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Maine Department of Transportation

Transportation Research Division

Technical Report 99-8

Experimental Use of Geogrids as an Alternative to Gravel Placement

Interim Report - Third Year, July 2004

Transportation Research Division

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Introduction

With the ongoing demand for improved infrastructure, the Maine Department of Transportation (MDOT) continues to identify and evaluate new and innovative construction methods and materials. The Department's Capital Highway Improvement Program (CHIP) attempts to reduce construction costs by utilizing existing roadway base and pavement materials. In the fall of 1998, MDOT began construction of a project that incorporated this philosophy and an experimental feature of geogrids to minimize the need for additional base gravel materials.

Project Location/Description

This project is located on Route(s) #6-15 in Big Moose Township (formerly Big Squaw Township), Piscataquis County. Figure 1 contains a location map. This 5.94-kilometer section of roadway was originally identified to receive a standard 16 mm maintenance mulch overlay. After further review and several discussions concerning the significant distortion (crown) of the existing roadway and the high volume of heavy truck traffic, it was determined that this section was an excellent candidate for the CHIP process.

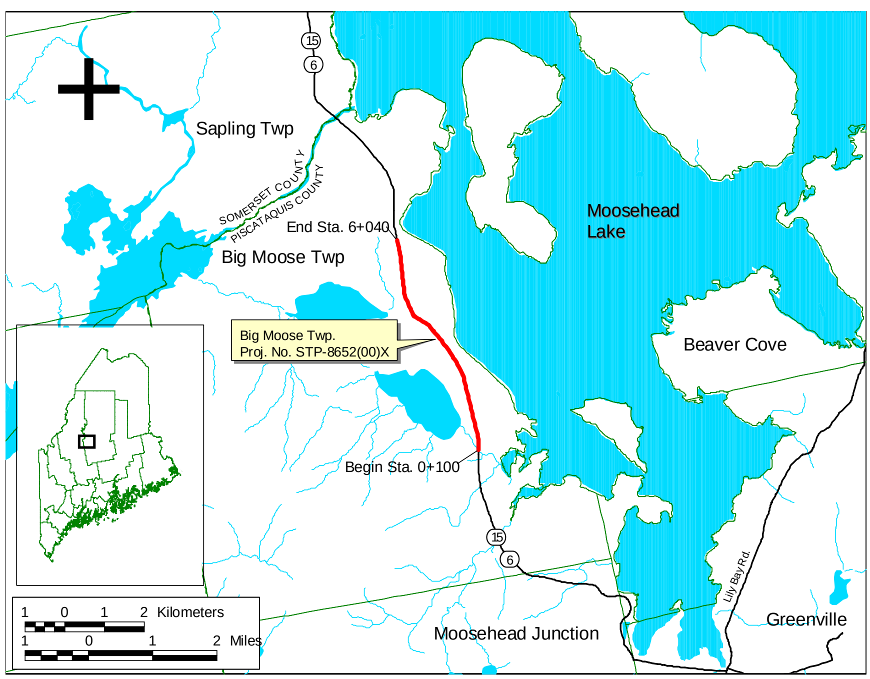

Figure 1: Project location map

The experimental feature of this project consists of 11 sections of varying length encompassing the entire project length. The primary focus of this research was to determine if placement of a geogrid product could minimize the need for additional base gravel materials.

As this research evolved, it became apparent that not only could MDOT evaluate the effectiveness of geogrids, but also conduct an analysis on each of the construction procedures utilized within this project.

MDOT's Geotechnical group played a significant role in selecting the geogrid product used in the research portion of this project and in establishing the overall research strategy. The geogrid product is Biaxial Geogrid BX1200 (SS-2), manufactured by The Tensar Corporation of Morrow, Georgia.

Construction Procedures

Preliminary data collection utilizing the Falling Weight Deflectometer plus construction procedures for each of the four types of treatments will not be included in this report. This information as well as typical cross sections and construction photos can be reviewed in the Construction or First Interim Report.

A summary of the length, location, and final average gravel and pavement depths for each section are presented in Table 1.

Table 1: Section Limits with Layer Depths

Section Number	Location, m	Treatment	Average Layer Depth, mm	
			Gravel	Pavement
1	0+100 - 0+220	Undercut	650	110
2	0+220 - 0+600	Geogrid	685	115
3	0+600 - 0+700	Control	750	115
4	0+700 - 2+770	Reclaim	685	115
5	2+770 - 3+270	Geogrid	700	95
6	3+270 - 3+390	Control	640	110
7	3+390 - 3+520	Geogrid	540	115
8	3+520 - 5+120	Reclaim	590	110
9	5+120 - 5+320	Geogrid	680	120
10	5+320 - 5+400	Undercut	420	165
11	5+400 - 6+040	Reclaim	650	115

Project Evaluation

The project will be evaluated by utilizing the Falling Weight Deflectometer (FWD) and Automatic Road Analyzer (ARAN) test vehicles and a visual inspection. The FWD records pavement deflections that are processed to measure Subgrade Modulus, Pavement Modulus, and Structural Number. The ARAN measures wheel rut depths and smoothness reported as International Roughness Index.

