*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 23, Issue 4 Ser. II (Jul. – Aug. 2026), PP 49-61*
*www.iosrjournals.org*

# Performance, Problems and Remedial Measures for Roads Constructed on Expansive Soil in Trinidad and Tobago

Saeed Mohamed[1], Damian Alexander[2], Bharat Jagdeo [3]
[1]*Project Management and Civil Infrastructure System, The University of Trinidad and Tobago, Trinidad*
[2]*Project Management and Civil Infrastructure System, The University of Trinidad and Tobago, Trinidad*
[3]*Project Management and Civil Infrastructure System, The University of Trinidad and Tobago, Trinidad*

***Abstract:***
*Expansive soils are among the most problematic soil types, significantly contributing to pavement and foundation settlement issues worldwide. The volume changes caused by the soil's characteristic swelling and shrinking behavior, driven by climate-induced moisture variations, lead to severe structural damage. This study aims to examine the impact of expansive soils on existing pavement structures and to propose evidence-based remediation techniques for Trinidad and Tobago. The methodology involved a thorough review of peer-reviewed studies, a comparative analysis of local geotechnical data for Trinidadian expansive soils, and an examination of international literature on similar soils. The study found that primary pavement defects, such as cracking, rutting, and instability, are not solely caused by expansive soils but are often initiated by pavement structural failure (fatigue), which allows moisture intrusion and triggers the shrink-swell cycle. A comprehensive feasibility assessment of international treatment methods was conducted, resulting in the selection of three suitable measures for Trinidad and Tobago: replacing or compacting non-expansive soils for embankments, using geosynthetics for reinforcement and barriers, and implementing robust drainage construction and maintenance.*
***Key Word**: Expansive Soil; Swelling; Shrinkage; Moisture; Subgrade; Stabilization; Geosynthetics; Soil Properties; Volumetric Change.*

---

Date of Submission: 12-08-2026 Date of Acceptance: 25-08-2026

---

## I. Introduction

Poor road conditions have been a persistent challenge for road users in Trinidad and Tobago over the past decades. These compromised infrastructural conditions have been linked to tragic incidents resulting in loss of life and property damage. This study investigates the performance, associated problems, and potential remedial measures for roads constructed on expansive clays within the country, aiming to provide verifiable data for local authorities, such as the Ministry of Works and Transport, to inform future pavement design and refurbishment.
The detrimental effects of expansive soil have been reported to cause greater damage to pavement infrastructure and other engineering structures than natural geohazards [1,2]. Globally, annual expenditure on damages caused by expansive soil amounts to billions of dollars [2]. In Trinidad and Tobago, this financial burden is substantial; local figures indicate that approximately TT$335 million has been spent on the Road Construction/Major Road Rehabilitation Project since fiscal year 2019, with an additional TT$201.9 million allocated to municipal corporations for local road rehabilitation [3].

The general objective of this research is to rigorously identify the performance characteristics, dominant problems, and feasible remedial measures for roads constructed on expansive soil in Trinidad and Tobago. Specific objectives included: reviewing existing geotechnical knowledge and practices; establishing and using local field data; identifying areas affected by the region; critically assessing current road designs; and quantitatively evaluating feasible mitigation methods. All proposed recommendations are developed with consideration for the American Association of State Highway and Transportation Officials (AASHTO) specifications and the American Society for Testing and Materials (ASTM) standards.

## II. Comprehensive Literature Review

**Expansive Soils and Mineralogical Aspects**: Expansive soils are defined as soils or rock materials that exhibit the potential for significant volume change (shrinkage or swelling) in response to changes in moisture content [4]. Such soils are predominantly found in arid and semi-arid regions characterized by alternating wet and dry cycles [5]. Given that Trinidad and Tobago experience distinct wet (June to December) and dry (January to May) seasons, these climatic cycles drive localized shrinking swelling activity. Highly expansive clays can exhibit volume changes of 10% or more [1, 4]. The depth of the active zone, where these changes occur, is typically 3 meters but may be extended by disturbance, such as the presence of deep-rooted vegetation [6, 7].

**Identification and Classification of Expansive Soils:** Initial identification of expansive soils can be achieved through visual inspection, observing macro-features such as surface cracks and a popcorn-like texture during periods of desiccation, as shown in Figure 1.

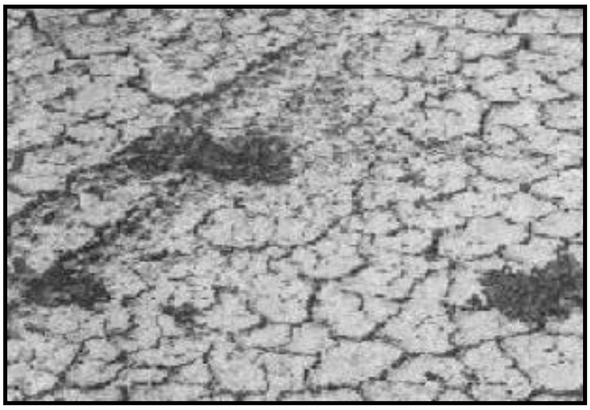

**Figure 1:** Typical surface cracking and popcorn-like texture observed in expansive soils, adapted from Zumrawi [11].

Laboratory analysis relying on Atterberg Limits (Liquid Limit (LL), Plastic Limit (PL), Shrinkage Limit (SL), and Plasticity Index (PI)) is considered the best indicator for assessing potential swell [12, 13]. The definitive swell test quantifies the degree of expansiveness and categorizes soils from Low (<1%) to Very High (>5%), as shown in Table 1.

