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Transportation Research Division

Technical Report 92-34

Field Trial of Gravel Stabilization Methods
Route 1, Cyr - Van Buren, Maine

Final Report, April 2006

Transportation Research Division

Field Trial of Gravel Stabilization Methods

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Introduction

This experimental construction project was developed, designed, and inspected by personnel from the University of Maine, Civil Engineering Staff. The project was constructed on and as a part of Project Number 2586.00 in Cyr Plantation - Van Buren (see Figure 1).

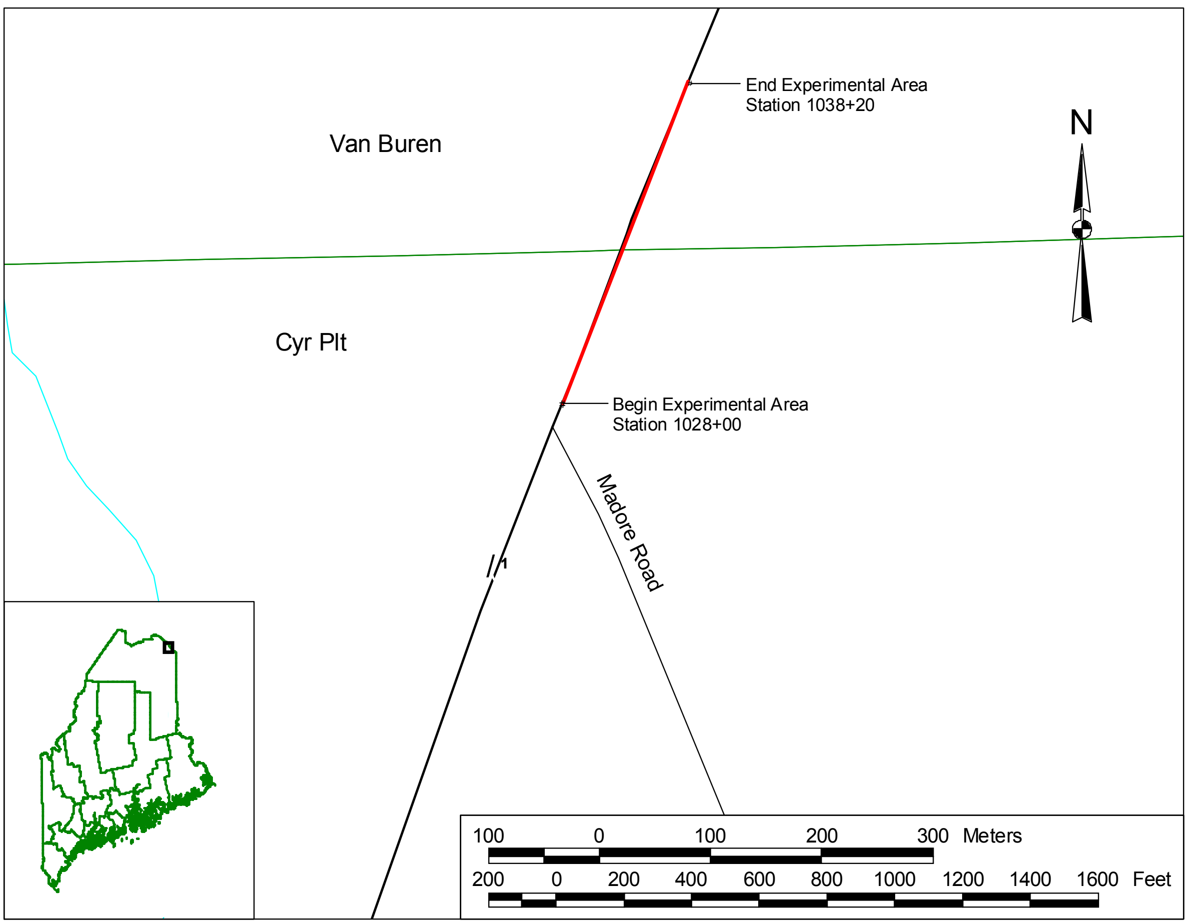

Figure 1. Project Location Map

This was a complete reconstruction project 2.2 miles (3.5 kilometers) in length. The experimental section contains 6 experimental base types and is 1020 feet (311 meters) in length. The experimental section began at Station 1028+00 and ended at Station 1038+20. The test section consisted of 200 foot (61 meter) segments of soil cement, asphalt, calcium chloride, modified, standard and one 20 foot (6 meter) untreated section. The stabilized and control sections were located as follows:

Soil Cement Stabilized	Station 1028+00 to 1030+00
Modified Subbase Control	Station 1030+00 to 1032+00
Asphalt Stabilized	Station 1032+00 to 1034+00
Untreated Section	Station 1034+00 to 1034+20
Calcium Chloride Stabilized	Station 1034+20 to 1036+20
Standard Subbase Control	Station 1036+20 to 1038+20

The Soil Cement Stabilized section is a mixture of Modified Subbase (mentioned later) and 6 percent by weight of Type I Portland Cement.

The Modified Subbase Control section is standard subbase aggregate MDOT specification 703.06b Type D with a 2 inch (51 mm) maximum aggregate size. This aggregate was used on all stabilized sections to facilitate blending of each treatment.

The Asphalt Stabilized section is a mixture of Modified Subbase and 4.5 percent of MS-4 Emulsified Asphalt.

The Untreated section consists of Modified Subbase.

The Calcium Chloride Stabilized section is a mixture of Modified Subbase and 0.75 gal/yd^2 (3.4 L/m^2) of 35 percent liquid calcium chloride solution.