Visual Inspection

A visual inspection of the experimental project was completed on October 22, 2002. The overall appearance of the project is very good after three years of traffic. Table 2 contains a summary of cracking for each section. Types of cracking surveyed in the summary include centerline, transverse, longitudinal, and load cracking. To equally represent the amount of cracking in each section, centerline and longitudinal cracking is a percentage of the section length, transverse cracking is the number of full width cracks per 100 meters, and load cracking is a percentage of the section area.

Two sections have no cracking, Control Section 3 and Undercut Section 10. Control Section 6 has centerline cracking only. Undercut Section 1 has a high amount of centerline and transverse cracking. Transverse cracks are located in an area with ledge under the roadway between station 0+150 and 0+170. This may be generating differential movement of the subbase.

Reclaim sections 8 and 4 are showing the most pavement deterioration with cracking in all categories. The third reclaim section has centerline and transverse cracking only.

All Geogrid sections have cracking of one form or another. Section 2 has longitudinal cracking only. Section 5 has centerline and a small amount of initial load cracking. Section 7 has centerline and the second highest amount of transverse cracking. Section 9 has a small amount of initial load cracking.

Table 2: Crack Survey Summary

Section # / Treatment	Crack Type					
	Centerline, % of length	Transverse, # / 100 meters	Longitudinal, % of length	Load, % of area		
				Initial	Moderate	Severe
1 / Undercut	8.3%	2.1	0.0%	0.0%	0.0%	0.0%
2 / Geogrid	0.0%	0.0	0.8%	0.0%	0.0%	0.0%
3 / Control	0.0%	0.0	0.0%	0.0%	0.0%	0.0%
4 / Reclaim	8.1%	0.4	1.3%	0.5%	0.0%	0.0%
5 / Geogrid	2.6%	0.0	0.0%	0.1%	0.0%	0.0%
6 / Control	5.8%	0.0	0.0%	0.0%	0.0%	0.0%
7 / Geogrid	7.7%	0.8	0.0%	0.0%	0.0%	0.0%
8 / Reclaim	9.3%	0.3	1.1%	0.3%	0.0%	0.0%
9 / Geogrid	0.0%	0.0	0.0%	0.1%	0.0%	0.0%
10 / Undercut	0.0%	0.0	0.0%	0.0%	0.0%	0.0%
11 / Reclaim	0.2%	0.5	0.0%	0.0%	0.0%	0.0%

Falling Weight Deflectometer

FWD readings were collected in July of 2002. The FWD measures deflections by dropping a weight onto a force platform generating approximately 9000 pounds of force on the pavement. Seven sensors record deflections at various distances from the platform. Deflections are processed using DARWin 3.01 software. Subgrade Modulus, Pavement Modulus and Effective Existing Structural Numbers were calculated for each test point. There are a minimum of ten tests per section.

Figure 2 contains a summary of the Subgrade Modulus. Modulus results for all sections are lower than last year. With the exception of Undercut Section One, all remaining sections have about the same Subgrade Modulus. Section one has ledge under the roadway resulting in a higher average Subgrade Modulus value. A statistical analysis of the data using Tukey's Studentized Range (HSD) Test verifies that Section 1 is significantly higher than the remaining sections.

All Pavement Modulus values are lower than the previous year as can be seen in Figure 3. Undercut Section 10 has the highest Pavement Modulus and Control Section 3 has the lowest. The high value for section 10 is attributed to the extra depth of HMA, which is a minimum of 45 mm (1.8 in) more than the remaining sections. It’s puzzling why Control Section 3 has a low average Pavement Modulus. This section has a similar amount of HMA and a greater amount of gravel than the remaining sections. All

Geogrid sections have similar Pavement Modulus values ranging between 456,429 and 397,791 kPa (66199 and 57695 psi). Statistical analysis of the Pavement Modulus results reveals that Undercut Section 10 is significantly higher than all other sections with the exception of Undercut Section 1, Undercut Section 1 is significantly higher than Sections 3, 4, 5, and 11, and Control Section 3 is significantly lower than Sections 2, 7, 8, and 9.

