Mitigation of Cracks in Flexible Pavements with Expansive Subgrade Using Geosynthetics: A Case Study in Austin, Texas

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ABSTRACT

Geosynthetics have been effective in minimizing the detrimental effects of expansive soil subgrades on the performance of flexible pavements. This study presents a case history on the use of geosynthetic reinforcement to minimize cracks in a flexible pavement with an expansive soil subgrade in an urban roadway in Austin, Texas. The crack mitigation techniques included use of a fiberglass geogrid reinforcement at the interface of pre-existing asphalt layer and the overlay. Specifically, the geogrid was placed directly over the severely cracked surface, after cleaning dirt, dust and other deleterious material, and a trackless tack was then applied prior to the installation of the asphalt overlay. The test sections with and without geogrid reinforcement was monitored for over a period of 8 years and it was observed that the longitudinal edge cracks reappeared along the unreinforced section. While, the geosynthetic reinforced sections did not show any signs of crack development during the monitoring period. Overall, the field monitoring program demonstrated that the use of geosynthetic reinforcements could significantly help in mitigating the longitudinal cracks associated with volumetric changes in flexible pavements built over an expansive soil subgrade.

INTRODUCTION

Globally, expansive soils create serious engineering problems and economic losses in several countries. In the U.S., the Department of Agriculture estimates that 50% of the households are constructed on expansive soils. The U.S. Department of Agriculture (USDA) estimates that 50 percent of the houses in the U.S. are constructed over expansive soils, and the American Society of Civil Engineers (ASCE) estimates that one-quarter of all homes in the U.S. are affected by the volumetric changes associated with the expansive soil (Virginia Department of Mines, Minerals and Energy, 2021). According to ASCE, historically, expansive soils account for more home-related damage each year than floods, tornadoes, and hurricanes combined. A similar situation happens in China, where expansive soils are responsible for an economic loss of about 15 billion US dollars every year (Wang, et al. 2016). On the other hand, it is estimated that 20% of the surface soils in Australia are expansive and six out of their eight largest cities have large expansive soil deposits posing them serious problems (Delaney et al, 2005). Specifically, in the case of lightweight structures, such as pavements, where there is no construction load above the expansive soil layer to compensate clay swelling, the high volumetric changes due to the seasonal moisture fluctuations affects the stability and performance of pavement layers resulting in undulations and cracks. According to Zornberg et al. (2010), these ground movements are observed in the form of heave during wet season and shrinkage during dry season. A pavement section built over an expansive soil subgrade may have a compromised quality and performance life. Specifically, the load bearing capacity, fatigue performance, roadway serviceability and safety may be compromised. Problems involving the appearance of longitudinal cracking on pavements over expansive subgrade have been reported (Luo and Prozzi, 2010; Mezhoud et al. 2016; Zornberg and Roodi, 2021).

Several techniques that mitigate the cracking in flexible pavements have been evaluated. Traditionally, the problems associated with flexible pavements built over expansive soil subgrades have been addressed by completely replacing these soils or by stabilization techniques (Zornberg, 2010). Among them, excavation and replacement, pre-watering, chemical or mechanical modification using lime or cement stabilization and moisture barriers are the most common and economic alternatives. The construction of flexible pavements over expansive subgrades treated with lime has been the most common alternative in regions such as central Texas. However, situations of compromised performance due to the appearance of longitudinal cracks over lime-treated subgrades are also common. Figure 1 presents an example of a typical scenario of longitudinal cracks in flexible pavement with lime-treated expansive soil subgrades in Taylor, Texas. As shown in the figure, the longitudinal cracks initiated from expansive subgrades, subsequently propagated into the asphalt surface through the 10% lime-treated base layer.

Figure 1. Examples of longitudinal cracks from expansive subgrades, in Taylor, Texas.

