UTILIZATION OF DATA COLLECTED THROUGH PAVEMENT MANAGEMENT INFORMATION SYSTEMS TO EVALUATE GEOSYNTHETIC-STABILIZED ROADWAY PERFORMANCE UNDER ENVIRONMENTAL AND TRAFFIC LOADS

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ABSTRACT

Expansive clay subgrades have been the primary cause of damage to many Texas roadways. To mitigate this damage, the Texas Department of Transportation (TxDOT) has used geosynthetics to stabilize the base course of such roadways. However, suitability of this practice has not been fully evaluated. This paper presents an evaluation of the long-term performance of three Texas roadways founded on expansive clay subgrades. Geosynthetic-stabilized test sections and control (non-stabilized) test sections were constructed along the three identified roadways. Long-term performance of the test sections under traffic and environmental loads (induced by swelling and shrinkage of expansive clay subgrades) was evaluated using performance data collected as part of an annual performance monitoring program under TxDOT Performance Management System (PMS). Specifically, three performance measures including the condition score, the percentage of the longitudinal cracks, and the percentage of the total length of rut were used in the evaluation. Significant benefits were found for geosynthetic stabilization in all the three roadways. Benefits included enhanced overall condition and ride quality of the road under traffic and environmental loads as well as reduced percentage of longitudinal cracks. Two improvement factors (IFs), including Condition Score IF and Longitudinal Cracks IF, were defined to compare improvement from geosynthetic stabilization among various roadways. Evaluation of Longitudinal Cracks IF values indicated that the geosynthetic stabilization reduced the percentage of the longitudinal cracks by 70 to 95 %. On the other hand, evaluation of the Condition Score IF values showed that the geosynthetic stabilization increased the condition scores by 25 to 45 %. Utilizing information from PMS databases to evaluate benefits from geosynthetic stabilization introduces a suitable evaluation approach that can conveniently be adopted by researchers and practitioners. This approach is particularly useful for performance evaluation of long and/or high-traffic test sections for which other approaches for collection of performance data may not be practical. The evaluation presented in this paper also highlights the significance of collecting systematic performance data by transportation agencies to provide objective information to support important decisions on rehabilitation projects.

1. INTRODUCTION

Expansive soils are referred to the types of clay that are prone to large volume changes, in form of swelling and shrinkage, as they absorb or exude moisture. These soils have been one of the major sources of damages to a wide range of structures in the United States and around the world (Jones and Jones 1987). Roadways are specifically vulnerable to the damages resulted from expansive clay subgrades, partly due to comparatively small surcharge of roadway structures. The main type of roadway distresses induced by expansive clay subgrades has been identified as the environmental longitudinal cracks that develop mostly along the edges of the roadway following heave and settlement of the shoulders relative to the center of the roads (Zornberg et al. 2012; Roodi 2016).

Geosynthetics have been widely used to stabilize roadway base courses under traffic loads. However, the Texas Department of Transportation (TxDOT) has been using geosynthetics mostly for mitigation of problems associated with environmental loads, specifically to mitigate damages from expansive clay subgrades (Chen 2007). Several research efforts have been conducted to evaluate performance under traffic and environmental loads of geosynthetic-stabilized roadways in Texas. While most of these research efforts have been experimental, a few research studies have focused on collection of real performance data from actual roadways (e.g., Roodi and Zornberg 2012). However, considering limitations for collecting data from long and/or high-traffic road sections, most of the field studies have adopted comparatively short experimental test sections along with a manual performance data collection approaches based on visual condition surveys. Specifically, a rich pavement performance database, known as TxDOT Pavement Management Information System (PMIS) database, has remained mostly unused for evaluation of the benefits from geosynthetic base stabilization.

This study utilizes the performance data in the TxDOT PMIS to evaluate the performance of three roadways that involved geosynthetic base stabilization. One of the roadways was a high-volume road, while the other two were low-volume. All three roadways were founded on expansive clay subgrades. The high volume of traffic and/or the long stretch of the roadways have made manual collection of performance data not viable or safe. Therefore, the TxDOT PMIS database was investigated to evaluate the performance of the three roadways under traffic and environmental loads.

2. TXDOT PAVEMENT MANAGEMENT INFORMATION SYSTEM (PMIS)

According to FHWA (1989), Pavement Management System (PMS) involves "*a set of tools or methods that can assist decision-makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition*." The goal of PMSs is to provide managers with objective information on pavement conditions in order to help them make consistent, cost-effective, and convincing decisions on maintenance priorities, rehabilitation strategies, and prediction of pavement performance. TxDOT has utilized an automated system, referred to as Pavement Management Information System (PMIS), to store, retrieve, analyze, and report pavement data that are collected as part of its Pavement Management System. According to TxDOT (2003), "*PMIS is not a system for giving all of the answers, but a set of tools to compare alternatives – pavement managers must still make the final decisions. PMIS is automated, so that you can quickly retrieve and analyze pavement information*."

As part of TxDOT PMS, three separate surveys have been conducted in the fall on an annual basis on more than 195,000 "*data collection sections*". The three surveys include (1) visual evaluation surveys, (2) ride quality surveys, and (3) skid resistance tests (TxDOT 2015). Specially trained operators collect ride quality and, at the same time, automated rut data using the Profiler/Rut bar vehicle. Skid trucks are used to collect skid resistance data. Deflection data to evaluate structural integrity of pavement layers, such as FWD test data, may also be collected, but it is not part of the current PMIS analysis procedure. The overall condition of the state-maintained highway system is typically described based on the condition of pavement surface, which is evaluated by analysis of the visual survey data and rut depth measurements. Ride quality, skid resistance, structural capacity, climate and traffic data are also used to complement findings obtained from visual surveys (TxDOT, 2015).

Distress and ride quality data must be annually collected for all state-maintained Texas roads. Collection of deflection data has been optional (but strongly recommended) for all highways, while the sample size for skid resistance data ranged from 25 to 50 %. Collected data is stored in forms of inventory data, distress rating, and scores for each data collection section. The data collection section is defined as a section of highway that is typically 0.8 km (0.5 mile) but may range from 0.16 km (0.1 mile) to 1.6 km (1.0 mile). The data collection sections are defined for all routes in the highway systems with specific rules detailed under Texas Reference Marker System in TxDOT PMIS Rater's Manual (TxDOT, 2015). According to Texas Reference Marker System, each data collection sections is identified by a Reference Marker Numbers (RMN). The RMNs plaques are installed at 1.6-km (1-mile) intervals on interstate highways in both directions and at approximately 3.2 km (2 mile) intervals on non-interstate highways. Data collected in the PMIS database is analyzed and typically reported in five categories as follows: 1) Visual Distress Ratings, 2) Ride Quality and Rutting Data, 3) Deflection Data, typically from FWD test, 4) Skid (Surface Friction) Data, and 5) PMIS Scores.