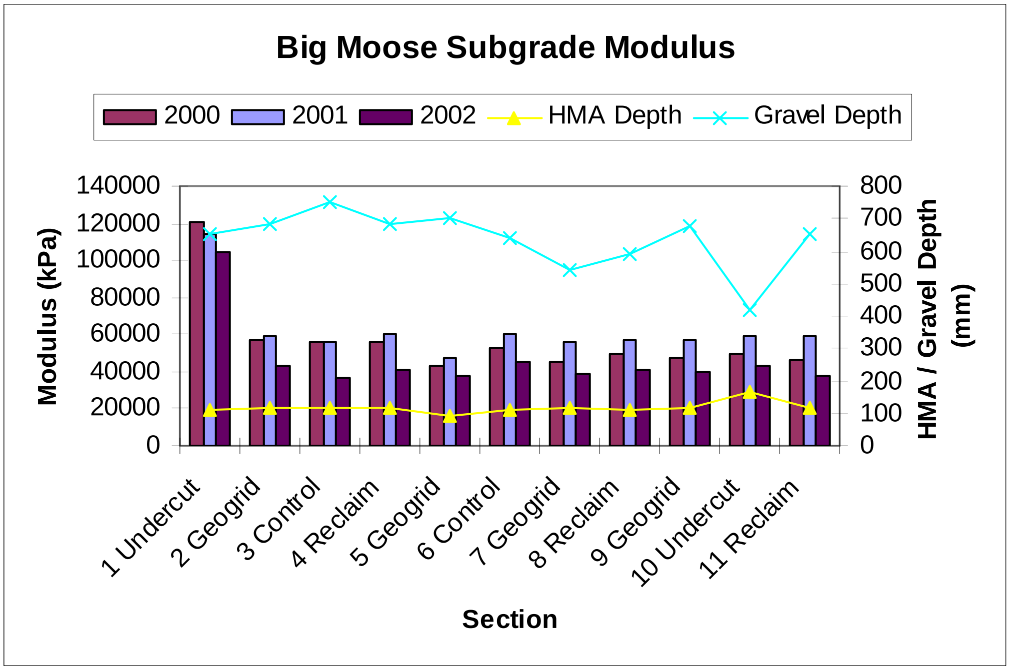

Figure 2: Subgrade Modulus summary

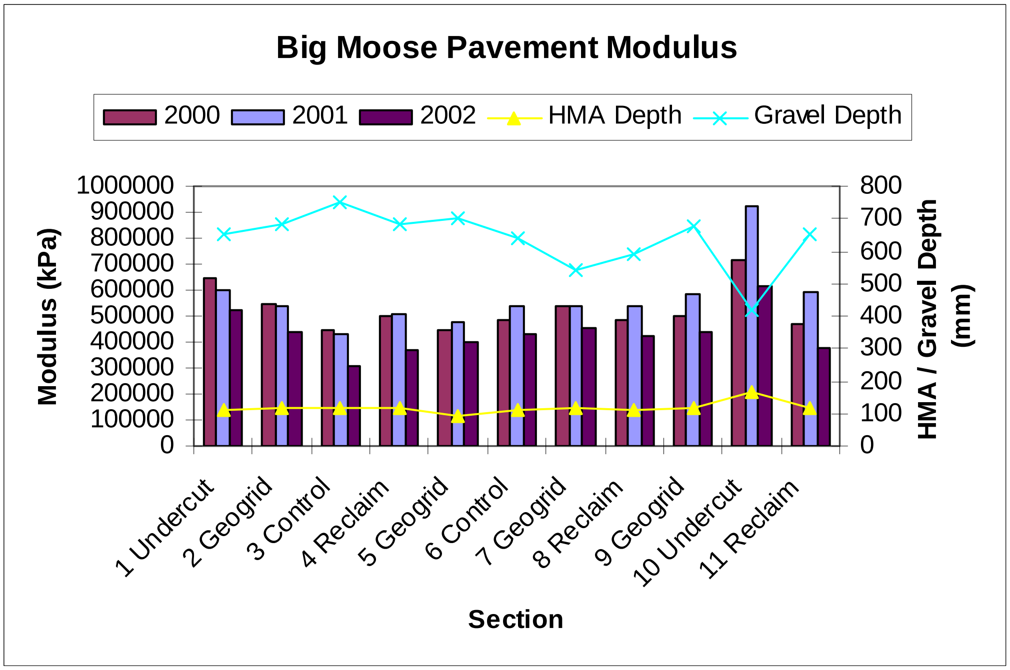

Figure 3: Pavement Modulus summary

A summary of the Effective Existing Structural Number is presented in Figure 4. The Structural Number indicates the load carrying capacity of the pavement and subbase gravel combined.