The Standard Subbase Control section consists of standard subbase aggregate MDOT specification 703.06b Type D with a 6 inch maximum aggregate size.

Construction on this project started in September 1990 and was completed in the summer of 1991. A background of the stabilization agents, their uses, advantages and disadvantages is explained in the MDOT construction report titled "Field Trial of Gravel Stabilization Methods", Experimental Construction Report 92-34, printed December 1991. This report also provided preliminary design results as well as test results obtained during construction. In addition to the test results, a plan for long term monitoring was also included in Appendix G and reproduced for this report in Table 1. Some of the features to be monitored are rutting and serviceability, such as roughness and overall performance. Strength measurements using pavement deflection was also suggested. Most of the evaluations can be performed with the Automatic Road Analyzer and Falling Weight Deflectometer test vehicles. Long term monitoring of the calcium chloride is specifically mentioned. For this phase they recommend boring test holes and sampling the base every 5th year to monitor the possibility of leaching calcium chloride.

Project Evaluation

This report covers the period of time from December 2003 thru September 2005 and is the Final report for this experimental project.

Table 1 contains a Testing Schedule for the project. The table has been updated as a result of recommendations in the 5th Interim Report. Calcium Chloride was not recommended as a stabilizing agent due to low structural readings and the high incidence of pavement distress. As a result, $CaCl^2$ Leaching tests have been discontinued. Cross Section and Profile Elevation measurements exhibited little change in six years and have also been discontinued. According to the revised Test Schedule, roughness, rut depths, pavement deflections and crack survey data were obtained for this report. Results of the 2005 testing and visual evaluation indicated very little change in condition. For this reason, it was determined that 2005 would be the final year for evaluation of this project.