PMIS database has been used throughout TxDOT for decision making at various levels (TxDOT, 2003). As illustrated in Figure 1, this database is used at Network Level by TxDOT Administration for their policymaking processes. At this level, the database helps administrators to answer high-level questions on topics such as the total amount of resources required to maintain or improve the current condition of Texas pavements or allocation of funds among districts. At Program Level, District Administration and Divisions use PMIS database to allocate funds to Areas Offices or to reserve funds for backlog projects or major repairs. At Project Level, PMIS database is used by Area Engineers and Maintenance Supervisors to answer more detailed questions for design and rehabilitation projects in a specific road or specific part of a highway.

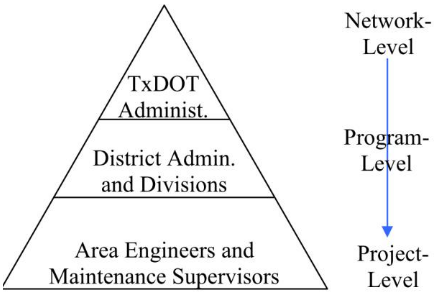


Figure 1. Several levels of application for PMIS database (TxDOT 2003)

Following investigation of the TxDOT PMIS database, three performance evaluation parameters were considered the most relevant to the focus of this study:

- *Longitudinal Cracks*, which is characterized as part of visual evaluation surveys and is reported as "the percentage of the longitudinal cracks" defined as the total length of the longitudinal cracks in each test section divided by the total length of the section.

- *Rutting Depth*, which is measured using five ultrasonic sensors installed on an assembly mounted on the front bumper of a TxDOT Profiler/Rut bar vehicle. Rutting measurements are summarized every 0.16 km (0.1 mile) intervals and are reported as the percentage of wheel path length with rutting. In this paper, rutting information is presented as the percentage of the total length of rut, which is defined as the percentage of the wheel path length in each data collection section that had shallow (6.2 to 12.7 mm (0.25 to 0.49 in)) or deep (12.7 to 25.4 mm (0.5 to 0.99 in)) rutting.
- *Condition Score*, which is determined based on pavement overall condition in terms of distress and ride quality. This score ranges from 1 (worst condition) to 100 (best condition) with the five classes of A (Very Good), for Condition Scores ranging from 90 to 100, to F (Very Poor), for Condition Scores below 34.

A particular limitation of PMIS data involves evaluation of short-length sections. Since the PMIS performance data are averaged for data collection sections, which are typically 0.8-km (0.5-mile) long, this data may not be useful for evaluation of roadway sections shorter than 0.8 km (0.5 mile). Moreover, PMIS data is limited in that it assigns only a single number to a two-lane road (i.e., a single carriageway with one lane in each direction). This makes PMIS data not suitable to be used in comparison of test sections that are designed side by side on a two-lane road. On the other hand, PMIS data may be particularly suitable for evaluation of long test sections or sections with high traffic, where manual collection of data may not be practical.

In this study, TxDOT PMIS database was used at Project Level to evaluate the performance of geosynthetic-stabilized test sections and compare it to the performance of equivalent non-stabilized (control) sections.

3. PERFORMANCE EVALUATION OF PALMER LANE, AUSTIN, TX

3.1 Project Description

A 4.8-km–long stretch of Palmer Lane (also known as FM734), extending from Samsung Blvd to State Highway (SH) 130, had historically shown poor conditions. The main distresses that have been reported in this road included frequent swells and dips as well as longitudinal cracks that their width sometimes exceeded 25 mm (1 inch). Causes for the observed damages were expected to be seasonal swelling and shrinkage in the expansive clay subgrade and potential sulfate heave of the subgrade. The original road profile consisted of a 200-mm-thick lime-stabilized subbase, a 305-mm-thick flexible base, and a 250-mm-thick hot mix asphalt (HMA) layer (Figure 2a). In 2001, TxDOT initiated a rehabilitation design for Palmer Lane that included construction of two test sections, extending from Harris Branch Parkway to SH130, to evaluate suitability of two alternative rehabilitation approaches to mitigate problems associated with the expansive soil subgrade. Specifically, a 250-mm-thick new base course overlain by a 200-mm-thick HMA layer was used for both test sections (Figure 2b). However, Section 1 was constructed on a 200-mm-thick lime-stabilized subgrade, while Section 2 was constructed using a layer of biaxial geogrid (GG1) placed at the interface between the natural subgrade and the new base layer (Figure 2b). The performance of the test sections was evaluated from 2001 to 2006 and findings from this evaluation were used to establish the final design for the reconstruction of the main section of the road (Section 3). Section 3, extending from Samsung Blvd. to Harris Branch Parkway, was constructed in 2008 using a geogrid (GG1) layer placed between a 100-mm-thick subbase layer and a 460-mm-thick base layer (Figure 2b). The subbase consisted of recycled asphalt pavement (RAP) and the base course involved a 50/50 mixture of salvaged base and RAP stabilized with 3% cement. The use of recycled materials for construction of the base course, which was adopted based on environmental and cost considerations, led to the increased thickness of the base course in Section 3 as compared to Sections 1 and 2. Therefore, direct comparison between the performance of Section 3 with Sections 1 and 2 may not be appropriate. However, comparisons among the overall performance of the three test sections and changes in the performance trends could provide valuable findings. Similar to Sections 1 and 2, Section 3 was paved using a 200-mm-thick HMA layer (Figure 2b).