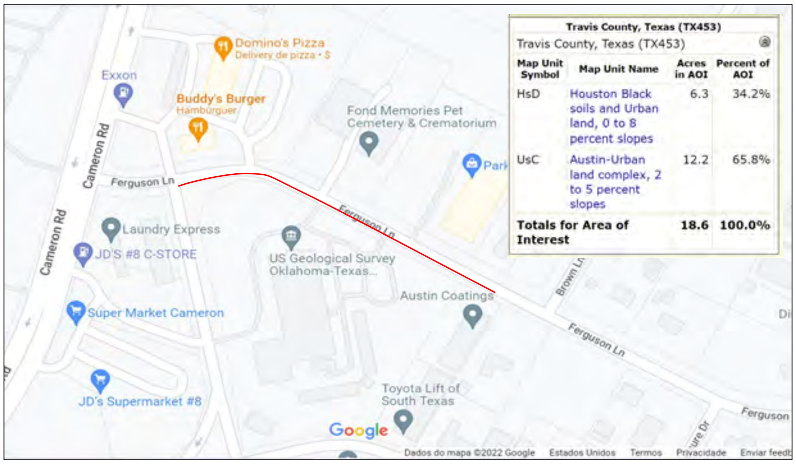
On the other hand, geosynthetic reinforcements have been effective in minimizing the detrimental effects of expansive soil subgrades on the performance of flexible pavements, mainly on the mitigation of longitudinal cracks (Gupta 2009, Zornberg et.al 2008). Comprehensive laboratory and field investigations have been conducted to evaluate the ability of geosynthetic reinforcements stabilizing the expansive subgrade and enhancing the flexible pavement performance. Dessouky et al. (2015), conducted a field study involving 14 years of performance and condition monitoring of various treatment techniques and reported that geogrid reinforcement combined with lime-treatment of expansive subgrade was an effective repair at areas with low to moderate plasticity subgrade soil. While, Roodi and Zornberg (2020) conducted an extensive field study in Texas (9 years of wet and dry season cycles) and reported that the geosynthetics restricted the development of longitudinal cracks in low volume roadways built over an expansive clay subgrade that is subjected to high environmental loads. In addition, they reported that the performance improvement expected from the implementation of geosynthetic stabilization in roadways founded on expansive clays may be due to the stiffness of the soil-geosynthetic composite. On the other hand, Zornberg and Roodi (2021) suggested that the crack mitigation techniques for roads founded over expansive clays should avoid approaches that lead to stiff performance (e.g. lime stabilization of subbase layers) and focus instead on approaches leading to comparatively ductile responses, such as the use of geosynthetics. Shumbusho et al. (2021) suggested that a geogrid layer in a reinforced pavement section can reduce surface differential shrinking and swelling deformation resulting from underlying expansive soils by a factor of 2 and 3 respectively in comparison to unreinforced section.

Overall, existing literature studies highlights that the use of geosynthetics was found to effectively minimize the detrimental effects of expansive soil subgrades on flexible pavement performance. This study presents a case history on the use of geosynthetics to minimize longitudinal cracks from expansive soil subgrade in Austin, Texas. Specifically, the case history involves an urban roadway (Ferguson Lane in Austin, Texas) built on an expansive subgrade soil that is subjected to heavy passenger traffic and 8 years of wet and dry season cycles.

CASE STUDY: AUSTIN, TEXAS

Background:

The experimental test section is a small portion of an urban roadway with heavy traffic, which is located on the east portion of Austin, Texas, and to the east of Interstate Highway I-35. Specifically, the experimental section was a small portion of the roadway along Ferguson Lane, between Cameron Road (west) and Brown Lane (east) measuring about 220 m in length. The cross-section of the pre-existing pavement structure comprised of an expansive soil subgrade, 250 mm-thick granular base, and 75 mm thick asphalt layers. The subgrade soil up to a depth of 2 m under the roadway has been mapped as Houston Black clay, per USDA web soil survey. Figure 2 presents a google map view of the location of the experimental section under Houston Black soil.



Travis County, Texas (TX453)

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Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
HsD	Houston Black soils and Urban land, 0 to 8 percent slopes	6.3	34.2%
UsC	Austin-Urban land complex, 2 to 5 percent slopes	12.2	65.8%
Totals for Area of Interest		**18.6**	**100.0%**

Figure 2. Google Map View of Experimental section Location in Austin, Texas.