Table 1
Testing Schedule for Cyr – Van Buren
Field Trial of Gravel Stabilization Methods

Year	ARAN Ride (IRI)	ARAN Rut Depth	Pavement Deflection	Elevation X-Sections	Elevation Profile	Crack Survey	$CaCl_2$ Leaching
1991	*	*	*				
1992	*	*	*	*	*	*	
1993	*	*	*	*	*	*	
1994	*	*	*				
1995	*	*	*	*	*	*	*
1996	*	*	*				
1997	*	*	*	*	*	*	
1998						*	
1999	*	*	*			*	
2000						*	
2001	*	*	*			*	
2002						*	
2003	*	*	*			*	
2004						*	
2005	*	*	*			*	

Ride Summary

The Automatic Road Analyzer (ARAN) test vehicle was replaced in 1998 with an updated ARAN. The new ARAN was utilized to measure roughness; this is an ASTM Class II profiler using lasers to measure the vehicle's height above the road surface and accelerometers to measure vertical forces caused by surface deformities. Measurements are recorded every two inches in each wheel path. Data was collected on July 28, 2005 as part of the final evaluation. Results are graphically presented in Figure 2 using International Roughness Index (IRI) values.

The Standard Subbase section continues to have the smoothest ride with an average IRI value of 86.23 (1.36 m/km). This is an increase of 17.2 percent over the 73.56 (1.16 m/km) value reported in 2003. The Soil Cement section increased 2.7 percent to 100.23 (1.58 m/km) from a 2003 reading of 97.55 (1.54 m/km). The Asphalt Stabilized section showed the largest increase from 99.8 (1.58 m/km) in 2003, to 131.56 (2.08 m/km) in 2005 which was an increase of 31.8 percent. This increase is also significant in that it caused the Asphalt Stabilized section to become the roughest section, just slightly rougher that the Modified Subbase section.

When comparing original IRI values collected in 1991 with those collected in 2005, the percentage of overall increase (80.04 percent) was actually smallest in the Soil Cement section. The IRI value for the Asphalt Stabilized section increased 85.37 percent, while the Standard Subbase value increased 104.16 percent from its original reading. IRI values for the Calcium Chloride and the Modified Subbase sections increased the most at 123.66 percent and 124.91 percent, respectively.

A statistical analysis of 2005 IRI data using Tukey's Studentized Range (HSD) Test shows no significant difference between each section. IRI values for each section continue to be in the smooth range of 0 – 190 inches/mile (0 – 3.0 meters/kilometer).

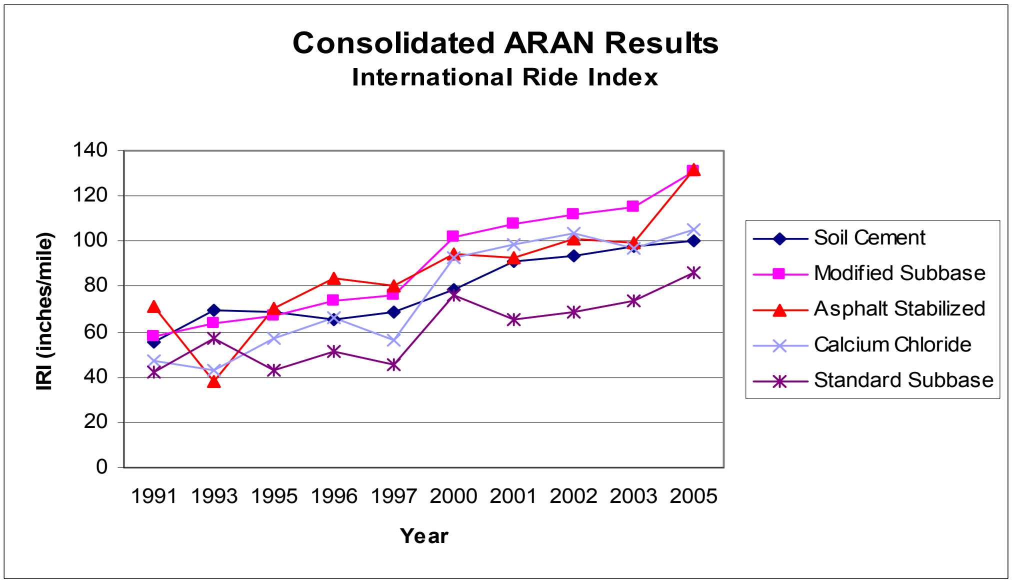

Figure 2. Ride Summary

Rut Depth Summary

The ARAN test vehicle was also utilized to measure rut depths. The ARAN calculates rut depths in real time using ultrasonic sensors spaced 4 inches (102 millimeters) apart on a bar that traverses the width of the travel lane. Rut depths are collected by measuring the distance between the bar and road surface creating a transverse profile of the roadway at 50 foot (15 meters) intervals. Figure 3 contains a graphical display of the test results.