There are three distinct groups of Structural Numbers, Section 1, 2, 3, 5, and 9 has Structural Numbers between 140 and 146, Sections 4, 6, and 11 are between 132 and 137, and Sections 7, 8, and 10 are between 119 and 126.

Section 2 and 9 has the highest SN at 146. Both sections have similar gravel and pavement depths with Geogrid reinforcement. Another Section with similar gravel and pavement depths but without Geogrid reinforcement is Reclaim Section 4. The SN in this section is nearly ten points lower suggesting the Geogrid material in Sections 2 and 9 is displacing traffic load more efficiently.

Another interesting comparison is between Control Section 3 and Geogrid Section 5. Geogrid Section 5 has 50 mm (2 in) less gravel and 20 mm (0.75 in) less HMA than Control Section 3 and they each have a SN of 140 indicating the Geogrid is supplying greater support with less gravel and HMA. The downside is Section 5 is showing signs of initial load cracking possibly due to the reduce thickness of HMA.

Geogrid Section 7 has the lowest SN of all the Geogrid sections at 121. This section has the lowest amount of gravel for Geogrid sections at 540 mm (21.25 in) suggesting that Geogrid reinforcement may need a sufficient amount of gravel to be effective in distributing load.

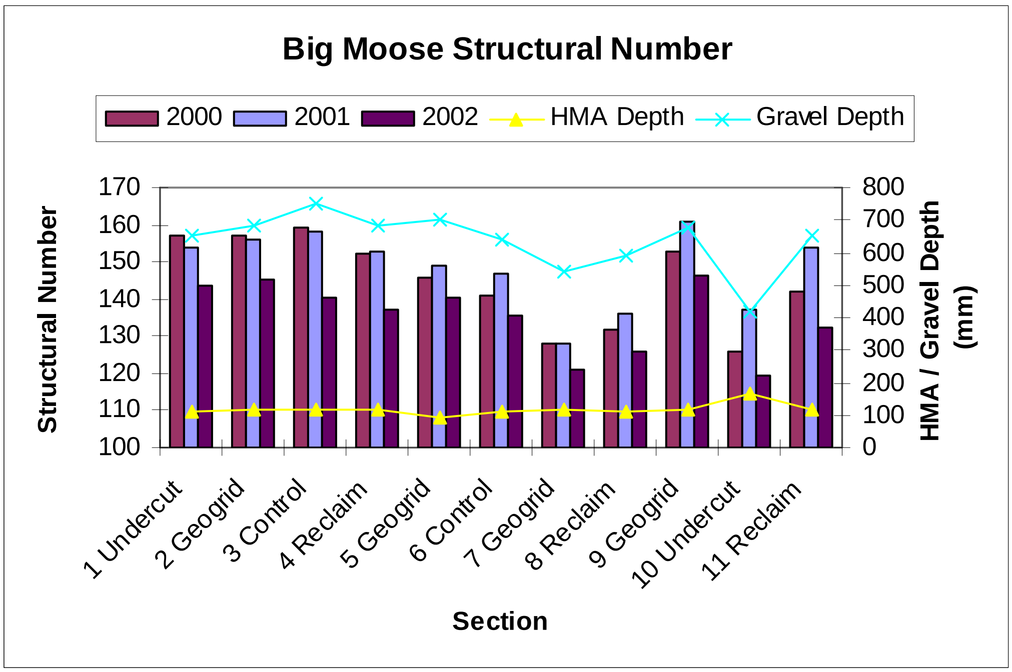

Figure 4: Effective Existing Structural Number summary

Effective Existing Structural Numbers were analyzed using Tukey's Studentized Range Test (HSD). This test compares test sections to determine if there is a significant difference between Structural Numbers. Results of the difference between means for each section are displayed in Table 3. Analysis shows that Geogrid Section 9 and Geogrid Section 2 are significantly different than sections 4, 6, 11, 8, 7, and 10; Undercut Section 1 and Geogrid Section 5 are significantly different than sections 11, 8, 7, and 10; Control Section 3 and Reclaim Section 4 are significantly different than sections 8, 7, and 10; Control Section 6 and Reclaim Section 11 are significantly different than sections 7 and 10.