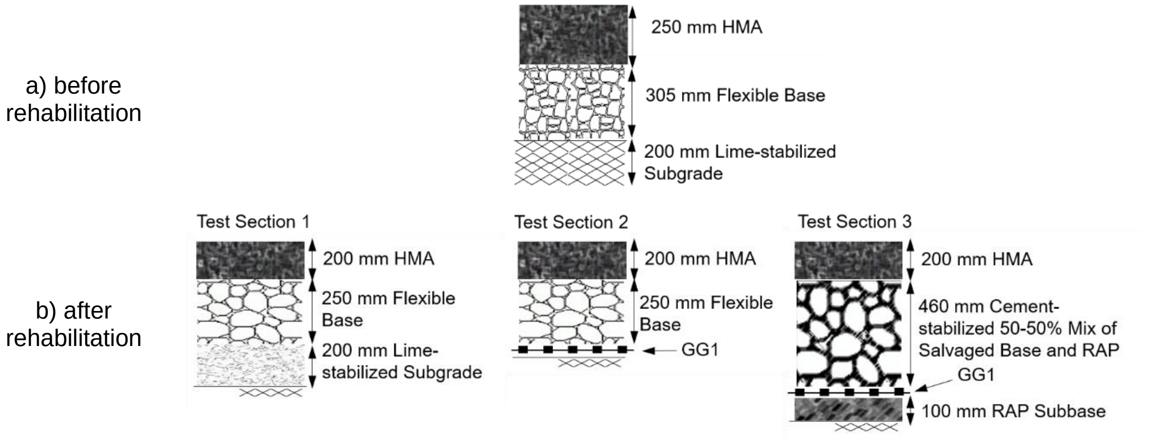


Figure 2. Road profile of the test sections in Palmer Lane

3.2 Material Characterization

Evaluation of the natural subgrade soil indicated that the subgrade soil in test Section 1 had similar characteristics to the subgrade soil in test Section 2. The subgrade soil in both sections classified as high plasticity clay with the Plasticity Index (PI) exceeding 35, which classifies as highly expansive clay according to USACE (1983) and USBR (1998). The base material used to construct test Sections 1 and 2 was a granular soil characterized by an optimum moisture content of 8 to 9% and maximum dry unit weight of 20.6 to 21.2 kN/m^3. The geogrid used to stabilize the base course was a biaxial extruded geogrid that had an open area of 75%, aperture dimensions of 25 x 33 mm, and an ultimate tensile strength of 12.4 and 19.0 kN/m in machine and cross-machine directions, respectively (Table 1).

Table 1. Characteristics of geogrid materials used in the test sections per manufacturers' datasheet

Property	Geogrid 1 (GG1)	Geogrid 2 (GG2)
Geosynthetic Type	Biaxial Geogrid	Biaxial Geogrid
Polymer Type	Polypropylene	Polypropylene
Manufacturing Process	Punched and drawn	Laser-bonded
Ultimate Tensile Strength (kN/m)	12.4 (MD), 19 (CMD)	20 (MD), 32 (CMD)
Tensile Modulus at 2% strain (kN/m)	205 (MD), 330 (CMD)	300 (MD), 500 (CMD)
Tensile Modulus at 5% strain (kN/m)	170 (MD), 268 (CMD)	240 (MD), 400 (CMD)
Junction Efficiency (%)	93	--
Flexural Stiffness (mg-mm)	2,500,000	4,500,000
Aperture Stability (N-m/deg)	0.32	--
Aperture Size (mm)	25 x 33	44 x 44

Note: MD = Machine Direction; CMD = Cross-machine Direction;

3.3 Evaluation of the Performance under Traffic and Environmental Loads Using TxDOT PMIS Database

To evaluate the performance of the test sections at Palmer Lane using the information from TxDOT PMIS database, RMNs for the three test sections in Palmer Lane were obtained from TxDOT statewide map system as follows: test Section 3 extended from RMN 435.5 to 436.5, test Section 2 extended along RMN 437.5 and test Section 1 extended from RMN 437.5 to 438. The PMIS database was investigated to collect relevant performance data for the identified RMNs. In particular, the condition scores, the percentage of the total length of rut, and the percentage of the longitudinal cracks were evaluated for the data collection sections corresponding to each of the test sections. The total length of rut was reported as almost zero for all identified data collection sections over the years. Therefore, the condition scores and the percentage of the longitudinal cracks are discussed next.

Figures 3 and 5 present the condition scores and the percentage of the longitudinal cracks for the data collection sections at the Palmer Lane test sections from 2001 to 2014. The data collection sections that correspond to test Section 1 (subgrade-lime-stabilized), Section 2 (geogrid-stabilized), and Section 3 (geogrid-stabilized) are presented using green, black, and red colors, respectively. Evaluation of the data presented in these figures indicates that test Sections 1 and 2 were constructed in 2001 when the condition scores at RMNs 437, 437.5, and 438 were 100 % and the corresponding percentages of longitudinal cracks were zero. From 2001 to 2004, both test Sections 1 and 2 maintained an excellent condition with the condition score of 100 % and negligible longitudinal cracks. However, as of 2005, while the geogrid-stabilized test section (Section 2) continued performing very well, the subgrade-lime-stabilized test section (Section 1) started developing longitudinal cracks along with reduction in its condition score. For example, as presented in Figures 4 and 6, in 2009 the percentage of the longitudinal cracks in Section 1 was ranged from 70 to 85 % and the condition score for this section ranged from 87 to 94 %.

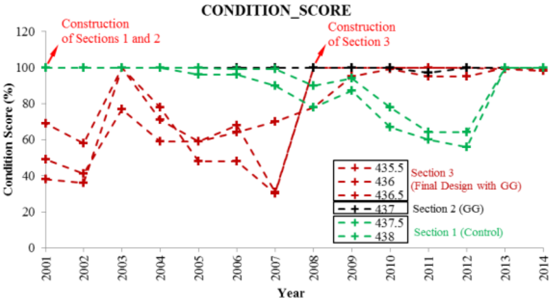


Figure 3. Condition scores at Palmer Lane test sections over time.

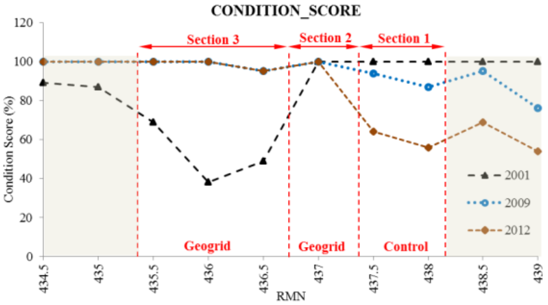


Figure 4. Condition score at Palmer Lane test sections in 2001, 2009, and 2012.