Rut Depths in 2005 remained relatively constant when compared to 2003 readings. The Soil Cement section showed the largest increase from 0.240 inches (6.1 mm) in 2003, to 0.283 inches (7.2 mm) in 2005. Rut Depths for each section are minimal considering this project has been in service for approximately 14 years. A statistical review of this data indicates no significant difference between sections with respect to rutting.

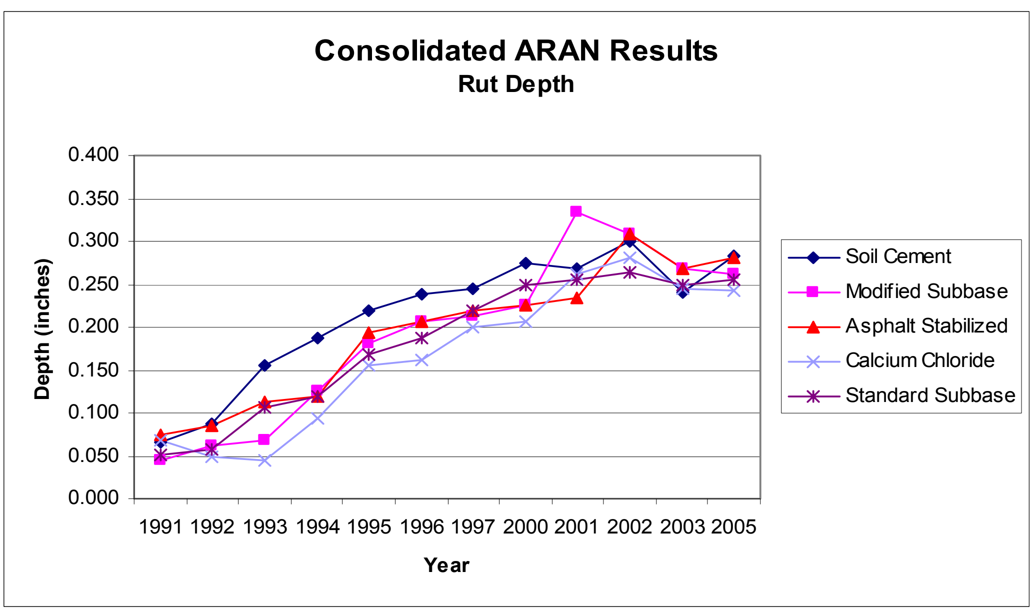

Figure 3. Rut Depth Summary

Pavement Deflection Summary

Structural conditions were measured using two different test vehicles, the Road Rater and the Falling Weight Deflectometer (FWD).

The Road Rater was used from 1991 to 1996. This test vehicle has five sensors that measure pavement deflections as a weight vibrates the pavement at a specific frequency. The results are displayed in Figure 4 as an overlay required which is the depth of overlay necessary to restore each section to a 20 year design life using 24 inches (610 millimeters) of subbase and 6 inches (153 millimeters) of bituminous pavement, the lower the number the stronger the section. All readings are negative suggesting no overlay is necessary.

During this time period the Calcium Chloride, Modified Subbase, and Standard Subbase sections were structurally similar. The Asphalt Stabilized section has improved stability and the Soil Cement section has the greatest stability.