Table 3: Structural Number comparison using Tukey's Studentized Range Test (HSD)

Alpha	0.05
Error Degrees of Freedom	175
Error Mean Square	60.11215
Critical Value of Studentized Range	4.61291

Comparisons significant at the 0.05 level are indicated by *

	2 Geogrid	1 Undercut	3 Control	5 Geogrid	4 Reclaim	6 Control	11 Reclaim	8 Reclaim	7 Geogrid	10 Undercut
9 Geogrid	0.553	2.598	5.753	5.922	* 9.136	* 10.653	* 13.767	* 20.338	* 25.115	* 26.719
2 Geogrid		2.045	5.200	5.370	* 8.583	* 10.100	* 13.214	* 19.786	* 24.563	* 26.167
1 Undercut			3.155	3.324	6.538	8.055	* 11.169	* 17.740	* 22.517	* 24.121
3 Control				0.170	3.383	4.900	8.014	* 14.586	* 19.363	* 20.967
5 Geogrid					3.214	4.730	* 7.845	* 14.416	* 19.193	* 20.797
4 Reclaim						1.517	4.631	* 11.202	* 15.979	* 17.583
6 Control							3.114	9.686	* 14.463	* 16.067
11 Reclaim								6.571	* 11.348	* 12.952
8 Reclaim									4.777	6.381
7 Geogrid										1.604

ARAN International Ride Index

Smoothness data was collected on November 1, 2002 using the ARAN test vehicle. This is an ASTM Class II profile-measuring device that is capable of accurately measuring roadway smoothness. Smoothness is reported in International Ride Index (IRI) values. Table 4 contains ranges of IRI values and a verbal description of each range.

Table 4: IRI Range and Description

IRI (Meters/Kilometer)	IRI (Inches/Mile)	Verbal Description
1.02 - 1.57	65 - 99	Comfortable ride at 105/65 kph/mph. No noticeable potholes, distortions, or rutting. High quality pavement.
1.58 - 3.15	100 - 199	Comfortable ride at 88/55 kph/mph. Moderately perceptible movements induced by occasional patches, distortions, or rutting.
3.16 - 4.73	200 - 299	Comfortable ride at 72/45 kph/mph. Noticeable movements and swaying induced by frequent patches and occasional potholes. Some distortion and rutting.
Greater than 4.73	Greater than 299	Frequent abrupt movements induced by many patches, distortions, potholes, and rutting. Ride quality greatly diminished.

Figure 5 contains an International Ride Index (IRI) summary of each section from 2000 to 2002. Over the past year, eight sections have higher IRI values and three have lower. Most IRI readings are in the high quality pavement range between 1.02 and 1.57 m/km (65 -99 in/mi) with the exception of Undercut Section 1 which increased 9.2 percent to 1.79 m/km (113 in/mi). Section 1 smoothness values may be influenced by ledge under the roadway.

Geogrid Section 7 has the second highest IRI at 1.56 m/km (99 in/mi) which is 8.6 percent lower than 2001 results. As mentioned earlier in the report, Section 7 has a gravel depth of 540 mm (21 in) which may be too thin for the Geogrid to effectively support the roadway.

Geogrid Section 2 has the smoothest ride with an IRI of 1.22 m/km (77 in/mi), a 0.8 percent increase, followed by Geogrid Sections 5 and 9 with IRI values of 1.25 m/km (79 in/mi), a 3.2 percent increase and 3.1 percent decrease respectively.

Control Sections 6 and 3 also have smooth roadways with respective IRI readings of 1.27, a 2.6 percent decrease, and 1.30 m/km (80 and 82 in/mi), the largest increase at 9.4 percent.

Undercut Section 10 with 165 mm (6.5 in) of HMA has an IRI of 1.32, a 3.4 percent increase. The additional HMA is contributing to the smooth ride.

Reclaim Sections 4, 11 and 8 have IRI values of 1.39, 1.39 and 1.40 an increase of 9.2, 3.4, and 5.7 percent respectively.

Undercut Section 11 with 165 mm (6.5 in) of HMA increased 3.4 percent to an IRI of 1.32.

Tukey's Studentized Range (HSD) Test analysis of IRI data reveals a significant difference between Geogrid Section 5 and sections 1 and 11.

Future tests will determine if geogrid material improves long-term smoothness of the road.

