance Spectroscopy to measure the electrical response of asphalt from which the density is calculated. The electrical field transmits through the material from the sensor plate of the PQI. The impedance is then measured and used in the calculation of the density for that specific aggregate.

The SDG operates by using electrical impedance spectroscopy (EIS). The SDG's measurement permits separation of the effects of density and moisture content on the response of the soil to electromagnetic probing. The density, or compaction level, is measured by the response of the SDG's electrical sensing field to changes in electrical impedance of the material matrix. Since the dielectic constant of the air is much lower than that of the other solid constituents, as density/compaction increase, the combined dielectric constant increases because the percentage of air in the soil matrix decreases. The SDG performs a calculation on the measurement data that enables the device to report he soil's density and moisture content.

TransTech Systems also indicated in their literature that the SDG 200 is intended primarily for making density measurements on a standard 12 inch lift of soil during or after compaction. It is designed to measure coarse and fine grained materials common in standard soils used in civil construction projects. After configuring the gage with soil properties from a standard particle size distribution report (ASTM D422) and Proctor test (ASTM D1557), the gage will provide reliable and consistent measurements.

TransTech Systems, Inc. indicated that these systems had been evaluated by several national agencies, including AASHTO and the United States Corps of Engineers. They also indicated that the equipment was being used extensively throughout Asia and portions of the Middle East due to the convenience and benefits over the ND. As far as actual simplicity of use, they indicated that both the PQI and the SDG do not require any additional tests between gathering the data in order to determine the density and moisture; that no surface prep is required except on extremely irregular surfaces; and the data is not affected when used in trenches.

A technical panel composed of members from the NMDOT and from the FHWA was created to oversee and direct the evaluation and potential implementation of this equipment, should it be appropriate. The proposed Technical Panel was also established. The initial members of the Technical Panel were Robert McCoy, Tom Brown, Brian Legan, Cliff Lucas, Jessica Sena, Ken Murphy, Frank Lozano, Steve Von Stein and Monica Jurado. Beginning in August, 2010 regular meetings of the technical panel were held to monitor and respond to the progress of the program, the procedures to be followed and who was to be tasked with individual responsibilities.

3 PROCEDURE

OBJECTIVE AND PROCEDURE

Objective

The objective of this project is to compare the reliability and accuracy of the ND to the reliability and accuracy of the TransTech Systems SDG 200 (SDG) and PQI 380 (PQI) for determining density and moisture content of soils, base course and hot-mixed asphalt (HMA). Also, if found to be appropriate an implementation program would be developed to provide guidance and support in the replacement of ND's with this technology**.**

Procedure

The committee decided to focus on the equipment manufactured by TransTech Systems, Inc. This equipment was the only non-nuclear technology that could be found after performing an extensive internet search and a review of AASHTO and FHWA documentation. This equipment was also selected based on preliminary experience by local contractors working with the NMDOT on various projects around the state. Discussion with the manufacturer confirmed that the PQI cannot be used on unbound soils and base course materials. The software which it uses is based on hot mixed asphalt characteristics and is not able to work with unbound soils and base course. TransTech Systems indicated that they do have a loan program that might be useful for both the PQI and the SDG. However, when the details of the loan program were evaluated it revealed that the maximum time allowed for the loaned equipment was not more than one month. If the equipment was kept after that time, an extremely large monthly fee would be assessed until its return.

The price of purchasing the equipment was considered by the Technical Panel. The price quoted for two (2) PQI's and two (2) SDG's was $8600 for each unit. This price included an on-site training session to be held in Albuquerque at a mutually convenient time. It was the decision of the Technical Panel that the potential benefits to the Department if this technology was found to be acceptable justified the expense of buying the equipment and expending the necessary effort and time to thoroughly and comprehensively evaluate the technology and the equipment.

The original intent was to equip two separate teams of investigators with one of each of these units and allow them to work concurrently throughout the state to collect data from actual projects over the course of the next year. However, further discussion questioned the repeatability between two separate units. A serious concern existed that one unit might generate a result while the companion piece of equipment generated a completely different result. Based on the magnitude of this concern the program was modified to have a single team to utilize both pieces of equipment at the same time. This would allow for a comparison between the conventional ND readings, and comparative readings from each of the two separate units. It would also allow for comparison to each other.

It was determined that a split program would be necessary. The first program would utilize the SDGs and a ND at each location to evaluate the performance of the gage used for unbound materials. The second program would utilize the PQIs and a ND to evaluate the performance of these gages on Hot Mix Asphalt.

Approval to purchase equipment through sole source procurement methods was received and a purchase order was issued for two PQI 380's and two SDG 200's. The Technical Panel indicated that since this alternate technology might allow an alternative to Nuclear Densometers, it would be desirable to put a hold on any further purchases of Nuclear Densometers. Steve Von Stein of FHWA-NM Division notified FHWA headquarters that NMDOT will no longer be purchasing nuclear devices directly or through contracted construction projects.

The equipment was received in mid-March 2011 and opened for inspection by the Technical Panel. The wrong power cords were shipped with the equipment and the vendor was contacted. The vendor shipped out the correct power cords for next day delivery. Upcoming potential test sites on the Project Letting Schedule were reviewed. Staffing requirements and specific individuals were considered to perform the field testing part of this project. Potential candidates included District Record Samplers and personnel from the State Materials Bureau. There was also some discussion about getting support from the construction crews.