**Table 1:** Degree of Expansiveness Based on Potential Swell adapted from Merwe [14]

| Potential Swell (%) | Degree of Expansiveness |
|---|---|
| <1 | Low |
| 1 - 2 | Medium |
| 2 - 5 | High |
| >5 | Very High |

Local investigations conducted by Ramana [9] established index soil parameters at 17 locations, as shown in Table 2.

**Table 2:** Trinidad Soil Parameters, adapted from Ramana [4]

| No. | Location | Short | Clay Content <2 µm (%) | Clay Content <1 µm (%) | LL (%) | PI (%) | SL (%) | Natural Moisture Content (%) | Activity (PI/Clay) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Barrackpore | BKP | 82 | 65 | 84 | 56 | 24 | 39 | 0.69 |
| 2 | Brasso-Venado | BRS | 52 | 42 | 79 | 46 | 18 | 34 | 0.88 |
| 3 | Caparo | CPR | 40 | 35 | 55 | 32 | 21 | 25 | 0.79 |
| 4 | Caigual | CGL | 35 | 30 | 56 | 33 | 13 | 23 | 0.94 |
| 5 | Chaguanas | CHG | 35 | 35 | 51 | 23 | 14 | 14 | 0.67 |
| 6 | Couva | CVA | 36 | 30 | 60 | 33 | 19 | 25 | 0.91 |
| 7 | Gran Couva | GCV | 69 | 55 | 93 | 65 | 21 | 33 | 0.94 |
| 8 | Guayaguayare | GUY | 39 | 32 | 47 | 23 | 20 | 16 | 0.59 |
| 9 | Mayaro | MYR | 70 | 60 | 74 | 48 | 12 | 36 | 0.69 |
| 10 | Moruga | MGA | 35 | 30 | 43 | 26 | 25 | 15 | 0.73 |
| 11 | Pleasantville | PVL | 50 | 45 | 94 | 71 | 16 | 31 | 1.43 |
| 12 | Poole | POO | 57 | 50 | 81 | 48 | 19 | 37 | 0.83 |
| 13 | Princes Town | PRT | 72 | 60 | 83 | 58 | 14 | 37 | 0.79 |
| 14 | Rio Claro | RIO | 22 | 17 | 70 | 44 | 24 | 39 | 1.99 |
| 15 | Sang Grande | SNG | 49 | 45 | 76 | 44 | 13 | 38 | 0.89 |
| 16 | Tabaquite | TBQ | 62 | 50 | 106 | 67 | 19 | 43 | 1.08 |
| 17 | Talparo | TPR | 60 | 52 | 73 | 48 | 16 | 32 | 0.80 |

Recognizing the inapplicability of international standards due to regional climatic and geological disparities, local modifications were made to the U.S Bureau of Reclamation (USBR) classification system shown in Table 3 to produce Table 4.

**Table 3:** adapted from USBR Classification [15]

| Colloid Content (<0.0001mm) % | Plasticity Index % | Shrinkage Limit % | Probable Expansion (% Total Volume Change) | Degree of Expansion |
|---|---|---|---|---|
| >28 | >35 | <11 | >30 | Very high |
| 20 - 31 | 25 - 41 | 7 - 12 | 20 - 30 | High |
| 13 - 23 | 15 - 28 | 10 - 16 | 10 - 20 | Medium |
| <15 | <18 | >15 | <10 | Low |

**Table 4:** Modified USBR Classification System for Local Soils adapted from Ramana [4]

| Clay Content (<0.0002 mm)% | Plasticity Index, % | Shrinkage Index, % | Liquid Limit | Probable Maximum Swell, % | Degree of Expansion |
|---|---|---|---|---|---|
| < 30 | < 25 | < 30 | < 50 | < 2 | Low |
| 30 - 50 | 25 - 45 | 30 - 40 | 50 - 70 | 2 - 5 | Medium |
| 50 - 65 | 45 - 65 | 40 - 50 | 70 - 90 | 5 - 10 | High |
| > 65 | > 65 | > 50 | > 90 | > 10 | Very High |

The Modified USBR Classification System and the Vander Merwe Chart shown in Figure 2 were used to create Figure 3, the Modified Vander Merwe Chart for Local Soils. Additionally, a Modified Plasticity Chart was developed for quick qualitative analysis, as shown in Figure 4.