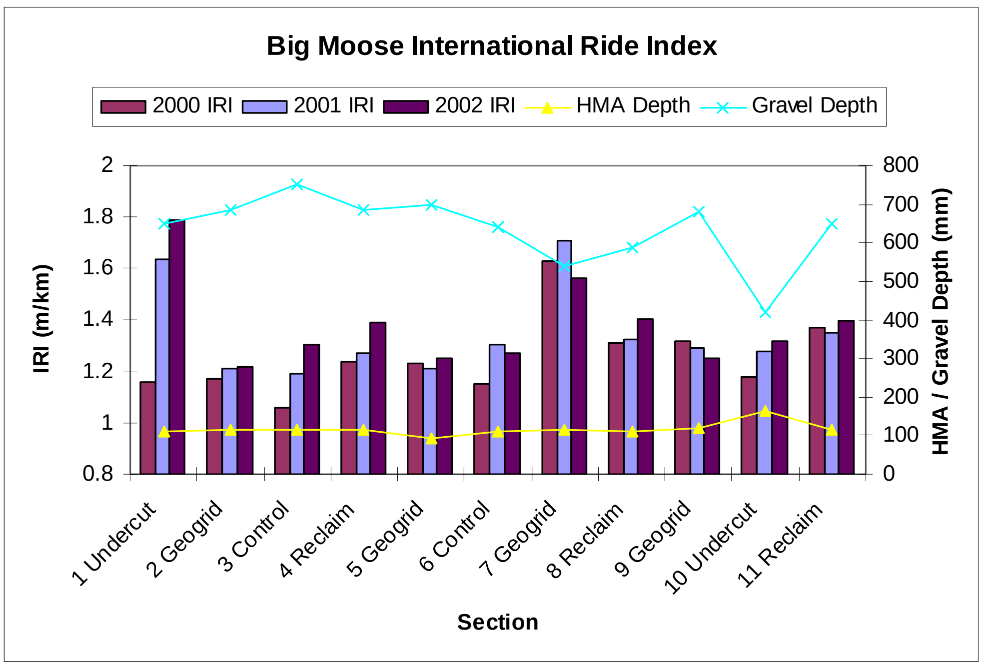

Figure 5: International Ride Index summary

ARAN Rut Depth

The ARAN test vehicle was utilized to measure rut depths. Measurements are recorded at each 20 m station to an accuracy of 1.5 mm (0.06 in). Figure 6 contains average rut depths for each section from 2000 to 2002.

Ruts range in depth from 4.23 to 5.52 mm (0.17 to 0.22 in), nearly twice as deep as last year.

Geogrid Section 9 has the smallest amount of rutting at 4.23 mm (0.17 in) an increase of 42 percent. This section has the greatest average thickness of HMA of all Geogrid sections at 120 mm (4.7 in). That combined with 680 mm (26.7 in) of subbase gravel may be distributing the weight better and reducing the amount of rutting.

The remaining sections that have less than 5 mm (0.20 in) of rut depth include; Undercut Section 1 at 4.69 mm (0.18 in) a 52 percent increase, Geogrid Section 2 at 4.78 mm (0.19 in) a 63 percent increase, Geogrid Section 5 at 4.83 mm (0.19 in) an increase of 65 percent, and Undercut Section 10 at 4.97 mm (0.20 in) an increase of 77 percent.

Sections with greater than 5 mm (0.20 in) of rut depth include Reclaim Section 11 at 5.10 mm (0.20 in) an increase of 50 percent, Reclaim Section 4 at 5.16 mm (0.20 in) an increase of 58 percent, Reclaim Section 8 at 5.33 mm (0.21 in) a 63 percent increase, Geogrid Section 7 at 5.44 mm (0.21 in) an increase of 48 percent, Control Section 3 at 5.45 mm (0.21 in) an increase of 82 percent, and Control Section 6 at 5.52 mm (0.22 in) an increase of 72 percent.

The low average rut depth in Undercut Section 1 may be influenced by ledge supporting the roadway. Three of the four Geogrid sections are in the top four sections with less than 5 mm (0.20 in) of rut depth. Although average rut depths nearly doubled, this is typical of a project exposed to traffic for three years.

Statistical analysis of the data reveals that Geogrid Section 9 is significantly different than sections 6, 7, 8, 4, and 11.