Another idea presented was the possibility of getting an Engineer in Training (EIT) assigned to the project. An attempt was made to hire a summer student or EIT to provide technical support and aid in the administration of this project but the effort failed due to limited Department budget and slow response time

Fixed Asset numbers were established for the purchased equipment and the equipment was temporarily moved to TTCP for storage pending the upcoming training. The dates for the training were identified and scheduled. Invitations were sent to twenty-five individuals who had expressed interest or who were considered to be possible participants in this program to attend this training.

On May 24 – 25, 2011 Mr. Ron Berube of TransTech Systems Inc. provided an equipment training session in Albuquerque, New Mexico at the TTCP facility on Edith Boulevard. Participants included Lab personnel from NMDOT Districts 1, 2, 3, 4, 5, 6; TTCP Instructors and two professors from the University of Texas – El Paso. At the completion of this training Mr. Berube indicated that he would be very interested in witnessing and assisting our efforts at the actual projects when those were arranged. He requested that we notify him so that he could attend in person, if possible.

It was thought that the difference between the ND would be constant for a given soil type. Consequently the difference between readings from the SDG and the ND were monitored as a part of the effort on this project. If the difference was approximately the same, then a correction factor could be determined when using these gages on specific projects. For the field corroborations, the difference between the results obtained from the ND was compared to those from the individual units. The difference between the two results was also determined.

Based on the consensus of the Technical Committee it was decided to break the evaluation effort into two separate programs. The first program would evaluate the effectiveness of the SDG's while the second program would focus on the PQI's.

THIS PAGE LEFT BLANK INTENTIONALLY

4 SOIL DENSITY GAGE EVALUATION PROGRAM

FIELD PROJECT CORROBORATION

Upon the successful completion of the training program, an effort was made to find active projects on which this equipment could be used and tried. A project on I-25 near Bernalillo was under construction at this time. On June 23, 2011, Brian Legan and Bryce Simons took the two SDG's and a ND to the project in a preliminary effort to achieve some hands-on experience with the equipment before beginning the formal data collection efforts. The basic soil information provided by the project personnel was loaded into each SDG. It was noted by Mr. Simons during this effort that the user interface on the SDGs was difficult to anticipate and utilize. Additionally, it was found to be very difficult to navigate the software in the gage to insure that the proper information was being utilized in the processing of the collected data. After an extensive amount of time, it was confirmed that the data entered for the specific material on that project was being used by the unit to generate the results.

The Northbound lanes of I-25 near the south side of the U.S 550 overpass was the location selected for testing. The ND was used to measure the in-place density of the material in the location selected. The exact "footprint" on which the ND was set was marked with paint to ensure that the SDG's were placed over the exact same location. The first reading of the SDG did not correlate well with the ND so a judgment was made that the SDG had not been properly set, and an alternate location would be tested. The ND was placed over the second location and marked. The SDG's were then placed on the same spot and this time the readings were very similar to those of the ND. It was felt that this initial trial demonstrated that, contrary to the initial claims from TransTech Systems, site preparation requirements were minimal, the setting of the gages is actually very important and the readings appear to be influenced if the machines are not properly set.

US 64 West of Eagle Nest, New Mexico

The first formal effort to utilize this program on unbound soils was performed on August 17, 2011, on Project Number TPM-064-8(9)275; Control Number 3436 located west of Eagle Nest, New Mexico. TransTech Systems, Inc. was notified of the date but was unable to attend. The base course for the project was in the preliminary stages of distribution and compaction. There was some compacted base course material in two trenches. Those were the locations chosen for these tests. The project team performing this correlation was Jennifer Crooker, Deirdre Billingsley, Jessica Sena and Bryce Simons. Project Level support was provided by Joseph Leger and Lawrence Lujan. Initially the team reported to the project office where the specific information for the base course material was entered into the equipment. The team then went out to the project where the ND was placed in the initial test location and the footprint marked. The Nuclear Densometer used for this effort was A-958. The SDG's were then placed into the same footprint to obtain their readings. Each final reading was determined after the SDG was placed:

- first in the center of the footprint and started;

- moved approximately 2-4 inches upward and to the right and started;
- moved approximately 6 inches straight down so that the gage was approximately 2 – 4 inches down and to the right of the original center and started;
- moved straight to the left so it was located down and to the left from the original placement by approximately 2-4 inches and started;
- and finally moved straight up approximately 6 inches so that the gage was approximately 2 – 4 inches up and to the left of the original center and started.

This was the pattern that was used throughout the rest of this study to obtain each composite reading from each of the SDG gages. The results obtained from this project near Eagle Nest are shown below in Table 4.1. Although the temperatures were available as part of the normal read-out from each of the SDG Gages, the actual data was not initially recorded.