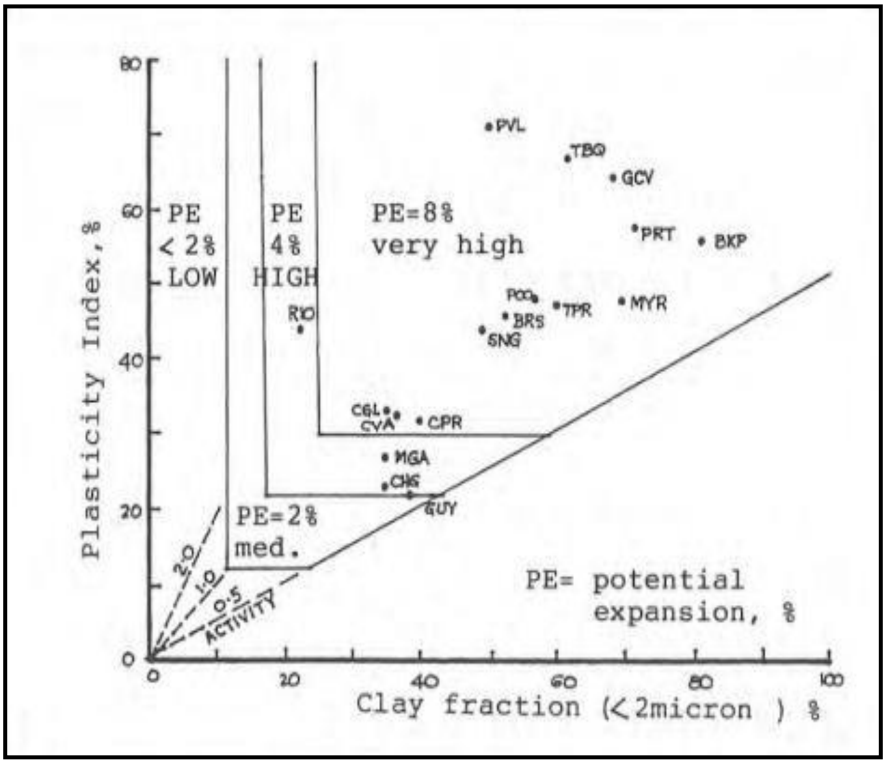


**Figure 2:** Vander Merwe Chart adapted from Merwe [14].

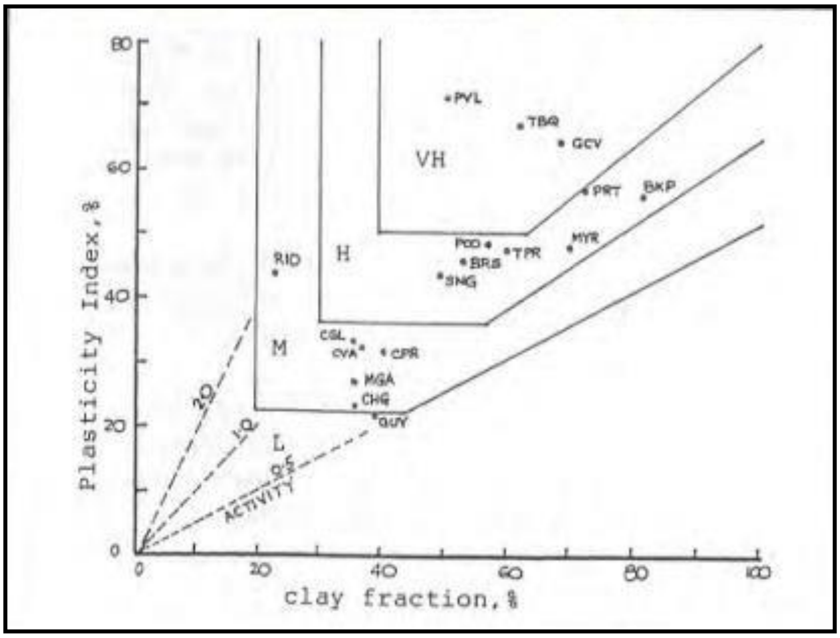


**Figure 3:** Modified Vander Merwe Chart for Local Soils adapted from Ramana [4].

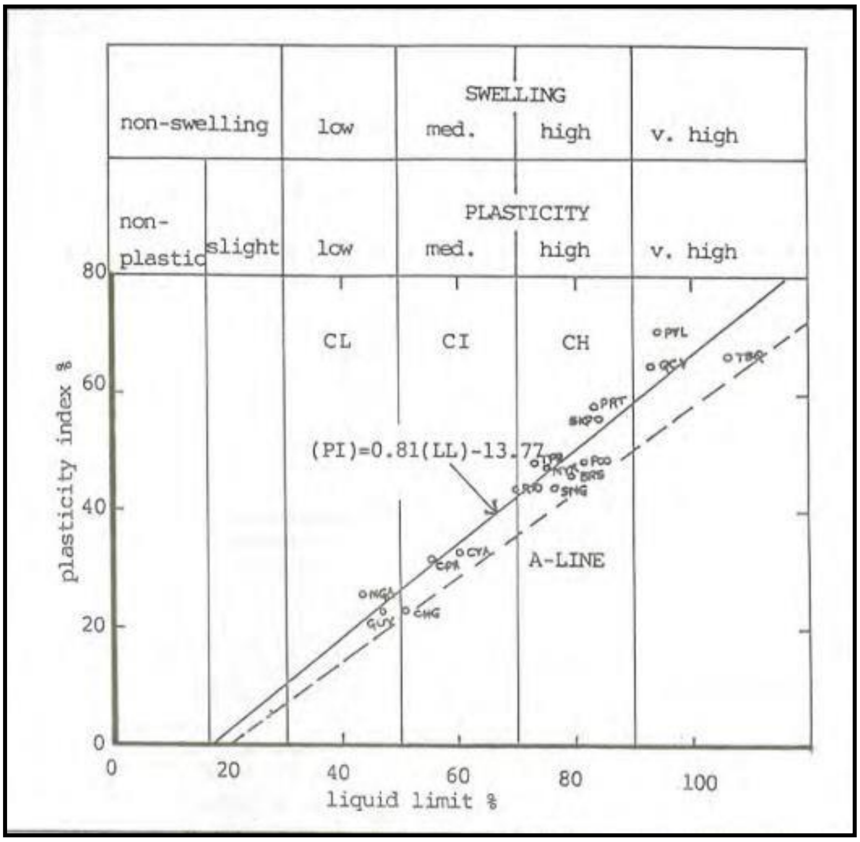


**Figure 4:** Modified Plasticity Chart for Local Soils adapted from Ramana [4].

**Distribution and Problems of Expansive Soils:** Expansive soils are distributed primarily across the central and southern regions of Trinidad (Figure 5) and the southern/south-western regions of Tobago [16]. The Talparo Clay and Tarouba Clay series represent the most prevalent expansive types shown in Table 5.

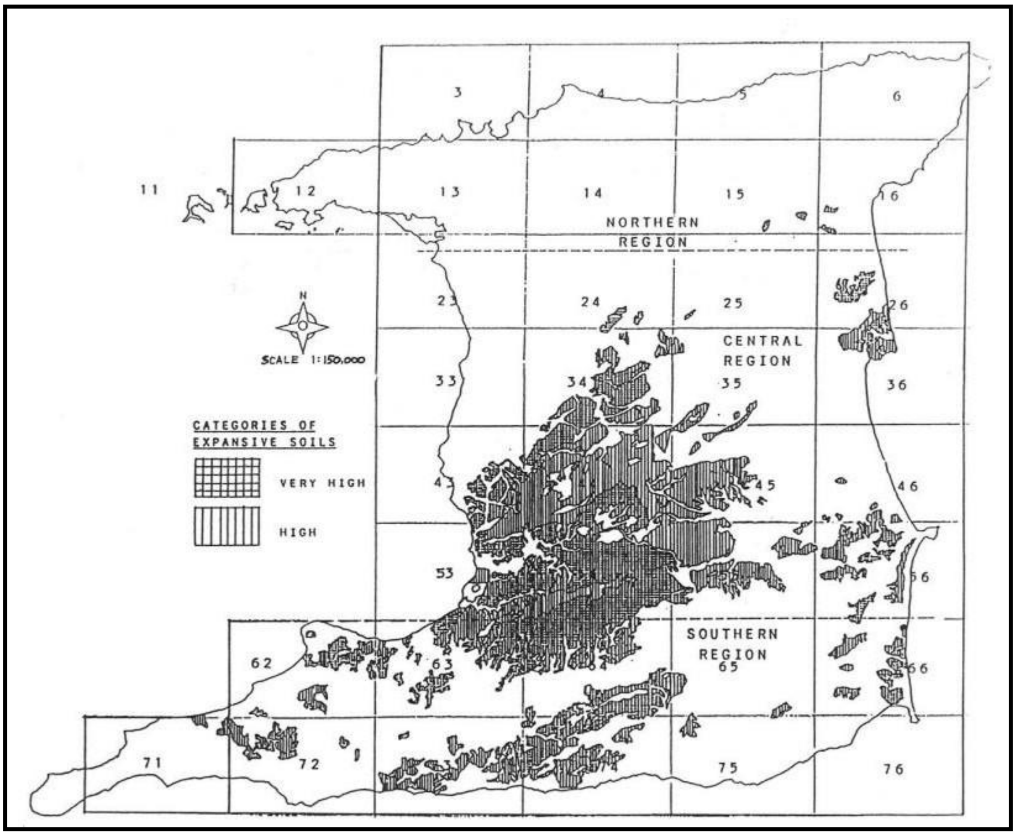


**Figure 5:** Hazard Map for Expansive Soils of Trinidad adapted from Venkataramana [10].

**Table 5:** Classification of Expansive Soils in Trinidad adapted from Venkataramana [4 - 10].

| Soil Series | Name | Parent Material | Formation |
|---|---|---|---|
| 177 | Talparo Clay | Clay Shale | Nariva |
| 474/L | Princes Town Clay | Marl | Nariva |
| 239 | Debe Clay | Clay Shale | Upper Cipero |
| 278/L | Tarouba Clay | Clay Shale | Nariva |
| 77 | Ecclesville Clay | Clay Shale | Upper Lengua |

Detailed site-specific parameters and classifications are documented in Table 6. Pavement distress typically manifests as surface roughness and longitudinal cracking [17].