As presented in Figures 3 and 5, Section 3 (geogrid-stabilized) was rehabilitated in 2008. Before reconstruction, the performance data at the data collection sections that corresponded to Section 3 (i.e., RMNs 435.5, 436, and 436.5) showed a particularly poor performance. The observed poor performance of this section was initially attributed to sulfate heave as well as seasonal swelling and shrinkage of the underlying expansive clay subgrade. As shown in Figures 3 and 5, from 2001 to 2008, the condition scores at some data collection sections in test Section 3 fell below 40 %and the percentage of the longitudinal cracks in this section exceeded 85 %. However, the rehabilitation of this test section in 2008 using geogrid stabilization was particularly effective in enhancing its performance in the following years. As of 2008, test Section 3 maintained an excellent condition. As presented in Figures 3 and 4, the condition scores for test Section 3 remained close to 100 % from 2008 to 2014. Figures 5 and 6 also show that the percentage of the longitudinal cracks in this section did not exceed 30 % during this period.

Evaluation of the condition scores from 2008 to 2014 presented in Figures 3 and 4 indicates that the condition scores in the geogrid-stabilized test sections (Sections 2 and 3) were significantly higher than in the subgrade-lime-stabilized test section (Section 1). Although test Sections 2 and 3 were constructed at two different time periods, the excellent condition scores maintained by both sections until 2014 underline the benefits from geogrid stabilization. Moreover, evaluation of the percentage of the longitudinal cracks until 2014 (presented in Figures 5 and 6) further highlights the benefits from geogrid stabilization in mitigation of environmental longitudinal cracks. In comparison, in the same period, the subgrade-lime-stabilized section (Section 1) had an enormously high percentage of longitudinal cracks that exceeded 150 %, which probably resulted in rehabilitation of this section in 2013 (see the reduced percentage of longitudinal crack for this section in 2013 in Figure 5).

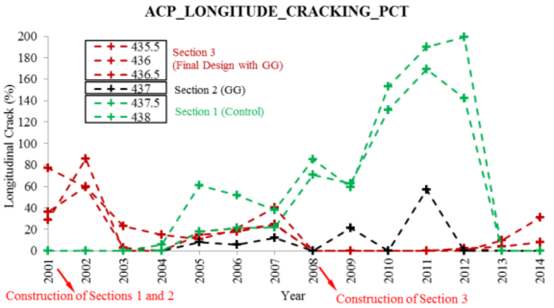


Figure 5. Percentage of longitudinal cracks at Palmer Lane test sections over time.

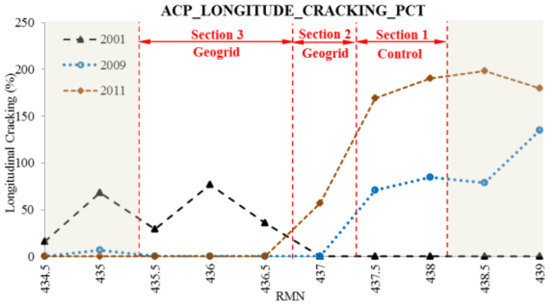


Figure 6. Percentage of longitudinal crack at Palmer Lane test sections in 2001, 2009, and 2011.

4. PERFORMANCE EVALUATION OF STATE HIGHWAY OLD SAN ANTONIO ROAD (SH OSR)

4.1 Project Description

State Highway Old San Antonio Road (SH OSR) is a section of the historic royal Spanish road (extended from Louisiana to Mexico) that has been maintained by TxDOT. A long stretch of this road extending from Navasota River to FM39 had shown poor performance over the years. This section was rehabilitated in 1999 and 2000 by construction of two test sections with and without geosynthetic stabilization. The first section, referred to as the control section, was constructed without geosynthetic in 1999. This section extended approximately 5.6 km (3.5 miles) from the intersection with Navasota River in the West to the intersection with County Road 351 in the East. The second test section, which was constructed in 2000, had a similar design to the control section but with inclusion of a geogrid layer to stabilize the base course. The geogrid-stabilized section started from the intersection with FM39 in Normangee, TX, and extended for approximately 3 miles to the West.

4.2 Material Characterization

Prior to construction of the test sections in SH OSR, TxDOT conducted a subgrade investigation along the project limit starting at the intersection with FM39 and extending 7.6 km (4 miles) to the West. A total of eight borings were drilled to a depth of 2.5 m (8 ft) into the subgrade. Characterization of the obtained soil samples indicated that the subgrade soil was composed of high plasticity clay in most areas. The PI value of the clay subgrades ranged from 21 to 37 (classifies as medium to highly expansive clays) in the surface layers and exceeded 50 in the deeper layers. Sandy clays with considerably smaller PI values were also found in a few borings. The geogrid material used in this project was the same as the geogrid material used in Palmer Lane (Table 1).

4.3 Evaluation of the Performance under Traffic and Environmental Loads Using TxDOT PMIS Database

The condition scores, the percentage of the longitudinal cracks, and the percentage of the total length of rut from TxDOT PMIS database were collected to evaluate the performance of the two test sections in SH OSR.

RMNs for the data collection sections in test Section 1 (control) was found to range from 634.5 to 638 and for test Section 2 (geogrid-stabilized) was found to range from 639 to 642.

The condition scores, the percentage of the longitudinal cracks and the percentage of the total length of rut were averaged for all the data collection sections in each test section. The results are presented in Figures 7 to 9. Evaluation of the data presented in these figures indicates that the geogrid-stabilized section has continuously performed better than the control section. The condition scores presented in Figure 7 show that the rehabilitation of the test sections was completed in 1999 (in the control section) and 2001 (in the geogrid-stabilized section). After reconstruction, the geogrid-stabilized section had a considerably higher condition score (Figure 7), and significantly smaller percentage of longitudinal cracks (Figure 8) than the control section. For example, in 2009 the percentage of the longitudinal cracks in the control section reached approximately 30 %, while it was below 10 % in the geosynthetic-stabilized section. The performance of the sections under traffic load, which is evaluated using the percentage of the total length of rut (Figure 9), was quite similar between 2001 and 2007. The total length of rut was found to significantly rise from 2008 to 2010. This sudden increase may be attributed to potential increase in the volume of traffic in these particular years. However, from evaluation of the data presented in Figure 9, it can be concluded that the geogrid-stabilized section had a significantly better performance over this period of time. Specifically, from 2008 to 2010, the percentage of the total length of rut was approximately 20 % in the control section, whereas for the same period this parameter was below 10 % in the geogrid-stabilized section.