Non-Nuclear Test Data

Eagle Nest, New Mexico

Test Date	TPM-064-8(9)275 CN 3436	Maximum Density	124.7					
8/17/11		Optimum Moisture Content	11%					
Test No.	Test Location		Percent Compaction	Dry Density (PCF)	Wet Density (PCF)	Moist Cont (%)	Temp (Degrees F)	Difference in Compaction from Nuc (% Points)
1A	Top of Corrugtated Culvert, E side of Rd @ approx Station 430+57.41 (Trial Test Only-Soil surface was questionable and material preparation was marginal)	Nuclear Densometer	91.8	114.5	121.3	5.9		
		SDG C First Reading	82.9	103.4	106.0	2.6		8.9
		SDG C Second Reading	80.4	100.2	101.7	1.5		11.4
		SDG D First Reading	81.1	101.1	103.0	1.9		10.7
		SDG D Second Reading	80.0	99.8	101.3	1.5		11.8
1B	Offset from #1A by approx 4 ft W & 10 ft N (Same concerns as those expressed for Test 1A above)	Nuclear Densometer	97.9	122.0	128.5	5.4		
		SDG C First Reading	79.0	98.6	99.5	0.9		18.9
		SDG D First Reading	82.9	103.4	105.9	2.4		15.0
2A	Backfill for 24" Pipe Culvert, Station 442+05	Nuclear Densometer	103.9	129.5	142.1	9.7		
		SDG C First Reading	97.8	122.0	129.2	5.9		6.1
		SDG C Second Reading	96.4	120.2	126.9	5.6		7.5
		SDG D First Reading	97.6	121.8	129.2	6.1		6.3
		SDG D Second Reading	95.4	119.0	125.6	5.5		8.5
2B	Same as Test 2A	Nuclear Densometer	101.0	125.9	138.9	10.3		
		SDG C First Reading	94.8	118.3	124.4	5.2		6.2
		SDG C Second Reading	94.6	118.0	124.4	5.2		6.4
		SDG D First Reading	94.2	117.4	123.4	5.1		6.8
		SDG D Second Reading	94.1	117.3	123.3	5.1	71.6	6.9
3A	Same as Test Set 2, Next Lift Up	Nuclear Densometer	100.8	125.7	137.6	9.5		
		SDG C First Reading	97.2	121.3	128.4	5.9	66.2	3.6
		SDG C Second Reading	97.3	121.3	128.4	5.8	66.2	3.5
		SDG D First Reading	97.7	121.8	129.1	6.0	68.0	3.1
		SDG D Second Reading	98.0	122.2	129.5	6.0	68.0	2.8
3B	Same as Test Set 2, Next Lift Up (Seating of SDG was unstable and the unit "wobbled")	Nuclear Densometer	101.0	126.0	138.9	10.3		
		SDG C First Reading	89.0	110.0	115.8	4.3	73.4	12.0
		SDG C Second Reading	89.8	112.0	117.2	4.6	71.6	11.2
		SDG D First Reading	91.1	113.6	119.0	4.8	73.4	9.9
		SDG D Second Reading	89.9	112.1	117.0	4.4	71.6	11.1

Note: Yellow shading reflect operator or other factors were present which may have influenced the test results.

Table 4.1

US 491 Near Shiprock, New Mexico

The second project on which this equipment was used was for Project Number ESG5B56 in the far northwest corner of the state on US491 south of Shiprock, NM. TransTech Systems, Inc. was again notified of the date on which this visit would take place but was unable to attend. The project team for this visit was Jennifer Crooker, Deirdre Billingsley and Bryce Simons. Project support was provided by Jeremiah Herrera, Jeremy Madrid and Derek Martinez (AMEC). The procedure was exactly the same as that used for the initial test program in Eagle Nest: Visit to the project office where the specific soil information was loaded into each of the SDG's. Then the gages were taken to the project which was a long roadway section where the base course had been compacted in anticipation of being paved with Hot Mix Asphalt. The ND was placed in each of the test locations selected and its footprint painted directly on the base course. The ND used for this visit was Seaman L-366. Each SDG was placed in the same footprint and the first reading was obtained. The SDG was then rotated 180^o and the second reading for that unit obtained.
The results of this visit are shown in Table 4.2 below.

Non-Nuclear Test Data

US 491 near Shiprock, New Mexico

Test Date	Project Number (See Info on Next Tab)	Maximum Density	139.5		Note:	(yellow)	= Wet Density is lower than Dry Density
10/12/11	ESG5B56	Optimum Moisture Content	6.0%				