Houston Black is a high plasticity clayey soil that possess high volumetric changes (shrink-swell behavior) associated with their moisture content variation. In order to understand expansive soil properties, the soil was tested at the University of Texas at Austin. The primary characterization of subgrade soil included Atterberg limits and Centrifuge swelling for Potential Vertical Rise (PVR) determination, per TEX-6048B. Based on the laboratory evaluation, it was determined that the Houston Black soil had a liquid limit, plastic limit, and plasticity index of 75%, 21% and 54% respectively, per ASTM D 4318, indicating great potential for swelling upon wetting. The PVR of subgrade soil (Houston Black) was determined by conducting centrifuge test on undisturbed samples at three different effective stresses (5g, 25g, 200g). Specifically, the swell and effective stresses were determined to calculate the PVR i.e., swell multiplied by the thickness of the soil layer, which was determined to be 3.8 inches and suggests a high potential for swelling in presence of moisture.

The asphalt surface along the Ferguson Lane had developed distresses in the form of longitudinal cracks, alligator cracks and undulations/rut along the wheel paths as shown in Fig. 3. The Austin city transport authority proposed to rehabilitate the roadway to restore the serviceability to road users and the rehabilitation process is discussed in the following section.

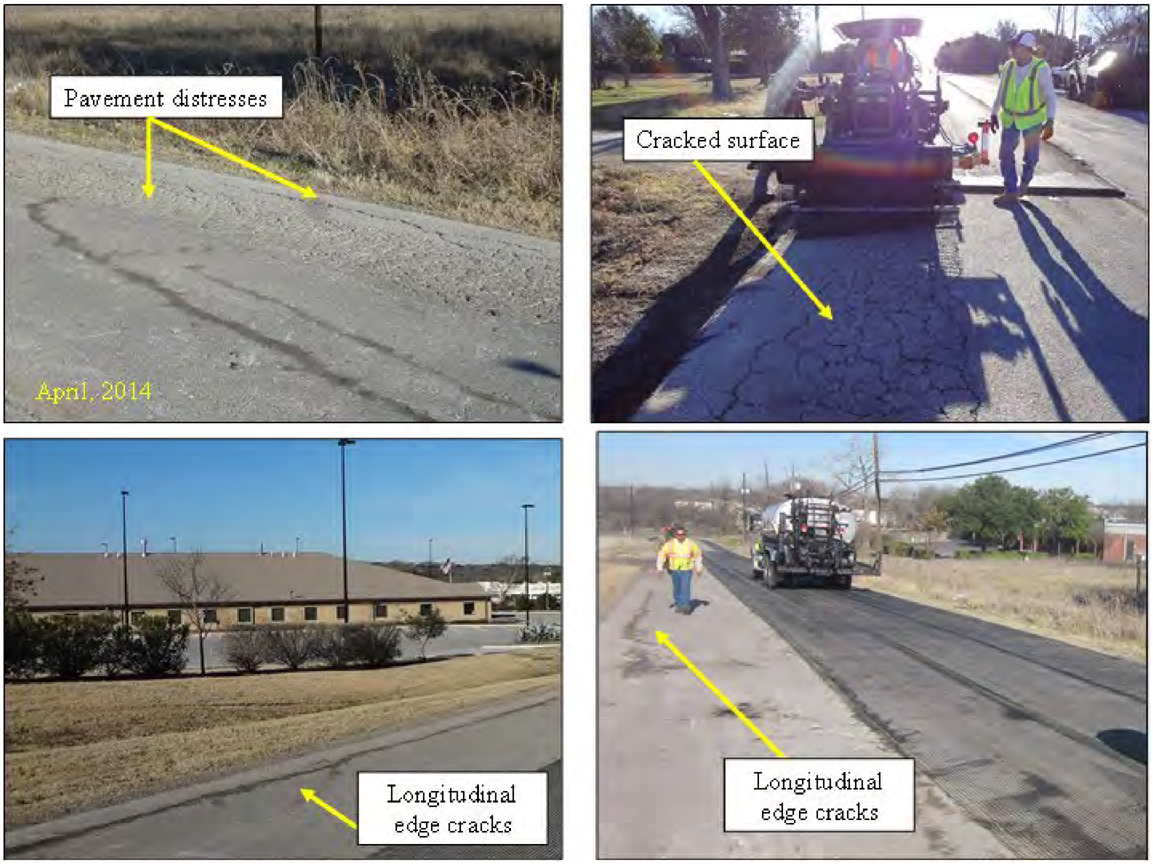

Figure 3. Distresses in the Pre-existing Roadway: April 2014.