**Table 6:** Classification of Expansive Soils in Trinidad, adapted from Ramana [18]

| No. | Location | Symbol | Soil series | Parent material | Textural Classification | Unified Classification | Clay |
|---|---|---|---|---|---|---|---|
| 1 | Barrackpore | BKP | 239 | Clay alluvium | Clay | CH | 82 |
| 2 | Brasso-Venado | BRS | 674/L | Calcareous silt stone | Silty clay | CH | 52 |
| 3 | Caparo | CPR | 335 | Clay alluvium | Silty clay loam | CI | 40 |
| 4 | Caigual | CGL | 39 | Clay alluvium | Silty clay loam | CI | 35 |
| 5 | Chaguanas | CHG | 33 | Clay alluvium | Silty clay loam | MI | 35 |
| 6 | Couva | CVA | 231 | Clay alluvium | Clay loam | CI | 36 |
| 7 | Gran Couva | GCV | 575/68/L | Mixed shale | Clay | CH | 69 |
| 8 | Guayaguayare | GUY | 75 | Clay shale | Silty clay loam | CL | 39 |
| 9 | Mayaro | MYR | 77 | Clay shale | Clay | CH | 70 |
| 10 | Moruga | MGA | 78/L | Volcanic mud | Silty clay loam | CL | 35 |
| 11 | Pleasantville | PVL | 278/L | Clay shale | Clay | CH | 50 |
| 12 | Poole | POO | 35/77 | Clay alluvium | Clay | CH | 57 |
| 13 | Princess Town | PRT | 474/L | Clay shale | Clay | CH | 72 |
| 14 | Rio Claro | RIO | 474/L | Marl | Silty loam | CI | 22 |
| 15 | Sangre Grande | SNG | 233 | Clay alluvium | Clay | CH | 49 |
| 16 | Tabaquite | TBQ | 177 | Clay shale | Clay | CH | 62 |
| 17 | Talparo | TPR | 177 | Clay shale | Clay | CH | 60 |

**Table 7:** Expansive Soils Properties in Trinidad, adapted from Ramana [18]

| No. | Location | Liquid Limit LL (%) | Plasticity Index (%) | Shrinkage Limit (%) | Activity | In situ density (kg/m³) | Natural moisture content (%) | Optimum moisture content (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Barrackpore | 84 | 56 | 22 | 0.69 | 1741 | 39 | 27 |
| 2 | Brasso-Venado | 79 | 46 | 18 | 0.88 | 1816 | 34 | 23 |
| 3 | Caparo | 55 | 32 | 21 | 0.79 | 1975 | 25 | 20 |
| 4 | Caigual | 56 | 33 | 13 | 0.94 | 1921 | 23 | 18 |
| 5 | Chaguanas | 51 | 23 | 13 | 0.67 | 1997 | 14 | 16 |
| 6 | Couva | 60 | 33 | 19 | 0.91 | 1887 | 25 | 18 |
| 7 | Gran Couva | 93 | 65 | 21 | 0.94 | 1818 | 33 | 30 |
| 8 | Guayaguayare | 47 | 23 | 19 | 0.59 | 1766 | 16 | 20 |
| 9 | Mayaro | 74 | 48 | 12 | 0.69 | 1796 | 36 | 23 |
| 10 | Moruga | 43 | 26 | 25 | 0.73 | 1995 | 15 | 15 |
| 11 | Pleasantville | 94 | 71 | 16 | 1.43 | 1647 | 31 | 28 |
| 12 | Poole | 81 | 48 | 19 | 0.83 | 1749 | 37 | 23 |
| 13 | Princess Town | 83 | 58 | 14 | 0.79 | 1927 | 37 | 25 |
| 14 | Rio Claro | 70 | 44 | 24 | 1.99 | 1726 | 39 | 26 |
| 15 | Sangre Grande | 76 | 44 | 13 | 0.89 | 1766 | 38 | 15 |
| 16 | Tabaquite | 106 | 67 | 19 | 1.08 | 1711 | 43 | 31 |
| 17 | Talparo | 73 | 48 | 16 | 0.80 | 1889 | 32 | 25 |

**Longitudinal Cracking:** Generated by tensile stresses induced during subgrade shrinkage, as shown in Figure 6. Crucially, this type of failure must be correctly differentiated from longitudinal cracks caused by traffic-induced pavement fatigue, as shown in Figure 7.

**Figure 6** Longitudinal cracking due to subgrade shrinkage adapted from Sebesta [19].

**Figure 7:** Longitudinal cracking due to pavement fatigue adapted from Scullion et al. [20].

**Edge Cracking:** A localised phenomenon near the pavement edge, resulting from the shrinking of surrounding plastic clays, often accelerated by water extraction from nearby vegetation, as shown in Figure 8.

**Figure 8:** Edge Cracks due to Shrinking of Soil, adapted from Sebesta [19].

**Pavement Rutting:** A consequence of cyclic shrinking and swelling, leading to differential settlement and potential water pooling on the surface, increasing the risk of hydroplaning, as shown in Figure 9.

**Figure 9:** Rutting of pavement due to cyclic moisture changes, adapted from Daniel [21].

**Shallow Landslides:** Infiltration of rainwater can reduce soil shear strength, causing slope instability and consequential pavement edge failure, as shown in Figure 10.

**Figure 10:** Pavement Failure due to Slope Instability, adapted from Hearn et al. [22].

## III. Review of Remedial Measures

The existing road network in Trinidad and Tobago utilizes Flexible Pavement structures as shown in Figure 11.