Test No.	Test Location		Percent Compaction	Dry Density (PCF)	Wet Density (PCF)	Moist Cont (%)	Temp (Degrees F)	Difference in Compaction from Nuc (% Points)
1	Station 6081, approximately 20 ft left of east shoulder	Nuclear Densometer	92.6	129.6	134.2	3.5		
		SDG C First Reading	80.4	112.2	117.7	4.9	62.6 oF	12.2
		SDG C Second Reading	62.4	87.2	83.2	-4.6	51.8 oF	30.2
		SDG D First Reading	60.6	84.6	80.0	-5.5	64.4 oF	32
		SDG D Second Reading	60.5	84.5	79.7	-5.7	55.4 oF	32.1
2	Station 6080 + 30, approximately 5 ft left of east shoulder	Nuclear Densometer	88.1	129.3	135.6	2.4		4.5
		SDG C First Reading	60.8	84.9	81.1	-4.5	66.2 oF	27.3
		SDG C Second Reading	60.4	84.3	80.4	-4.7	60.8 oF	27.7
		SDG D First Reading	60.4	84.3	80.4	-4.6	62.6 oF	27.7
		SDG D Second Reading	59.4	82.9	78.6	-5.2	68.0 oF	28.7
3	Station 6079, approsimatley 18 ft Left of east shoulder	Nuclear Densometer	89.3	125.8	130.3	3.6		
		SDG C First Reading	67.3	94.0	92.2	-1.3	69.8 oF	22.0
		SDG C Second Reading	66.8	93.3	91.8	-1.6	59.0 oF	22.5
		SDG D First Reading	66.6	92.9	91.5	-1.5	69.8 oF	22.7
		SDG D Second Reading	67.6	94.4	93.4	-1.0	59.0 oF	21.7
4	Station 6077, approximate CenterLine	Nuclear Densometer	92.3	129.3	133.9	3.6		
		SDG C First Reading	63.2	88.2	85.0	-3.6	55.4 oF	29.1
		SDG C Second Reading	62.9	87.8	84.5	-3.7	60.8 oF	29.4
		SDG D First Reading	62.9	87.8	84.5	-3.7	60.8 oF	29.4
		SDG D Second Reading	61.4	85.8	82.1	-4.3	57.2 oF	30.9
5	Station 6078, approximately 3 ft from east shoulder	Nuclear Densometer	91.8	128.5	132.2	2.8		
		SDG C First Reading	62.0	86.6	83.7	-3.3	69.8 oF	29.8
		SDG C Second Reading	65.9	92.1	91.4	-0.7	73.4 oF	25.9
		SDG D First Reading	61.5	85.8	82.9	-3.4	68.0 oF	30.3
		SDG D Second Reading	62.9	86.6	83.9	-3.1		28.9
6	Station 6076, approximately 6 ft from east shoulder	Nuclear Densometer	82.5	115.5	119.1	3.1		
		SDG C First Reading	58.1	81.2	76.3	-0.6	66.2 oF	24.4
		SDG C Second Reading	64.7	90.3	88.9	-1.6	73.4 oF	17.8
		SDG D First Reading	64.2	89.7	88.1	-1.7	69.8 oF	18.3
		SDG D Second Reading	64.1	89.6	87.9	-1.8	77.0 oF	18.4
7	Station 6075, approximately 10 ft left from east shoulder	Nuclear Densometer	89.6	125.4	128.6	2.6		
		SDG C First Reading	61.9	86.5	83.4	-3.5	71.6 oF	20.6
		SDG C Second Reading	62.2	86.8	83.9	-3.3	77.0 oF	20.3
		SDG D First Reading	61.9	86.4	83.4	-3.4	68.0 oF	20.6
		SDG D Second Reading	61.6	85.9	82.9	-3.6	82.4 oF	20.9
8	Station 6074, at Center lIne	Nuclear Densometer	89.5	125.3	128.9	2.9		
		SDG C First Reading	61.6	85.9	82.5	-3.9	71.6 oF	20.9
		SDG C Second Reading	62.4	87.1	84.2	-3.3	68.0 oF	20.1
		SDG D First Reading	60.9	85.1	81.5	-4.2	73.4 oF	21.6
		SDG D Second Reading	61.0	85.2	81.8	-4.1	75.2 oF	21.5
9	Station 6072, approximately 10 ft from east shoulder	Nuclear Densometer	90.6	127.0	130.7	2.9		
		SDG C First Reading	62.8	87.7	84.6	-3.5	71.6 oF	19.7
		SDG C Second Reading	62.7	87.5	84.3	-3.7	78.8 oF	19.8
		SDG D First Reading	62.3	87.0	83.9	-3.7	71.6 oF	20.2
		SDG D Second Reading	61.8	86.3	82.8	-4.0	77.0 oF	20.7
10	Station 60701, at Center Line	Nuclear Densometer	92.2	129.1	134.0	3.8		
		SDG C First Reading	66.2	92.5	90.8	-1.8	62.6 oF	16.3
		SDG C Second Reading	65.7	91.7	89.7	-2.2	77.0 oF	16.8
		SDG D First Reading	64.8	90.5	88.2	-2.6	75.2 oF	17.7
		SDG D Second Reading	64.8	90.4	88.1	-2.6	75.2 oF	17.7

Table 4.2

US60 South of Corona, New Mexico

The third project on which this equipment was used was on US 60, Project Number G3a52 south of Corona on November 9, 2011. The project team on this visit was Jennifer Crooker, Cliff Lucas, Jessica Sena, Brian Legan, Bryce Simons and Deirdre Billingsley. Project level support was provided by William Fulkrod and Ray Polanco. This effort was somewhat different than the previous projects. There was not a lot of base course placed and compacted so the Contractor volunteered to place and compact base course at the project yard. Some base course had been placed and compacted in some of the cross-overs so after all of the measurements had been taken at the project yard, the team moved to the cross-overs and obtained additional readings there. Finally, since the base course material was being obtained from a portion of US 60 east of Corona, the team went to that location where the compacted base course material had not been removed yet and obtained additional readings. The results of this visit are shown in Table 4.3 below.