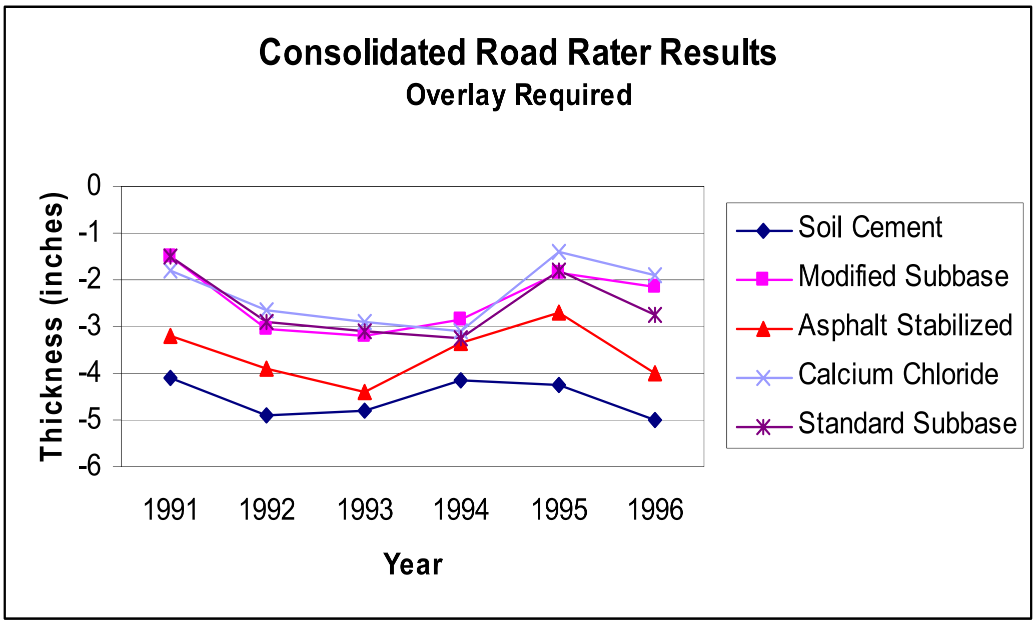

Figure 4. Road Rater Summary

The FWD also measures pavement deflections. This unit drops a weight onto a platform that is resting on the pavement, creating deflections that are recorded by seven sensors extending away from the platform. Pavement deflections indicate the structural stability of the roadway to a depth of 5 feet (1.5 meters). FWD deflections were recorded on September 7, 2005 and results are displayed in Figure 5 as an effective existing pavement structural number (SNeff) for 24 inches (610 millimeters) of subbase and 6 inches (153 millimeters) of bituminous pavement combined, the higher the number the stronger the section. Similar roadways of this design have structural numbers between 5 and 6.

Structural Numbers developed for this evaluation period actually showed an increase in strength when compared to the Structural Numbers reported in 2003. The cause of this “strengthening” is unknown. One possibility is rain fall and subsequent drainage issues. A review of climatological data indicated that there was 6.88 inches (174.7 mm)of precipitation for the thirty days previous to the August 18, 2003 test date, while 3.94 inches (100.1 mm)of precipitation fell during the 30 days previous to the September 7, 2005 test date. The additional rain fall in 2003 may have caused the sections to be more saturated, in turn causing increased deflections which would cause the Structural Numbers to decrease.

The Soil Cement section has consistently had the highest Structural Number throughout the life of this experimental project. The Asphalt Stabilized section has had the next highest Structural value, while the three remaining sections have performed similar to each other throughout the period.

A statistical analysis of FWD data is presented in Appendix A. Results indicate a significant statistical difference exists when comparing the Soil Cement section to the four remaining sections. The Asphalt Stabilized section is also significantly different than the Modified Subbase section. No significant difference exists between the Modified Subbase, Calcium Chloride and Standard Subbase sections.