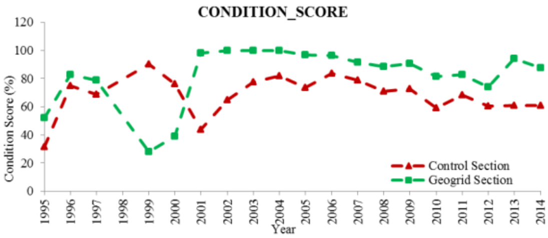


Figure 7. Condition scores at SH OSR test sections over time.

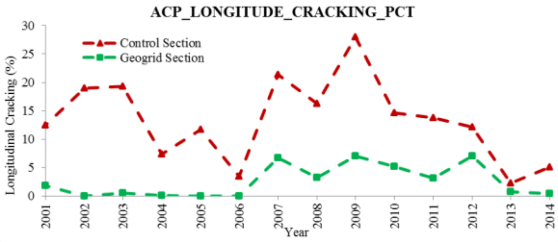


Figure 8. Percentage of longitudinal cracks at SH OSR test sections over time.

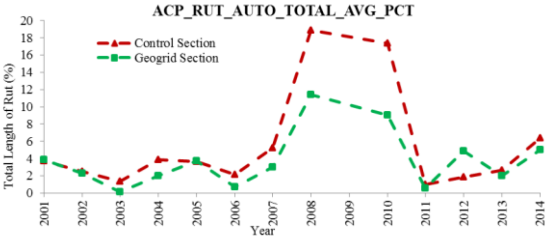
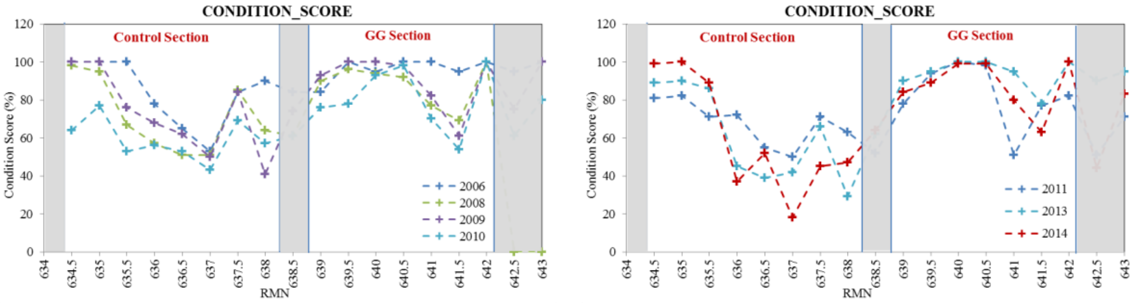


Figure 9. Percentage of total length of rut at SH OSR test sections over time.

Performance data for individual data collection sections in SH OSR is presented in Figures 10 to 12. The horizontal axis in these figures corresponds to the RMNs for the data collection sections. Evaluation of the condition scores presented in Figure 10 shows variation in the performance at various data collection sections. This may be attributed to variation in the subgrade soil properties along the road, discussed in the previous section. The data collection sections with relatively better performance were likely founded on the sandy clay subgrade, whereas others were probably founded on comparatively more plastic clays. Overall, the data collection sections located in the geogrid-stabilized test section had comparatively better performance than those in the control section.



a) Data from 2006 to 2010 b) Data from 2011 to 2014

Figure 10. Condition score at SH OSR test sections.

Evaluation of the percentage of the longitudinal cracks and the percentage of the total length of rut, presented in Figures 11 and 12, underlines the benefits from geogrid-stabilization in the performance under environmental and traffic loads. As presented in Figure 11, from 2006 to 2009 the percentages of the longitudinal cracks for the geogrid-stabilized section were significantly smaller than that in the control section. The percentage of the total length of rut was also found to be significantly smaller in the geogrid-stabilized section than in the control section (Figure 12).

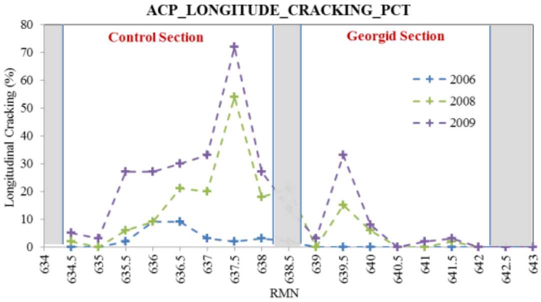


Figure 11. Percentage of longitudinal cracks at SH OSR test sections in 2006, 2008, and 2009.

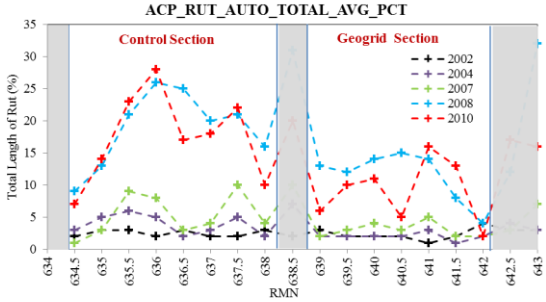


Figure 12. Percentage of total length of rut at SH OSR test sections from 2002 to 2010.

5. PERFORMANCE EVALUATION OF FARM-TO-MARKET ROAD 1774

5.1 Project Description

A long stretch of Farm-to-Market (FM) Road 1774, extending from SH90 to FM2445, was reconstructed in August 2002. The reconstruction was part of the restoration of distressed roads in Grimes County, Texas. Investigations of the subgrade soil before reconstruction revealed the presence of expansive clays under two separate road sections extending for 0.5 and 3.4 km. Coring the original roadway indicated that the original road profile consisted of an asphaltic coat overlain by 75 to 250 mm of flexible base composed of limestone aggregate and RAP (Figure 13a). The original road was fully excavated and leveled, and the original material was recycled to construct a 250-mm-thick lime-stabilized subbase. A new 175-mm-thick base course was then placed and overlain by a thin asphaltic layer. In addition, a geogrid layer was installed at the subbase-base interface to further stabilize the two sections of the roadway founded on expansive subgrade. However, to evaluate the impact of different geogrid properties on the road performance, Section 1 (approximately 500 m long) and Section 3 (approximately 3,400 m long) were constructed using two different geogrids. The road section between the two geosynthetic-stabilized test Sections 1 and 3 was constructed without geosynthetic and is referred to as test Section 2 (control) (Figure 13b).