Non-Nuclear Test Data

US 60 South of Corona, New Mexico

Test Date	Project Number (See Info on Next Tab)	Maximum Density	128					
11/9/11	G3a52	Optimum Moisture Content	11.0%					
Test No.	Test Location		Percent Compaction	Dry Density (PCF)	Wet Density (PCF)	Moist Cont (%)	Temp (Degrees F)	Difference in Compaction from Nuc (% Points)
1	At stockpile compacted pad prepared for this test program	Nuclear Densometer	99.6	127.5	139.0	9.0		
		SDG C First Reading	111.7	145.2	148.3	2.2	41.0 oF	-12.1
		SDG C Second Reading	104.4	135.8	135.9	0.1	42.0 oF	-4.8
		SDG D First Reading	108.3	140.7	142.4	1.2	50.0 oF	-8.7
		SDG D Second Reading	100.5	130.7	129.3	-1.1	48.2 oF	-0.9
2	At stockpile compacted pad prepared for this test program	Nuclear Densometer	95.5	122.2	134.8	10.25		4.1
		SDG C First Reading	116.5	151.5	158.6	4.7	44.6 oF	-21.0
		SDG C Second Reading	90.7	118	112.7	-4.4	48.2 oF	4.8
		SDG D First Reading	95.1	123.7	122.0	-0.3	46.4 oF	0.4
		SDG D Second Reading	83.3	108.3	101.3	-6.4	44.5 oF	12.2
3	At stockpile compacted pad prepared for this test program	Nuclear Densometer	91.8	117.6	126.2	7.4		
		SDG C First Reading	90.4	117.5	112.5	-4.3	44.6 oF	1.4
		SDG C Second Reading	88.9	115.6	109.6	-5.2	46.4 oF	2.9
		SDG D First Reading	90.7	117.9	112.6	-4.5	42.8 oF	1.1
		SDG D Second Reading	112.7	146.5	152.7	4.2	46.4 oF	-20.9
4	At stockpile compacted pad prepared for this test program	Nuclear Densometer	97.1	124.4	135.6	18.1		
		SDG C First Reading	113.4	134.4	132.6	-0.6	46.4 oF	-16.3
		SDG C Second Reading	92.0	119.6	115.0	-3.8	55.4 oF	5.1
		SDG D First Reading	95.9	124.1	120.0	-3.3	48.2 oF	1.2
		SDG D Second Reading	99.7	129.6	127.2	-1.9	52.2 oF	-2.6
5	At stockpile compacted pad prepared for this test program	Nuclear Densometer	90.9	116.4	126.7	8.8		
		SDG C First Reading	101.4	131.8	130.7	-0.8	53.6 oF	-10.5
		SDG C Second Reading	114.5	148.9	152.4	2.4	51.8 oF	-23.6
		SDG D First Reading	91.5	119.0	113.8	-4.3	50.0 oF	-0.6
		SDG D Second Reading	94.2	122.5	118.8	-3.1	59.0 oF	-3.3
6	At stockpile compacted pad prepared for this test program	Nuclear Densometer	95.2	121.9	131.1	7.6		
		SDG C First Reading	88.7	115.4	109.0	-5.5	55.4 oF	6.5
		SDG C Second Reading						
		SDG D First Reading	90.6	117.8	111.9	-5.0	51.8 oF	4.6
		SDG D Second Reading	96.0	124.7	121.3	-2.8	53.6 oF	-0.8
7	At stockpile compacted pad prepared for this test program	Nuclear Densometer	95.2	121.9	129.9	6.5		
		SDG C First Reading	87.2	113.4	106.3	-6.2	48.2 oF	8.0
		SDG C Second Reading	102.0	132.6	132.7	0.1	59.0 oF	-6.8
		SDG D First Reading	84.8	110.2	102.4	-7.1	51.8 oF	10.4
		SDG D Second Reading	80.2	104.9	95.2	-8.7	53.6 oF	15.0
8	At stockpile compacted pad prepared for this test program	Nuclear Densometer	99.8	127.7	138.3	8.3		
		SDG C First Reading	106.0	137.8	137.6	-0.2	55.4 oF	-6.2
		SDG C Second Reading	120.1	156.1	163.0	4.4	46.4 oF	-20.3
		SDG D First Reading	135.0	137.5	137.7	0.1	50.0 oF	-35.2
		SDG D Second Reading	121.1	157.4	164.5	4.5	55.4 oF	-21.3
9	North Detour #1, Location #1	Nuclear Densometer	81.4	104.2	119.0	14.3		
		SDG C First Reading	84.1	109.3	101.9	-6.8	71.6 oF	-2.7
		SDG C Second Reading	84.2	109.5	102.0	-6.8	62.6 oF	-2.8
		SDG D First Reading	82.5	107.3	99.1	-7.6	68.0 oF	-1.1
		SDG D Second Reading	86.6	112.6	106.2	-5.7	57.2 oF	-5.2
10	North Detour #1, Location #2	Nuclear Densometer	82.0	105.0	113.7	8.3		
		SDG C First Reading	119.7	155.7	165.2	6.1	59.0 oF	-37.7
		SDG C Second Reading	108.0	140.4	145.2	3.7	48.0 oF	-26.0
		SDG D First Reading	73.5	95.6	84.5	-11.6	64.4 oF	8.5
		SDG D Second Reading	75.0	97.5	86.8	-11.0	62.6 oF	7.0
11	North Detour #1, Location #3	Nuclear Densometer	82.8	106.0	115.8	3.1		
		SDG C First Reading	107.6	139.9	144.2	3.1	66.2 oF	-24.8
		SDG C Second Reading	76.2	99.0	89.1	-10.1	62.6 oF	6.6
		SDG D First Reading	75.6	98.2	87.7	-10.7	57.2 oF	7.2
		SDG D Second Reading	89.5	116.3	112.0	-3.8	51.8 oF	-6.7
12	Original Grade from which Base Course Material is being removed, Location 1	Nuclear Densometer	98.8	126.4	134.3	6.3		
		SDG C First Reading	98.8	128.4	125.4	-2.4	59.0 oF	0.0
		SDG C Second Reading	97.7	127.6	123.6	-2.7	60.8 oF	1.1
		SDG D First Reading	97.8	127.2	124.0	-2.5	57.2 oF	1.0
		SDG D Second Reading	109.4	142.2	144.6	1.7	57.2 oF	-10.7
13	Original Grade, Location 2	Nuclear Densometer	98.6	126.3	135.4	8.2		
		SDG C First Reading	90.4	117.5	112.6	-4.2	50.0 oF	8.2
		SDG C Second Reading	90.1	117.1	112.0	-4.3	48.2 oF	8.5
		SDG D First Reading	89.8	116.7	111.8	-4.2	53.6 oF	8.8
		SDG D Second Reading	88.6	115.2	109.6	-4.8	50.0 oF	10.0
14	Original Grade, Locaiton 3	Nuclear Densometer	93.3	119.5	126.8	6.2		
		SDG C First Reading	76.5	99.4	88.7	-10.7	57.2 oF	16.8
		SDG C Second Reading	81.1	105.5	96.9	-8.1	51.8 oF	12.2
		SDG D First Reading	75.7	98.4	87.3	-11.2	62.6 oF	17.6
		SDG D Second Reading	79.8	103.8	94.6	-8.8	68.0 oF	13.5
15	Original Grade, Location 4	Nuclear Densometer	87.6	112.2	123.6	10.2		
		SDG C First Reading	76.1	89.9	87.9	-11.1	55.4 oF	11.5
		SDG C Second Reading	75.5	98.2	87.0	-11.4	55.6 oF	12.1
		SDG D First Reading	76.9	100.0	89.6	-10.4	50.0 oF	10.7
		SDG D Second Reading	76.7	99.8	89.2	-10.6	55.4 oF	10.9
16	Original Grade, Locaiton 5	Nuclear Densometer	90.9	116.4	126.5	8.9		
		SDG C First Reading	83.1	108.0	100.4	-7.1	51.8 oF	7.8
		SDG C Second Reading	78.3	101.7	92.0	-9.6	48.2 oF	12.6
		SDG D First Reading	77.4	100.6	90.7	-9.9	65.4 oF	13.5
		SDG D Second Reading	74.3	96.6	85.4	-11.6	53.6 oF	16.6