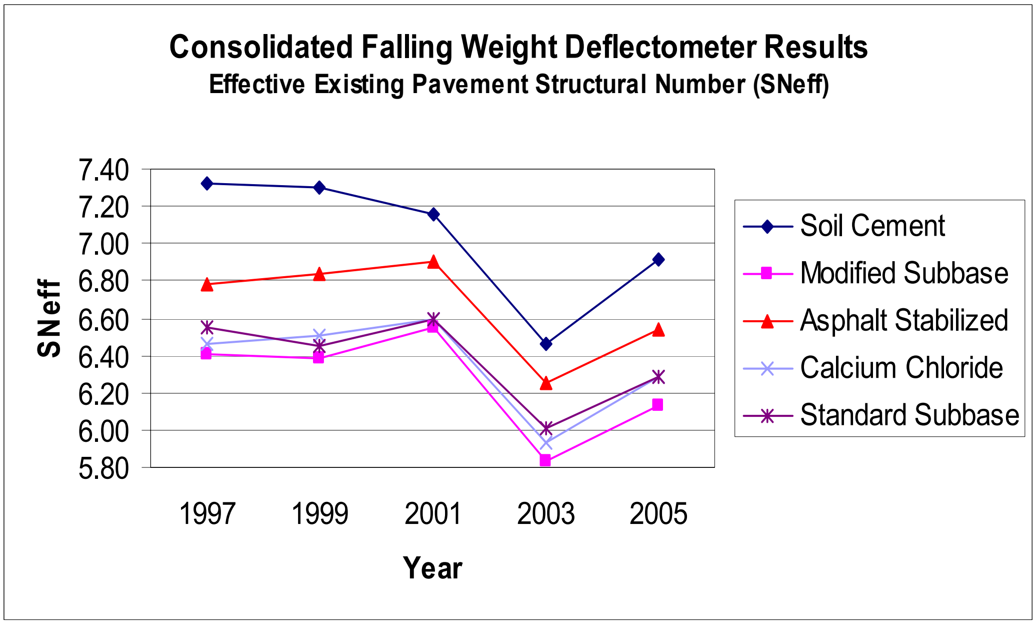

Figure 5. Falling Weight Deflectometer Summary

Crack Survey Summary

The final scheduled visual inspection was conducted on September 6, 2005. Some increase in cracking was identified since the previous inspection conducted in September, 2003. All of the cracks identified up to and including the 2002 evaluation have been crack sealed. Photos of each section are included at the end of this report.

Asphalt flushed areas have remained the same since the last evaluation in 2003. One area is 45 feet (13.7 meters) in length between stations 1032+00 and 1033+00. The asphalt has pooled at centerline on the inner wheelpath and is flowing to the shoulder in the outer wheelpath (Photo 6). The asphalt is 0.5 inches (13 mm) thick in some areas. To a lesser degree, flushing is also present in the Soil Cement, Modified Subbase, and Standard Subbase sections. These sections have areas of flushing 1 to10 feet (0.3 to 3 meters) in length. The Calcium Chloride section has no flushed asphalt areas.

As stated in 2003, the Modified Subbase, Asphalt Stabilized and Calcium Chloride stabilized sections have full length centerline joint separation. In the Soil Cement section, the centerline joint separation increased 17 feet (5.2 meters) to a total length of 105 feet (32 meters). The Standard Subbase section had an increase of 22 feet (6.7 meters), for a total of 192 feet (58.5 meters) of centerline joint separation.

Joint separation at the shoulder is also present in each of the sections. Separation in the Asphalt Stabilized section increased slightly to 324 feet (98.8 meters) compared to the 320 feet (97.5 meters) that was reported in 2003. Shoulder joint separation in the Soil Cement section increased to 198 feet (60.4 meters), while the Modified Subbase section increased 10 feet (3.1 meters) to a total of 192 feet (58.5 meters). Shoulder joint separation in both the Calcium Chloride and Standard Subbase sections remained constant at 153 feet and 192 feet (46.6 meters and 58.5 meters) respectively.