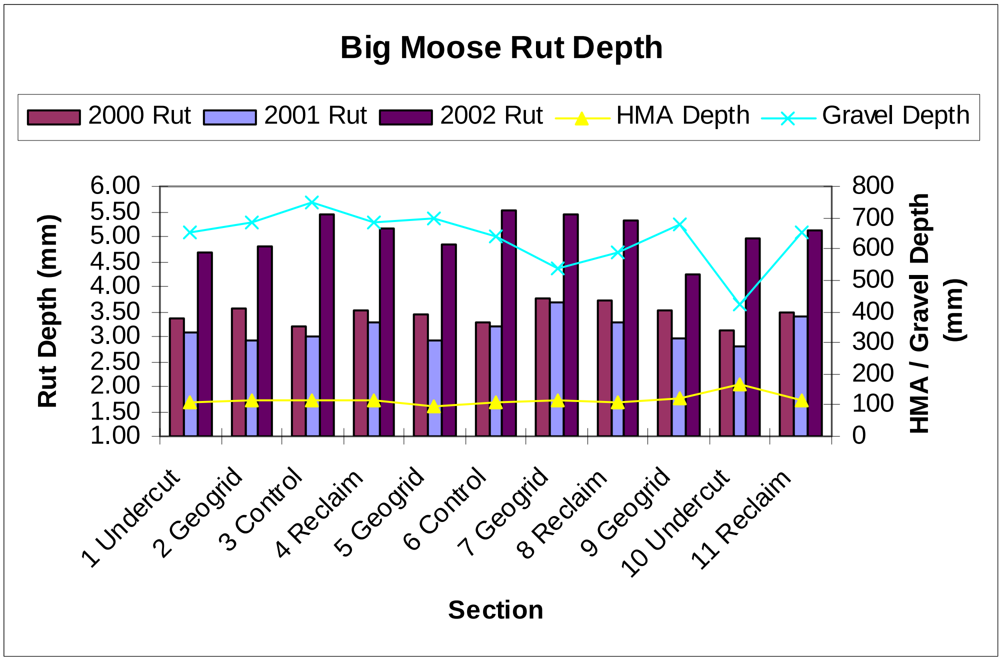

Figure 6: Rut depth summary

Rolling Dipstick

A Rolling Dipstick was utilized in an effort to monitor vertical movement of eight cross culverts along the project. Data was collected in April 2002 and again in October 2002 as part of the annual evaluation process. A total of three measurements were recorded in the right wheel path of each lane for a total of six profiles per culvert. Each profile is 20 meters (66 feet) in length centered over the culvert. Profiles are displayed as International Roughness Index values. There will be two summaries of IRI readings, one to compare fall IRI readings to monitor overall culvert movement from 2000 to 2002, and the other to compare spring and fall IRI readings within each year from 2000 to 2002 to monitor the amount of spring thaw displacement.

Fall IRI Comparison

Results of fall IRI readings are summarized in Figure 7.

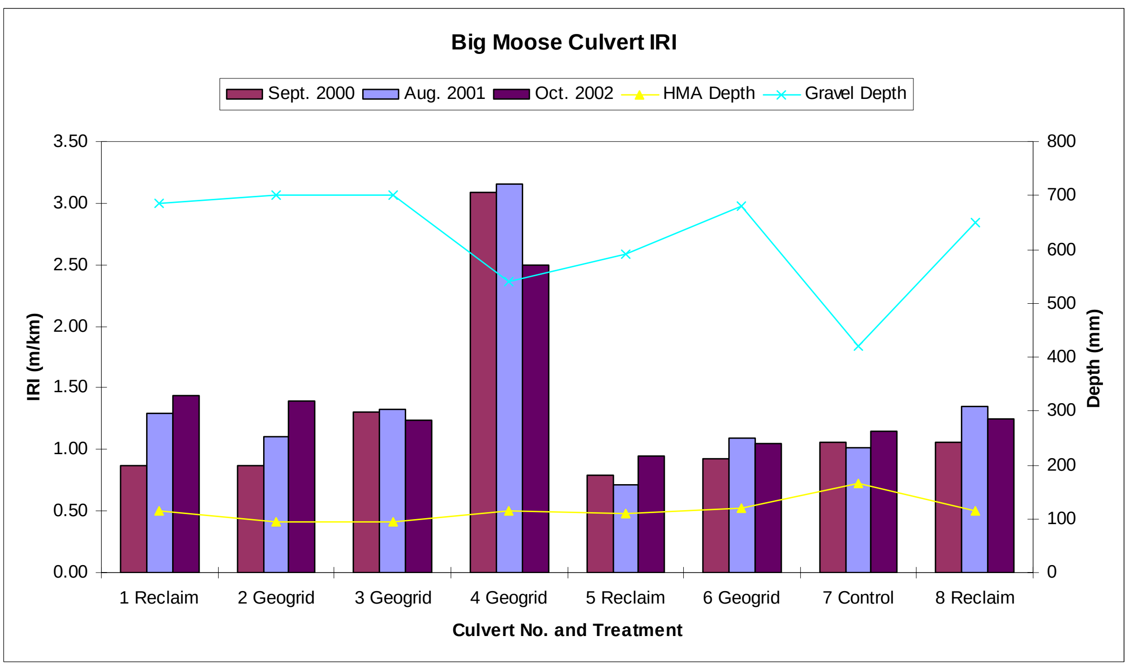

Figure 7: Culvert IRI summary

Three of the four Geogrid culverts had smoother profiles than in 2001. Reclaim culvert 8 also had a smoother profile than last year. The remaining culverts have a rougher profile.

Geogrid culvert 2 has the largest increase in IRI readings. Geogrid culvert 4 has the largest decrease in IRI readings. Frost movement lifted the east end of this culvert in the spring of 2001. It appears the culvert has settled in 2002 resulting in a smoother profile.