Table 4.3

Results

The initial information received from TransTech Systems both during the initial information gathering phase of this project, and again during the training, indicated that very little site preparation or effort was necessary to obtain good readings. However, it was found in the initial efforts to use this equipment, and again at every project visited, that proper preparation of the specific test location was quite important. Many of the readings obtained appeared to be very questionable due to the apparent lack of proper seating upon which to set the individual unit.

Virtually every operator who used the SDGs made note of the fact that the display on the SDG units was very difficult to see and to read. Due to the naturally bright light conditions in New Mexico, a great deal of effort was required on the part of each individual operating the units to try and shade the read-out and position themselves appropriately to read what was being shown on the gage. In some cases, the operator was required to focus extremely intently and to place themselves in positions that could have put them at risk from construction related activities near them. Some of the operators were essentially unable to read the gages at all.

It can be seen that significant difficulties were encountered in trying to get a well seated base on the SDGs in order to achieve dependable readings. Although each test location was set up so that the base was as level as possible and tamped down as good as possible, the readings still seemed to be quite variable and did not correlate well with the ND.

The Eagle Nest readings demonstrated several other issues as well:

- Significant differences were observed between individual readings for the same gage. The differences between the first and second reading from the same gage ranged from a low of 0.0% to a high of 2.8%.
- Significant differences were observed between each SDG gage and the ND. The differences ranged from a high of 18.9% to a low of 2.8%. The average difference between the Gages and the ND was 8.6% with a standard deviation of 4.0%.
- The SDG readings were all lower than those from the ND.

  A statistical method has been established to allow the user to evaluate how close the measured value is to the correct value. If all potential results on both the high side and the low side of the average have an exactly equal chance of occurring, then the data is said to have a "Standard Normal Distribution", and if the number of times any given result can occur is plotted, then a "Bell Curve" will be shown with equal areas on the right and on the left of the average. To have a 90% confidence that the "correct" value is within area under consideration, the standard deviation must be multiplied by a factor of 1.645 to determine what range of results must be considered in order to capture the "correct" value. If a more confident conclusion is required then the factor by which the standard deviation must be multiplied is 1.960 to determine the range of results that must be considered to be sure the "correct" result is included.

With this understanding, for the Eagle Nest data there is be a 90% chance that the correct (ND) in-place density of the test soil would be included within a range of 6.6% of the actual

SDG reading. There is a 95% chance that the correct in-place density of the test soil is included within a range of 7.9% of the actual SDG reading. As discussed above, a significant number of the readings were considered questionable because of the poor bedding that was achieved beneath the gages.

The readings obtained from the US 491 project near Shiprock, New Mexico provided the following observations:

- Many of the wet densities were lower than the dry densities and the designated moisture contents obtained from the SDG's were negative. Since these results were contradictory and physically impossible, each of the SDG's was closely checked to insure that the information specific to the base course material on that project was being utilized in the evaluation of the data. It was confirmed to the best ability of the operators that the correct information was being used.
- Again, every reading obtained by the SDG was lower than that from the ND.
- The issue of negative moisture contents and wet densities lower than the dry densities was brought to the attention of TransTech Systems, Inc. At their request, all of the raw data files were downloaded directly from the gages and sent electronically to them. They were unable to provide any useful or helpful insight or observations about why these anomalous readings were being generated.
- It can be seen that in many cases there was a significant difference in readings for the same machine with different orientations. There was also significant difference between the ND and each of the units, but also from test location to test location despite the fact that the base course material in each location was the same.
- The differences between the ND and the gages were not constant for this project either. They ranged from a high of 32.1% to a low of 4.5%.
- Based on the statistics from the readings for this project visit to US 491, there is a 90% chance that the correct (ND) in-place density of the test soil would be included within a range of 8.48% of the actual SDG reading. There is a 95% chance that the correct in-place density of the test soil is included within a range of 10.10% of the actual SDG reading.
- However, due to the unrealistic results generated by the gages, it is not appropriate to recognize the statistical results described above.