Transverse cracking was also identified in each section, with the Soil Cement section having the most at 87 linear feet (26.5 meters). The Asphalt Stabilized section had 60 linear feet (18.3 meters), while 56 linear feet (17.1 meters) were identified in the Standard Subbase section. Both the Modified Subbase and Calcium Chloride sections had 24 linear feet (7.3 meters), or 1 full width transverse crack.

Longitudinal cracking was present in both the Calcium Chloride and Soil Cement sections, with 160 and 13 linear feet (48.8 meters and 4 meters) of cracking identified respectively. The three remaining sections showed no sign of longitudinal cracking.

Load associated cracking was not observed within the experimental project.

Conclusion

Having been in service for approximately 14 years, each of the experimental subsections within this project are performing quite well.

One potential disadvantage to this Research feature was the limited length of each experimental section.

Of the four criteria evaluated (Roughness, Rutting, Structural Strength and Cracking), only Structural Strength exhibited a significant statistical difference in either of the sections.

Cracking is the most prevalent in the Calcium Chloride section, while the Modified Subbase section had the fewest cracks present.

The Standard Subbase section had the lowest IRI value, while the Asphalt Stabilized and Modified Subbase sections had the roughest ride values.

Rutting was considered minimal in each of the sections with depths ranging from 0.243 inches (6.2 mm) in the Calcium Chloride section, to 0.283 inches (7.2 mm) in the Soil Cement section. This one millimeter difference is considered insignificant and may be within the allowable margin of error for the ARAN vehicle, considering longitudinal alignment, etc.

Structurally, the Soil Cement section had a significant statistical difference when compared to the other four sections. The Soil Cement section consistently “outperformed” the other sections throughout the evaluation period with respect to Structural Strength.

This difference in strength has the potential to positively impact the performance of the Soil Cement section for follow-up treatments. A typical follow-up treatment for a reconstructed highway is an overlay. Considering the additional strength that the Soil Cement continues to provide, it is appropriate to assume that future overlays will be better supported by the Soil Cement treated base.

The positive, long term implications of a superior performing subbase layer, particularly in northern Maine where gravel subbase issues have long been a concern, makes the Soil Cement treatment a viable option in highway construction.

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Additional Available Documents:
Field Trial of Gravel Stabilization Methods, Construction Report # 92-34, December 1991
First Interim Report, May 1993
Second Interim Report, February 1995
Third Interim Report, January 1996
Fourth Interim Report, January 1997
Fifth Interim Report, May 1998
Sixth Interim Report, September 2000
Seventh Interim Report, June 2003
Eighth Interim Report, April 2004

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APPENDIX A

STATISTICAL ANALYSIS of FWD MEASUREMENTS
The SAS System
The GLM Procedure

Class Level Information

Class	Levels	Values
Section	5	AS CC MS SC SS

Number of observations 60
Dependent Variable: SN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	4.49114333	1.12278583	12.51	<.0001
Error	55	4.93547500	0.08973591		
Corrected Total	59	9.42661833			

R-Square	Coeff Var	Root MSE	TESTs Mean
0.476432	4.667611	0.299560	6.417833

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Section	4	4.49114333	1.12278583	12.51	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Section	4	4.49114333	1.12278583	12.51	<.0001

Tukey's Studentized Range (HSD) Test for TESTs

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	55
Error Mean Square	0.089736
Critical Value of Studentized Range	3.98855
Minimum Significant Difference	0.3449

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	group

	A	6.8942	12	SC – Soil Cement
	B	6.5258	12	AS – Asphalt Stabilized
C	B	6.2900	12	SS – Standard Subbase
C	B	6.2767	12	CC – Calcium Chloride
C		6.1025	12	MS – Modified Subbase


Photo 1. 2005, Soil Cement Section


Photo 2. 2005, Modified Subbase Section


Photo 3. 2005, Asphalt Stabilized Section


Photo 4. 2005, Calcium Chloride Section

Photo 5. 2005, Standard Subbase Section

Photo 6. 2002, Asphalt Stabilized Section, Asphalt Flushed Area