Overall there is little change and IRI values are in the High Quality Pavement Range of 1.02 to 1.57 m/km (65 to 99 in/mi) with the exception of Geogrid Culvert 4.

Spring vs. Fall IRI Comparison

Figure 8 contains IRI values of culvert areas comparing spring and fall profiles within the same year between 2000 and 2002.

Reclaim culvert 5 has the least amount of spring thaw movement. Geogrid culvert 4 has the most. As mentioned earlier in the report the section where culvert 4 is located has the least amount of gravel of all Geogrid sections and this may be a contributing factor in the higher amount of differential movement.

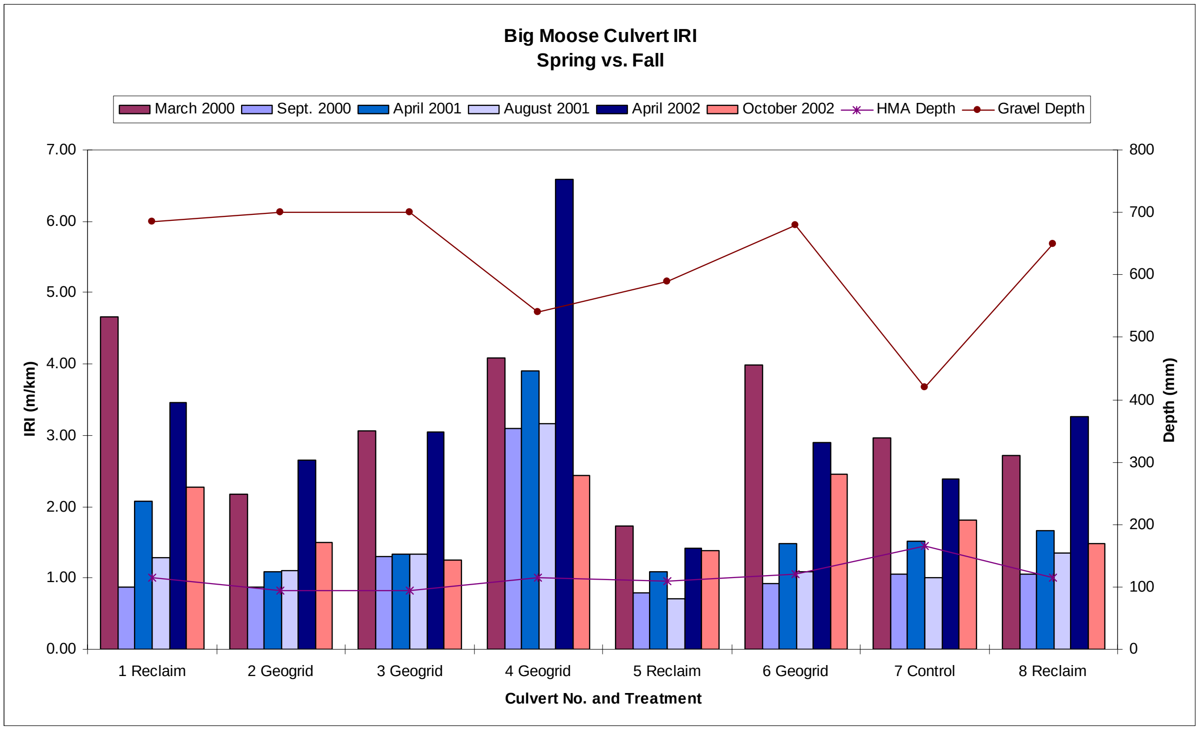

Figure 8: Spring vs. fall culvert IRI summary

Geogrid culvert 3 returns to a similar profile every fall. The remaining culverts have similar movement patterns.

Summary

When comparing Structural Numbers of sections with similar HMA and subbase gravel depths, Geogrid sections have higher Structural Numbers that displace traffic loads more efficiently which in turn extends roadway life.

Geogrid sections with suitable quantities of gravel have stabilized the roadway better than the remaining experimental sections. Geogrid manufactures claim the use of their products can reduce the amount of gravel necessary to stabilize the road. Based on available data this is true to a point but there may be a limit to the amount of gravel that can be reduced before structural integrity is compromised.

IRI data has not revealed any definitive advantage to utilizing Geogrid to stabilize cross culverts. Perhaps future tests can determine if the Geogrid culvert areas reduce the amount of frost movement.

The next field evaluation is scheduled for fall of 2003. FWD, ride, rut, and culvert data as well as visual analysis data will be collected and presented in the Fourth Year Interim Report

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Other Available Documents:
Construction Report, December 1999
Interim Report - First Year, February 2001
Interim Report – Second Year, August 2002