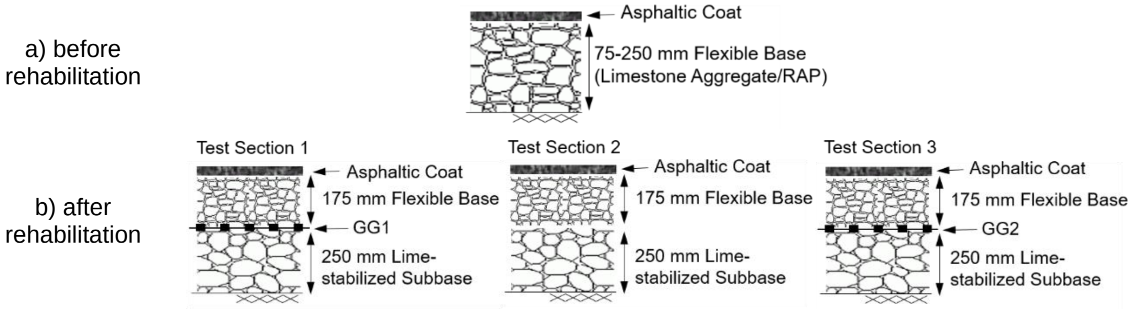


Figure 13. Road profile of test sections in FM1774

5.2 Material Characterization

Subgrade soil investigation before rehabilitation of FM1774 involved 13 borings drilled along the project limits to a depth of approximately 3 m. Characterization of the soil samples collected from the borings that were located within the test sections showed the presence of a highly expansive clay under test Section 1 (average PI of approximately 35) and a medium to highly expansive clay under test Section 3 (average PI of approximately 30). The subgrade soil under test Section 2 was comparatively less plastic and was characterized as low expansive clay. The geogrid material used in test Section 1 (GG1) was an integrally-formed biaxial geogrid from polypropylene, which was the same as the geogrid material used in Palmer Lane and SH OSR. The geogrid material used in test Section 3 (GG2) was a laser-bonded biaxial geogrid from polypropylene that had an open area of 75%, aperture dimensions of 44 x 44 mm, and an ultimate tensile strength of 20.0 and 32.0 kN/m in machine and cross-machine directions, respectively (Table 1).

5.3 Evaluation of the Performance under Traffic and Environmental Loads Using TxDOT PMIS Database

To evaluate the performance of the test sections, RMNs that corresponded to various FM1774 test sections were identified from TxDOT statewide road map system as follows: Section 1 (GG1) was found to start from

RMN 427.8 and end at RMN 428.1, Section 2 (Control) extended from RMN 428.1 to RMN 429, and Section 3 (GG2) extended from RMN 429 to RMN 431.1.

Long-term performance of the test sections in FM1774 was assessed by evaluation of the condition scores, the percentage of the longitudinal cracks, and the percentage of the total length of rut in each data collection section. Evaluation of the condition score data presented in Figure 13 indicates that all test sections were performing significantly poor from 2001 to 2003 with a condition score ranged from about 75 % (Class B) to less than 20 % (Class F). The rehabilitation of the roadway, which probably occurred in 2004 or 2005, improved the condition score to almost 100 %, as shown in Figure 13. However, the performance of the test sections was found to be very different in the years after the rehabilitation. As presented in Figure 14 for years 2006 to 2011, Sections 1 and 2 performed significantly better than Section 3. The condition score for Section 3 dropped to almost 50 % in 2011, while the minimum condition scores in Sections 1 and 2 were found to be 94 and 70 %, respectively.

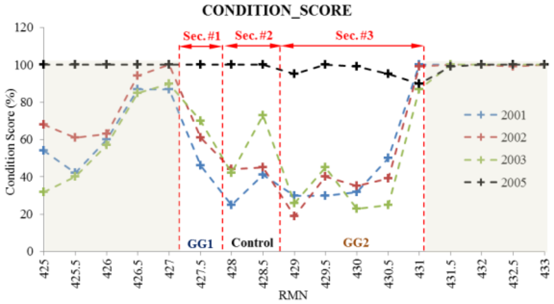


Figure 13. Condition score at FM1774 test sections before rehabilitation in 2005.

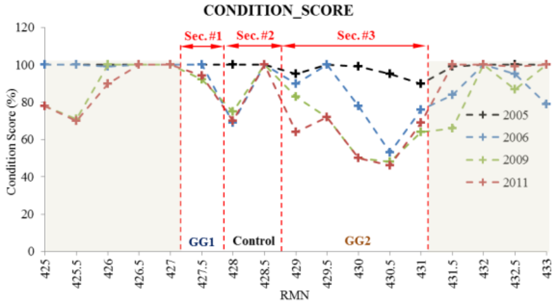


Figure 14. Condition score at FM1774 test sections after rehabilitation in 2005.

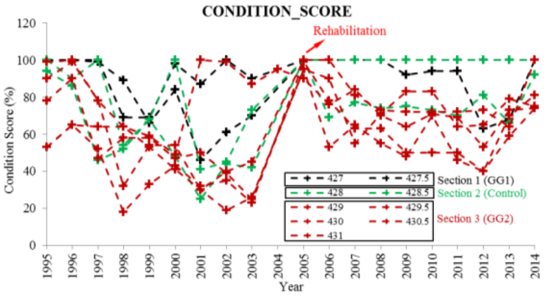


Figure 15. Condition score for all data collection sections at FM1774 test sections over time.

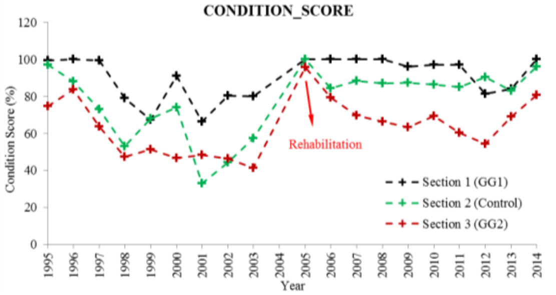


Figure 16. Average condition scores at FM1774 test sections over time.