Roadway Rehabilitation:

The roadway rehabilitation along Ferguson Lane involved placing and compacting 75 mm thick Type-C dense-graded asphalt overlay on the pre-existing asphalt surface, similar to any other traditional roadway rehabilitation technique. However, geosynthetic reinforcements were installed on the pre-existing asphalt surface, in portions that had severe cracks (e.g., alligator, longitudinal, and transverse), as an alternate and efficient solution against the base course reinforcement. Specifically, the west bound lane along the Ferguson Lane had a geosynthetic reinforcement below the overlay (reinforced section), while the east bound lane did not have any geosynthetic reinforcement below the overlay (unreinforced section).

The geosynthetic reinforcement adopted in the study was a biaxial geogrid made up of fiberglass strands that were coated with an elastomeric polymer and had a pressure sensitive adhesive backing to enhance their bonding with adjacent asphalt layers. The biaxial geogrid had an ultimate tensile strength of 100 kN/m at a strain of 3%, per ASTM D6637. The geogrid was placed directly on the pre-existing asphalt surface after removing dirt, dust, and other deleterious material. It is important to note that the pre-existing asphalt was not repaired i.e., neither milled nor levelled or any tack applied prior to the installation of geogrid. Figure 4 presents the treatment comprising the use of a geogrid reinforcement directly over alligator cracks and longitudinal edge cracks that were not treated. A polymer modified emulsion was then applied as a tack coat at a rate of 0.15 gal/yd² on the geosynthetic reinforcement.

Figure 4. Installation of geogrid reinforcement at Ferguson Lane in April 2014.

This trackless tack emulsion is applied hot and would cool down in less than 20 seconds, helping the truck pass over the geogrid without damaging the geosynthetic installation.

Subsequently, a 75 mm-thick dense graded asphalt (TY-C) was placed at a temperature of 122 °C and compacted. As the trackless tack emulsion is heat-activated, it allows a better bonding between interlayers when hot asphalt is placed over it. Figure 5 presents the cooled tack coat and the compaction and final overview of the geosynthetic-reinforced asphalt overlay section.

Figure 5. Final paving work at the geosynthetic-reinforced section.

Evaluation of Experimental Sections (2014-2022):

The experimental sections were evaluated in May 2022, after about 8 years of rehabilitation, to investigate the condition of unreinforced and geosynthetic-reinforced sections. The evaluation of experimental sections included visual examinations to identify the possible locations and types of distresses in both, unreinforced and geosynthetic-reinforced sections. Figure 6 shows the pavement surface conditions of the experimental sections during the visual examination survey conducted in 2022. As shown in the figure, the visual evaluation revealed that the longitudinal cracks reflected onto the asphalt overlays in the unreinforced section, while the geosynthetic reinforcements were effective in minimizing the reflection of such cracks from the pre-existing roadway. As shown in the figure, specifically, the longitudinal cracks existed on the pavement edges before pavement rehabilitation reflected in the unreinforced section. On the other hand, longitudinal edge cracks in the reinforced section did not reflect to the new surface suggesting that the geosynthetic reinforcement minimized the reflective cracks and any fresh longitudinal cracks from the expansive subgrade. This observation is particularly similar to the findings from Zornberg and Roodi (2021), in which environmental longitudinal cracks were found to be significantly lower in geosynthetic-stabilized sections than in control sections.

Figure 6. Road conditions during 2022 survey.

In addition, Figure 6 also revealed that some transverse cracks, roughly perpendicular to the centerline of the pavement, were observed in the unreinforced and geosynthetic-reinforced sections. However, it is important to note that these cracks are maybe caused due to the thermal expansion and contraction of the asphalt layer as a result of temperature variations. On the other hand, geosynthetic reinforcements were effective in resisting the reflection of severe alligator cracks for a duration of 8 years. Figure 7 shows a closer view of the edge cracks and the deteriorated surface condition in the unreinforced section, while the surface condition of geosynthetic-reinforced section looks much better in comparison.