The readings obtained from the US 60 project near Corona, New Mexico provided the following observations:

- Once again, many of the wet densities were lower than the dry densities, and the moisture contents were negative.
- For this project visit, the SDG readings were not always lower than the ND. Many of the SDG readings were higher than the ND. However, the readings from any single gage or even from both gages at a single location were not always consistently higher or consistently lower than the ND. The readings varied even from the same machine at the same location. In many instances the same machine in the same location

generated numbers higher than the ND in one orientation while the result was lower than the ND in the other orientation.

- Although the average difference was only -0.2% from the ND, the readings that were higher than the ND offset those that were less than the ND so the average result was very close. However, when the standard deviation is considered, the variance in differences is extremely large.
- There is a 90% chance that the correct in-place density of the soil is included within a range of 21.39% of the actual SDG reading. For a confidence of 95%, the range is 25.49% of the actual SDG reading.

5 PAVEMENT QUALITY ANALYZER EVALUATION PROGRAM

FIELD PROJECT CORROBORATION

The TransTech PQI's were to be evaluated in the field by loaning the gages to various projects around the state. The equipment was to be delivered by one of the members of the Technical Committee so that specific instruction and support could be provided on how to operate the gages and what information must be captured. However, the PQI gages were only used on one project in the NE corner of the state. The data from that project is shown in Table 5.1.

It can be seen that the ND readings and the PQI's were much more consistent. The average difference between the ND and the PQI's were 0.64% and 0.62% for the PQI-A and for the PQI-B, respectively. Additionally, for all but one measurement, both gages provided results that were very similar to each other.

The range of differences between the PQI's and the ND were from a high of 3.5% higher than the ND to a low of 4.9% less than the ND. The differences between the two different gages ranged from a high of 3.5% to a low of 0.0%.

It was determined that the difference between the ND and the PQI's was such that the readings from the PQI's could not be used directly. In order to use these gages the difference between a control reading of the ND and readings from the PQI for any given project and on any given day had to be determined. A correction factor was then determined for use on any subsequent readings for the PQI on a particular day for the specific mix.

PAVEMENT QUALITY ANALYZER FIELD CORROBORATION

Projct Number HWA2M400362

Las Vegas, New Mexico

HMA Mix SP-III CMD4974

Test #	Seaman	PQI-A	PQI-B	Average PQI Reading	Diff between PQI Gages	Diff between PQI Avg & Seaman	Seaman Compaction (%)	PQI-A Compaction (%)	PQI-B Compaction (%)	Diff Seaman vs PQI-A Compaction	Diff Seaman vs PQI-B Compaction	Diff PQI-A vs PQI - B Compaction
1	**136.7**	**132.7**	**132.5**	**132.6**	**0.2**	**4.1**	**92.1%**	**89.3%**	**89.2%**	2.7%	2.8%	0.1%
1 Retest	**138.1**	**138.0**	**132.9**	**135.5**	**5.2**	**2.6**	**93.0%**	**93.0%**	**89.5%**	0.0%	3.5%	3.5%
2	**139.4**	**137.5**	**138.4**	**138.0**	**0.8**	**1.4**	**93.9%**	**92.6%**	**93.2%**	1.3%	0.7%	0.6%
3	**138.5**	**137.6**	**138.0**	**137.8**	**0.4**	**0.7**	**93.3%**	**92.7%**	**92.9%**	0.6%	0.3%	0.3%
4	**137.7**	**136.8**	**137.4**	**137.1**	**0.6**	**0.6**	**92.7%**	**92.1%**	**92.5%**	0.6%	0.2%	0.4%
5	**141.4**	**141.4**	**141.6**	**141.5**	**0.1**	**-0.1**	**95.2%**	**95.2%**	**95.3%**	0.0%	-0.1%	0.1%
5 Retest	**141.4**	**138.7**	**139.3**	**139.0**	**0.7**	**2.4**	**95.2%**	**93.4%**	**93.8%**	1.8%	1.4%	0.4%
6	**143.2**	**142.1**	**141.8**	**141.9**	**0.3**	**1.3**	**96.4%**	**95.7%**	**95.5%**	0.7%	1.0%	0.2%
6 Retest	**143.2**	**139.3**	**139.6**	**139.5**	**0.3**	**3.7**	**96.4%**	**93.8%**	**94.0%**	2.6%	2.4%	0.2%
7	**140.2**	**139.5**	**139.8**	**139.6**	**0.3**	**0.6**	**94.4%**	**93.9%**	**94.1%**	0.5%	0.3%	0.2%
7 Retest	**140.2**	**139.3**	**139.7**	**139.5**	**0.4**	**0.7**	**94.4%**	**93.8%**	**94.1%**	0.6%	0.3%	0.2%
8	**139.8**	**139.7**	**139.9**	**139.8**	**0.2**	**0.0**	**94.1%**	**94.1%**	**94.2%**	0.1%	0.0%	0.1%
8 Retest	**139.8**	**139.3**	**139.1**	**139.2**	**0.1**	**0.6**	**94.1%**	**93.8%**	**93.7%**	0.4%	0.5%	0.1%
9	**142**	**139.9**	**140.0**	**140.0**	**0.1**	**2.0**	**95.6%**	**94.2%**	**94.3%**	1.4%	1.3%	0.1%
9 Retest	**142**	**138.8**	**139.2**	**139.0**	**0.3**	**3.0**	**95.6%**	**93.5%**	**93.7%**	2.1%	1.9%	0.2%
10	**140.4**	**139.5**	**139.6**	**139.6**	**0.1**	**0.8**	**94.5%**	**93.9%**	**94.0%**	0.6%	0.5%	0.1%
11	**140.5**	**139.0**	**139.3**	**139.1**	**0.3**	**1.4**	**94.6%**	**93.6%**	**93.8%**	1.0%	0.8%	0.2%
12	**138.3**	**138.3**	**138.6**	**138.5**	**0.2**	**-0.2**	**93.1%**	**93.2%**	**93.3%**	0.0%	-0.2%	0.2%
13	**143.9**	**139.7**	**139.7**	**139.7**	**0.1**	**4.2**	**96.9%**	**94.1%**	**94.1%**	2.8%	2.8%	0.0%
14	**141.2**	**138.5**	**138.6**	**138.5**	**0.0**	**2.7**	**95.1%**	**93.3%**	**93.3%**	1.8%	1.8%	0.0%
15	**138.1**	**138.2**	**138.3**	**138.3**	**0.1**	**-0.2**	**93.0%**	**93.1%**	**93.1%**	-0.1%	-0.1%	0.1%
16	**139.1**	**139.9**	**140.0**	**140.0**	**0.1**	**-0.8**	**93.7%**	**94.2%**	**94.3%**	-0.5%	-0.6%	0.1%
17	**139.7**	**138.2**	**138.5**	**138.4**	**0.3**	**1.3**	**94.1%**	**93.1%**	**93.3%**	1.0%	0.8%	0.2%
18	**139.6**	**138.7**	**139.4**	**139.1**	**0.7**	**0.5**	**94.0%**	**93.4%**	**93.9%**	0.6%	0.1%	0.5%
19	**139**	**137.5**	**137.3**	**137.4**	**0.1**	**1.6**	**93.6%**	**92.6%**	**92.5%**	1.0%	1.1%	0.1%
20	**139.3**	**137.5**	**138.2**	**137.9**	**0.7**	**1.4**	**93.8%**	**92.6%**	**93.1%**	1.2%	0.7%	0.5%
21	**138.1**	**138.1**	**138.3**	**138.2**	**0.3**	**-0.1**	**93.0%**	**93.0%**	**93.2%**	0.0%	-0.2%	0.2%
22	**135.7**	**137.9**	**138.6**	**138.3**	**0.8**	**-2.6**	**91.4%**	**92.8%**	**93.4%**	-1.5%	-2.0%	0.5%
23	**133.7**	**140.9**	**140.2**	**140.5**	**0.7**	**-6.8**	**90.0%**	**94.9%**	**94.4%**	-4.9%	-4.4%	0.5%
									Average:	0.64%	0.62%	0.34%
									Standard Deviation	1.44%	1.49%	0.62%
									90% Confidence Range	2.38%	2.45%	1.03%
									95% Confidence Range	2.83%	2.92%	1.22%
									Maximum Difference	2.8%	3.5%	3.5%
									Minimum Difference	-4.9%	-4.4%	0.0%