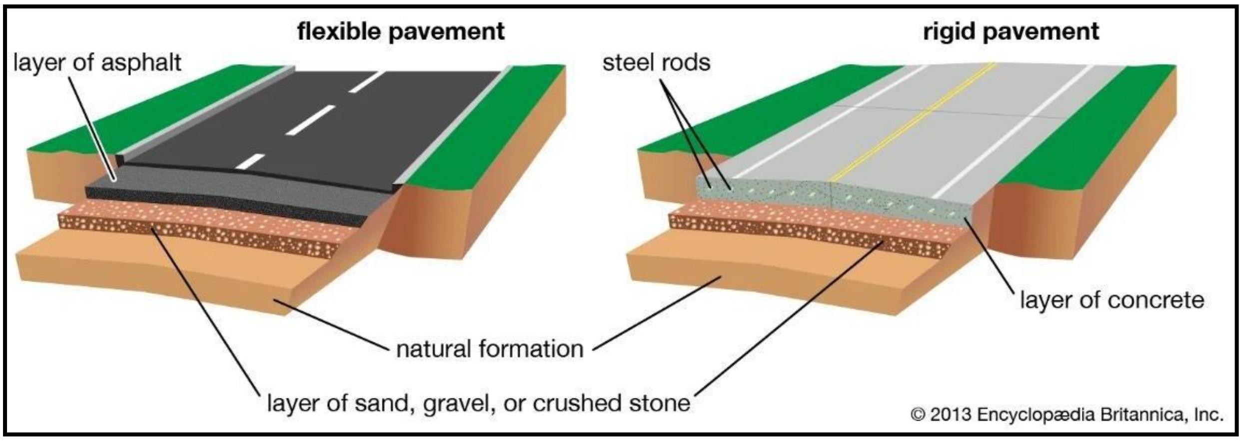


**Figure 11:** Types of Pavement Cross-Section adapted from Britannica [23].

While flexible pavements are designed to accommodate some deflection, volume instability remains a cause of distress [20]. Rigid pavements, conversely, possess higher flexural strength but are often considered unsuitable for highly expansive soils [24]. The choice between flexible and rigid pavement is fundamentally an economic decision based on the California Bearing Ratio (CBR) and the anticipated traffic load, as shown in Figure 12 and Table 8.

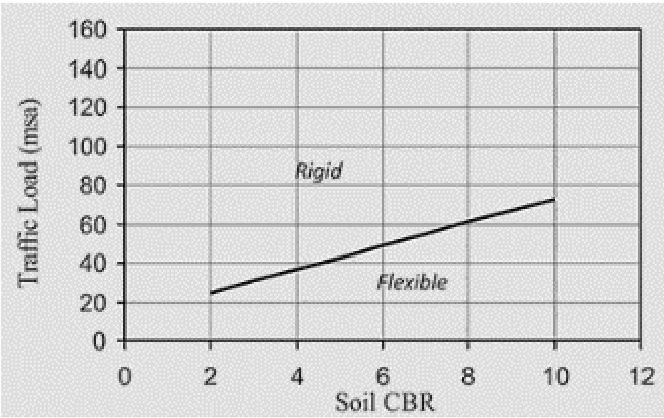


**Figure 12:** Economical selection based on Loading and Bearing Ratio, adapted from Chandra [25]

**Table 8:** Comparison of Flexible and Rigid Pavements adapted from the Constructor [26]

| No. | Flexible Pavement | Rigid Pavement |
|---|---|---|
| 1 | Consists of a series of layers with the highest quality materials at or near the surface. | Consists of one layer Portland cement concrete slab of relatively high flexural strength. |
| 2 | Reflects the deformations of subgrade and subsequent layers on the surface. | Able to bridge over localized failures and areas of inadequate support. |
| 3 | Stability depends upon aggregate interlock, particle friction, and cohesion. | Structural strength is provided by the pavement slab itself by its beam action. |
| 4 | Design is greatly influenced by the subgrade strength. | Flexural strength of concrete is a major factor for design. |
| 5 | Functions by way of load distribution through the component layers. | Distributes load over a wide area of subgrade because of its rigidity and high modulus of elasticity. |
| 6 | Atmospheric temperature variations do not produce stresses in flexible pavements. | Temperature changes induce heavy stresses in rigid pavements. |
| 7 | Has "self-healing" properties; deformations from heavy wheel loads are recoverable to some extent. | Excessive deformations from heavy wheel loads are not recoverable (permanent settlements). |

Treatment methods for expansive subgrades are generally classified into three categories:

**Mechanical, Chemical, or Physical Alteration:** Replacement and Compaction: Excavating the expansive soil (recommended depths of 1-3.5 m) and replacing it with a properly compacted non-expansive fill, as shown in Figure 13. This method is fast but highly dependent on the cost and availability of suitable fill [27].

**Figure 13:** Excavation and Replacement of Expansive soils adapted from Obinna [27]

**Lime Stabilization (Calcium Oxide):** A widely used method that increases compressive strength and stiffness, significantly reducing swelling potential (Figure 14) and decreasing the liquid limit (Figure 15). This is a cost-effective, long-term solution [28].