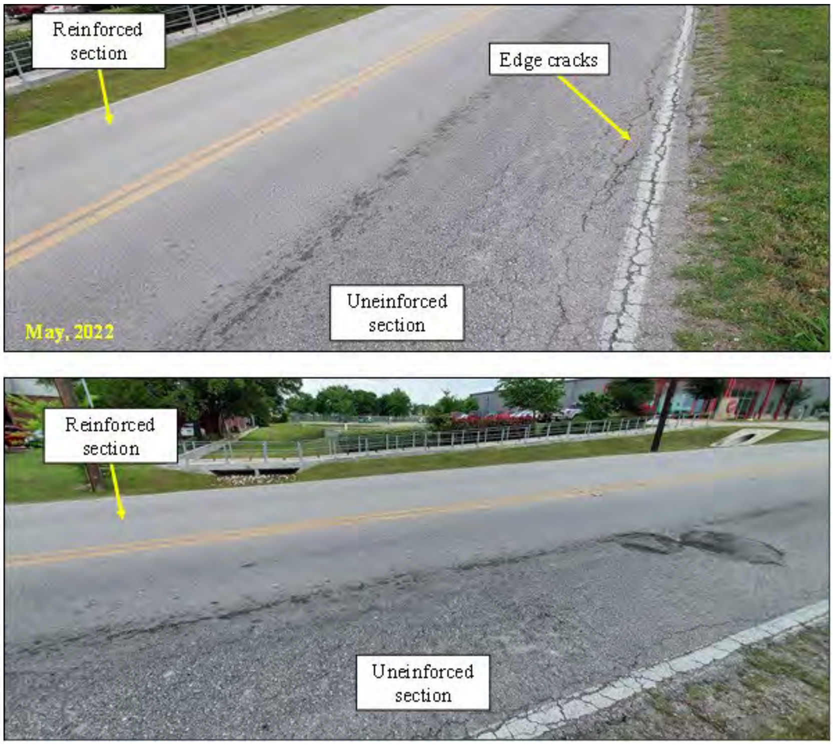

Figure 7. View of road condition of a geogrid-reinforced section (left) and control section (right) showing edge cracks in the unreinforced section.

Overall, geosynthetic reinforcement installed below the asphalt overlays were effective in resisting the reflection of longitudinal and alligator cracks from the pre-existing asphalt surface into the asphalt overlay effectively for a period of 8 years. The evaluation of experimental (unreinforced and reinforced) sections shall be continued to quantify the effectiveness of geosynthetic reinforcement against the reflection of cracks from pre-existing roadway.

CONCLUSIONS

This study presents a case history on the use of geosynthetic reinforcement to minimize cracks from expansive soil subgrade in an urban roadway in Austin, Texas. After 8 years, an investigation of the experimental sections showed the benefits of the geogrid reinforcement inclusion in the deteriorated pavement structure, mitigating cracks and pavement distresses. On the other hand, longitudinal cracks reflected around the edges of the asphalt overlay in the unreinforced section. Geogrid inclusion also highlighted their capability to resist the reflection of severe alligator cracks effectively for a duration of 8 years without any asphalt surface treatments prior to the geosynthetic installation (e.g. milling, level up).

Unlike other case studies evaluated and reported in the literature, this case study highlights the effectiveness of geogrid reinforcement installed below the asphalt overlay in minimizing cracks associated with expansive subgrade soil. This case study also highlights the inclusion of geosynthetic reinforcement below the asphalt overlay may be a viable solution for mitigating cracks and other pavement distresses associated with expansive subgrade soils. It is also worth noting that the above-mentioned findings were based on the observations from one site and may need additional evaluations before directly correlating the results to similar situations from a different location. This also points the need for continued evaluation of the experimental sections for the design of geosynthetic-reinforced pavements over expansive subgrades against reflective cracks and other pavement distresses.

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