Table 5.1

6 CONCLUSIONS AND RECOMMENDATIONS

SOIL DENSITY GAGE (SDG)

After significant discussion and review of the data, it was the consensus opinion of the Technical Committee that the TransTech SDG was not appropriate for further consideration to use as a tool for reliable testing of the in-place density of unbound soil materials. This conclusion was based on the following points:

- There was an extreme variability between the ND and the SDG readings;
- The differences between the ND and the SDG readings was not consistent or predictable;
- The extremely wide variability and the associated low statistical confidence in the actual readings from the SDG's make it inappropriate for use when project acceptance or pay factors are required.
- In many cases, the results generated by the SDG were unrealistic and physically not possible. The consistent tendency to generate wet densities that were lower than the dry densities, and the repeated negative moisture contents were clearly wrong.
- The lack of customer support by the manufacturer was a problem. Repeated attempts to get help and to have questions answered failed to have any success.
- The equipment was not user friendly or useful. The User Interface was not logical to those who tried to use it, and the ability and understanding required to navigate between on-screen options was difficult to understand and to utilize.
- The ability to read the screen on the gage in the daytime sunlight was extremely difficult. It was felt that the user of this equipment could be at risk from active on-site construction equipment while trying to focus attention on the gage. At the very least, the strain from continued use of this gage would be directly responsible for extreme fatigue and probable headaches after a day's use.
- The discomfort caused by this difficulty in reading the gage would also translate to a poorer attitude on the part of the user, resulting in a higher probability of compromised data.
- Even if the data had been repeatable and reliable, it still requires the use of a Nuclear Densometer to provide a daily correlation for each material and for each project, so the original intention of replacing the Nuclear Densometers will not be possible with this equipment.

PAVEMENT QUALITY INDICATOR (PQI)

- The results from the PQI were relatively consistent and the difference between the ND and the PQI was relatively consistent.
- It was still necessary to use the Nuclear Densometer to provide a daily correlation for each materials and for each project so the original intention of replacing the Nuclear Densometer will not be possible with this equipment.

CONCLUSION

Overall, due to the extreme unreliability and all of the other issues associated with the TransTech SDG, and the continued need for the Nuclear Densometer, it was concluded that this non-nuclear technology did not warrant further consideration for use on NMDOT projects.

New Mexico Department of Transportation
RESEARCH BUREAU
7500B Pan American Freeway NE
PO Box 94690
Albuquerque, NM 87199-4690
Tel: (505) 798-6730