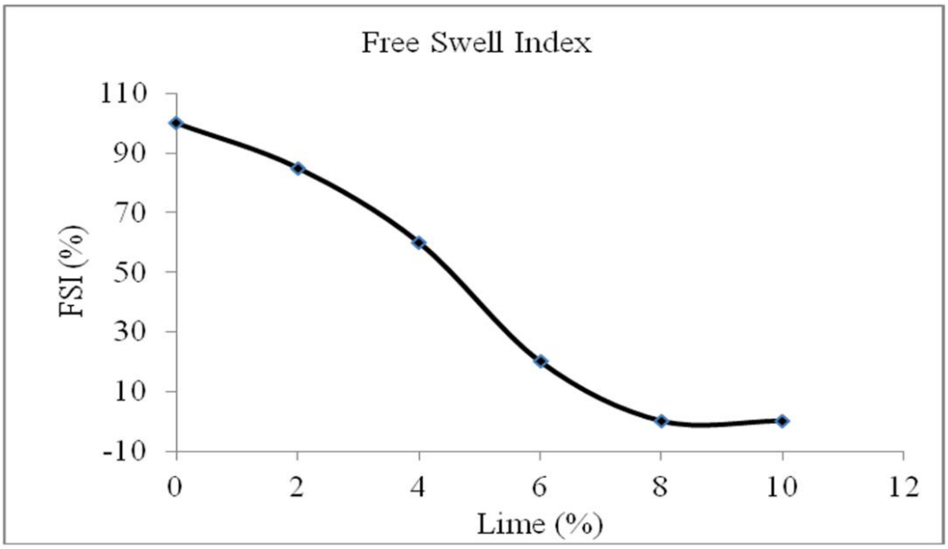


**Figure 14:** Lime (%) vs Free Swell Index (FSI) adapted from Chamberlin & Rao [29].

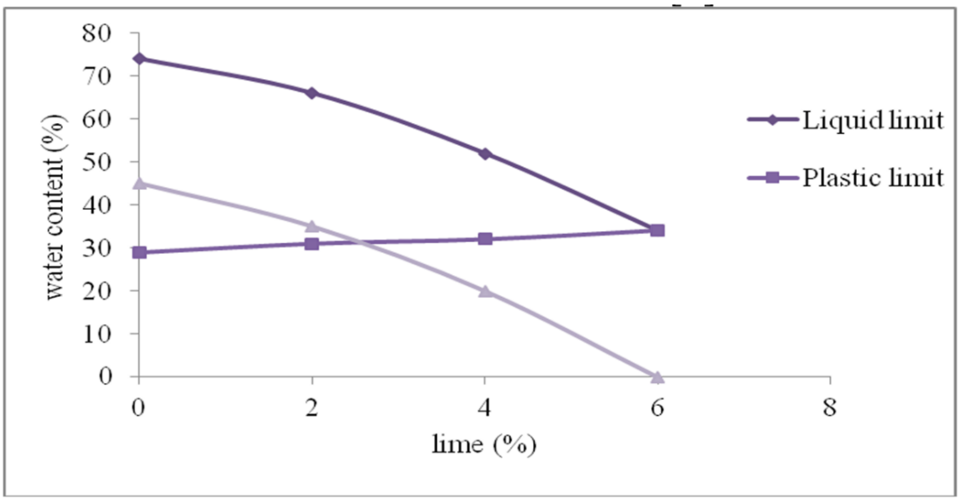


**Figure 15:** Lime (%) vs Water Content (Liquid Limit and Plastic Limit), adapted from Chamberlin & Rao [29].

**Bagasse Fibre and Lime/Ash:** Utilising local industrial waste products (Bagasse Fibre/Ash, Lime Sludge) as natural polymers and pozzolanic materials to control both shrinking and swelling and enhance compressive strength, as shown in Figure 16.

**Figure 16** Bagasse Fibre adapted from Nai [30].

**Cement and Fly-Ash:** Enhances shear strength and sub-base stability by acting as a pozzolana material [31].

**Pavement Reinforcement:** Geosynthetics (Geogrids). Employed to minimise longitudinal cracking by providing reinforcement and limiting subgrade deformation, as shown in Figure 17.

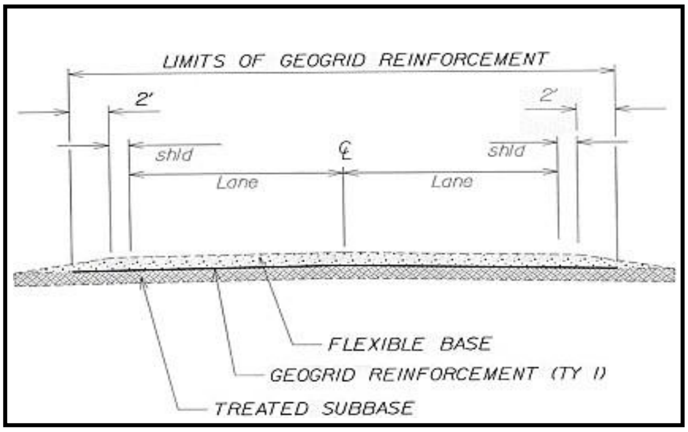


**Figure 17:** Application of Geogrid Reinforcement adapted from Dessouky et al. [32].

Moisture Control Methods: Moisture Barriers: Can be installed either horizontally or vertically to prevent moisture flow [33, 34], and an example is shown in Figure 18.

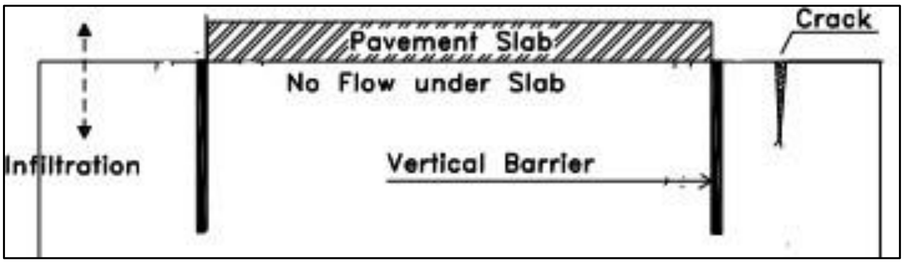


**Figure 18** Application of vertical moisture barriers adapted from Chen & Bulut [34]

Drainage: Essential for preventing moisture accumulation; proper construction and maintenance with a required 12% slope effectively controls the swelling potential [4].