Figures 15 and 16 provide more insight into the performance over time of the test sections at FM1774. Figure 15 presents the condition score of all data collection sections in the experimental area at FM1774 from 1995 to 2014. The black curves present the condition scores for Section 1 (GG1), and the green and the red curves correspond to the condition scores for Sections 2 (Control) and 3 (GG2), respectively. The data presented in this figure shows that the previous rehabilitation of the roadway (without geosynthetic stabilization) probably occurred between 1995 and 1997. The performance of all roadway sections in years following this rehabilitation (i.e., between 1997 and 2005) was particularly poor. Rehabilitation of the roadway in 2005 involved the use of two geogrids (i.e., GG1 and GG2) in the two sections of the roadway that were found on expansive clay subgrades (i.e., test Sections 1 and 3, respectively). The condition scores at the data collection sections located in each test section were averaged and the results are presented in Figure 16. Evaluation of the data presented in Figures 15 and 16 for geogrid-stabilized test sections indicates that the use of both geogrids resulted improvement in the performance of the sections after rehabilitation in 2005 when compared to the performance after previous rehabilitation in 1995. However, the level of improvement resulted from GG1 was significantly higher than the improvement resulted from GG2 such that the average condition score in test Section 3 (GG2) has been even lower than the average condition score for non-stabilized test Section 2 (Figure 16).

The percentage of the longitudinal cracks and the percentage of the total length of rut for each data collection section at FM1774 are presented in Figures 17 and 18, respectively. Evaluation of the data presented in these figures also underlines the lower performance in test Section 3 (GG2) as compared to the other test sections. The percentage of the longitudinal cracks in test Section 3 (GG2) was found to range from 2 to 13 % during 2008 to 2012 time period, while in the same period, test Section 1 (GG1) did not have longitudinal crack and test Section 2 (Control) had about 3 % of cracking. Evaluation of the rut data presented in Figure 18 also indicates that test Section 3 (GG2) had significantly larger rutted length as compared to test Section 1 (GG1). The total length of rut in Section 1 (GG1) was found to be smaller than 4 %, while it exceeded 10 % in test

Section 3 (GG2). Test Section 1 (Control), however, was found to have the highest total length of rut exceeding 15 % of the section length.

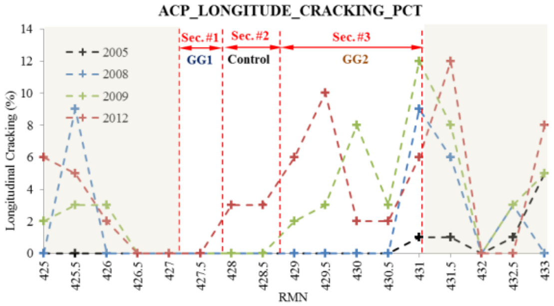


Figure 17. Percentage of longitudinal cracks at FM1774 test sections.

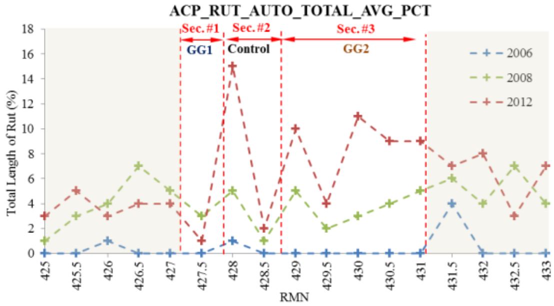


Figure 18. Percentage of total length of rut at FM1774 test sections.

Discussions regarding potential reasons for lower performance observed for GG2 as compared to GG1 is out of the scope of this paper and can be found in Roodi (2016).

6. DISCUSSION

The test sections in the three roadways evaluated in this study had significantly different designs and characteristics. Palmer Lane was a high-traffic road and was designed using a comparatively high structural number and thick hot mix asphalt layer and base course. On the other hand, FM1774 and SH OSR were low-volume roadways with comparatively small structural number and thin asphalt layer and base course. Figures 19 and 20 show the difference between traffic volume and classification among the three roadways. The data presented in these figures, which is also collected from TxDOT PMIS database, correspond to the annual average daily traffic (AADT) (in Figure 19) and the percentage of trucks in AADT (in Figure 20) from 2001 to 2017. The data presented in Figure 19 indicates that Palmer Lane had a significantly higher volume of traffic (ranged from approximately 6,000 to more than 10,000 AADT) than FM1774 and SH OSR. Although FM1774 and SH OSR had similar AADT, the data presented in Figure 20 indicates that the percentage of trucks was significantly different in the two roadways. The percentage of trucks in SH OSR was generally higher than FM1774.

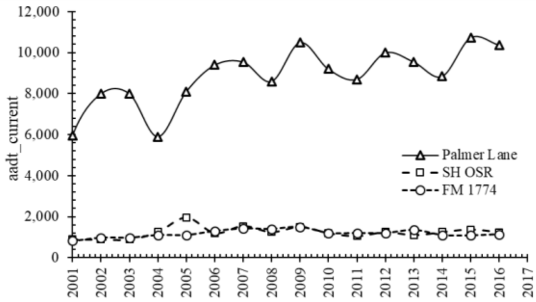


Figure 19. Annual average daily traffic (AADT) for the three roadways.

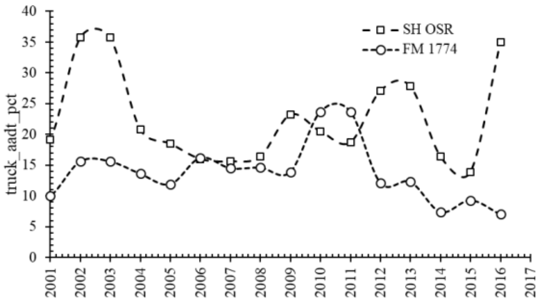


Figure 20. Percentage of trucks in AADT for FM1774 and SH OSR.

The performance data presented in the previous sections underlines the benefits from geosynthetic base stabilization for the three roadways with significantly different designs. To establish a basis to compare the benefits resulted from the geosynthetic stabilization among various roadways, two improvement factors (IFs) were defined. Using Equations (1) and (2), the Condition Score IF quantifies the percent improvement in the condition score and the Longitudinal Cracks IF quantifies the percent improvement in the percentage of the longitudinal cracks when a geosynthetic-stabilized section is compared to a non-stabilized (control) section:

$$Condition\ Score\ IF = \frac{Condition\ Score_{GS-Stabilized} - Condition\ Score_{Control}}{Condition\ Score_{Control}} \qquad [1]$$

$$Longitudinal\ Cracks\ IF = \frac{Longitudinal\ Cracks_{Control}(\%) - Longitudinal\ Cracks_{GS-Stabilized}(\%)}{Longitudinal\ Cracks_{Control}(\%)} \qquad [2]$$

Since longitudinal cracks are the main type of damage resulted from seasonal swelling and shrinkage of expansive clay subgrades, Longitudinal Cracks IF represents an indicator for benefits from the geosynthetic under environmental loads. On the other hand, since condition score is determined based on the pavement overall condition based on a wide range of distresses and ride quality, Condition Score IF is an indicator for benefits from the geosynthetic under both traffic and environmental loads.

Using the performance data presented in the previous sections of this study, Condition Score IFs and Longitudinal Cracks IFs were calculated for various years and test sections and the results are summarized in Figure 21. Specifically, for Palmer Lane and SH OSR, the condition score and the percentage of the longitudinal cracks from 2002 to 2012 were used to calculate the IFs. In both roadways, the IFs were calculated between the geogrid-stabilized and control (i.e., subgrade-lime-stabilized) test sections. In FM1774, however, a control section with similar subgrade characteristics to that in the geogrid-stabilized test sections did not exist. Therefore, in this roadway, the IFs were calculated between Section 1 (GG1), representing the geogrid-stabilized section, and Section 3 (GG2), representing the control section. This selection was justified by the poor performance observed in Section 3 (GG2) such that the benefit from geogrid stabilization was negligible.

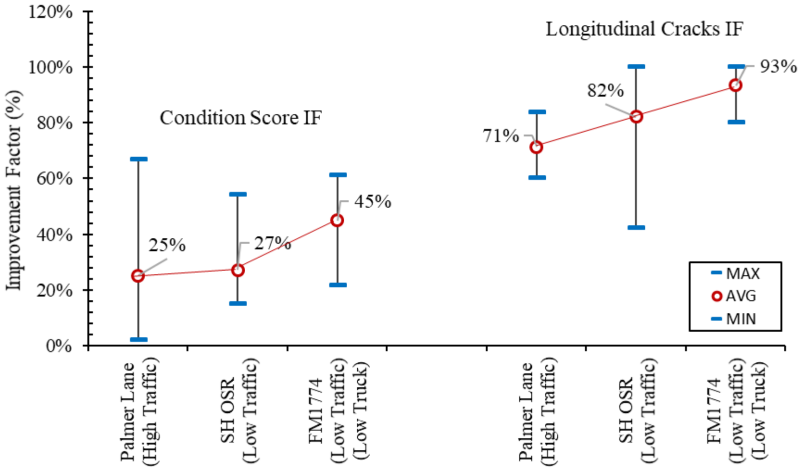


Figure 21. Improvement factors for the three roadways.

The data presented in Figure 21 corresponds to the minimum, average and maximum IF values calculated for the test sections in each roadway. Low IF values generally corresponded to the initial years after rehabilitation of the roadways when benefits from the geosynthetic have yet to be realized. On the other hand, high IF values typically corresponded to the years when the control sections were significantly degraded but the geosynthetic-stabilized sections were comparatively less degraded. The average IF values presented in Figure 21 indicates that the geosynthetic could enhance the condition score by 25 to 45 % in various test sections. The data presented in Figure 21 also shows that the geosynthetic could mitigate the development of longitudinal cracks by approximately 70 to 95 %.

Evaluation of the average IF values presented in Figure 21 also indicates that in each roadway the Longitudinal Cracks IF was significantly higher than the Condition Score IF. This observation may suggest that the benefits from geosynthetic stabilization under environmental loads were more significant than under traffic load. The data in this figure also shows that the improvement in the condition score as well as in the percentage of the longitudinal cracks was more significant in FM1774 than SH OSR than Palmer Lane. This finding indicates that the geosynthetic stabilization resulted the highest improvement in the low-volume roadway that had the lowest percentage of trucks (i.e., FM1774), whereas the improvement was the least (although still significant) in the high-volume roadway, which also had strongest road profile (i.e., Palmer Lane). Considering that the characteristics and design of the geosynthetic stabilization were reasonably similar in the three roadway rehabilitation projects, the aforementioned finding may have been expected. However, this finding underlines the significance of proper design and selection of geosynthetic material to achieve a target level of improvement.

7. CONCLUSIONS

Performance of three geosynthetic-stabilized base roadways founded on expansive clay subgrades in Texas was evaluated using the performance data collected from TxDOT PMIS database. Traffic counts and classification were significantly different among the three roadways and thus, characteristics of the three roadway profiles were also different. However, design and characteristics of the geosynthetic stabilization were similar among the three roadways. Three TxDOT PMIS performance parameters (including the condition score, the percentage of the longitudinal cracks, and the percentage of the total length of rut) were used to evaluate long-term performance of the geosynthetic-stabilized and the equivalent non-stabilized (control) test sections under traffic and environmental loads. The condition score is determined based on the pavement overall conditions in terms of distress and ride quality; thus, this parameter was used for evaluation of the overall performance of the test sections under both traffic and environmental loads. On the other hand, the percentage of the longitudinal cracks and the percentage of the total length of rut provided information on the performance under environmental loads (i.e., swelling and shrinkage of the expansive clay subgrade) and under traffic loads, respectively.

Overall, TxDOT PMIS database was found to be a suitable resource for evaluation of the performance of geosynthetic-stabilized roadways. Significant benefits were found in geosynthetic base stabilization in all the three roadways with various designs and characteristics. The benefits included enhanced overall conditions and ride quality of the road under traffic and environmental loads (which was quantified using the condition scores and the percentage of the total length of rut) as well as enhanced performance under environmental loads (which was quantified using the percentage of the longitudinal cracks). For all three roadways, improvement in the percentage of the longitudinal cracks was found significantly higher than the improvement in the condition scores. The average reduction in the percentage of the longitudinal cracks was 70 to 95 % and the average increase in the condition scores was 25 to 45 %. The most significant improvements were found in the low-volume roadway that had the lowest percentage of trucks. The improvements in the high-volume roadway, which also had the heaviest road profile, was comparatively less significant.

Evaluation of the performance of the test sections along the three roadways using the information from the TxDOT PMIS database presented in this study introduces a suitable approach for evaluation and comparison of performance among geosynthetic-stabilized and non-stabilized roadway sections. This approach can conveniently be adopted by researchers and practitioners whenever pavement management system databases are available. This approach is particularly useful to gain a deeper insight into the performance of long and/or high-traffic test sections (such as those evaluated in this paper) in which other approaches for collection of performance data may not be easily or safely available. The advent of machine learning and big data analysis techniques along with improvements in the data quality and data collection procedures allow for more detailed investigations of the performance of geosynthetic-stabilized and non-stabilized roadways using PMIS databases.

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