Remedial strategy selection requires a stepwise approach based on the failure mode, considering cost, durability, and serviceability as shown in Figure 19.

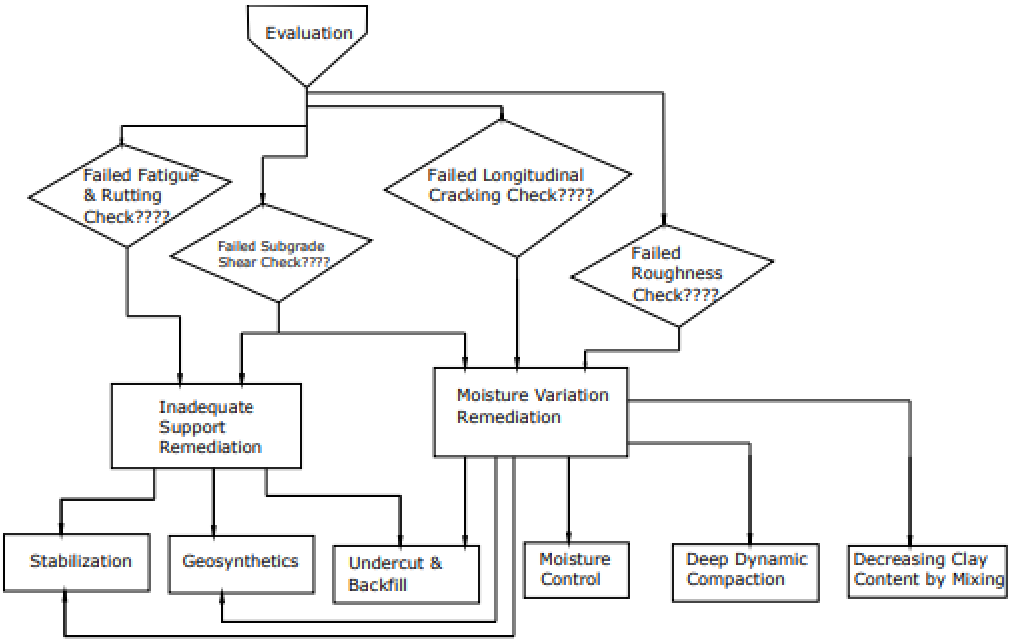


**Figure 19:** Schematic of Remedial Strategy adapted from Uba [35]

A local decision matrix was created, and it was determined that Mechanical/Physical Alteration, Geosynthetic Barriers, Geosynthetic Reinforcement, and Drainage were the most feasible options (scores 59-65), as shown in Table 9. The criteria and weighting listed in Table 9 were developed based on the literature discussed in the paper, with appropriate weights assigned. Overall, each category ranges from 1 to 5, representing Poor to Excellent.

**Table 9:** Matrix for Selection of Suitable Methods to be Implemented in Trinidad and Tobago.

| | Criteria/ Weight | | | | | | Score |
|---|---|---|---|---|---|---|---|
| Methods | Experience/ 7 | Cost/ 5 | Time/ 4 | Difficulty/ 2 | Efficiency/ 6 | Durability /3 | |
| Mechanical/ Physical Alteration | 1 | 2 | 4 | 2 | 3 | 2 | 61 |
| Chemical Stabilization | 5 | 4 | 4 | 4 | 1 | 2 | 91 |
| Geosynthetic Reinforcement | 2 | 3 | 2 | 1 | 3 | 2 | 63 |
| Geosynthetic Barriers | 1 | 3 | 3 | 2 | 2 | 3 | 59 |
| Drainage | 1 | 2 | 4 | 1 | 3 | 4 | 65 |

## IV. Methodology, Key Findings and Research Gaps

**Methodology and Critical Analysis:** The methodology involved a combined desktop review and field validation approach. It utilized existing laboratory test data from past local investigations to establish the expansive nature of the soil (e.g., using Table 7). This data was critically compared against international investigations with similar expansive soil properties (e.g., studies from Texas, India, and Australia). The primary mode of inquiry involved observing and classifying existing pavement defects via site investigations. Crucially, the study determined that the dominant form of damage observed, rutting and cracking along the wheel paths, was attributable to pavement fatigue, which is a structural failure under heavy traffic loading on the existing flexible pavement design. This structural compromise then created the pathway for water infiltration into the subgrade, thereby activating the expansive soil's shrink-swell mechanism. This re-contextualizes the problem from being solely expansive soil-driven to a structural-failure-initiated expansive soil problem. The financial estimates regarding road repairs reinforce the urgency of addressing this fundamental design deficit.

**Critique and Research Gaps:** Previous local investigations (e.g., Venkataramana) primarily focused on expansive soil problems related to building foundations, resulting in sparse data directly applicable to pavements. The absence of local California Bearing Ratio (CBR) data, a standard international metric for pavement subgrade strength, necessitated a reliance on other index properties, highlighting a critical research gap. The study identified the following crucial areas requiring future investigation:

- The environmental effects and possible positive effects result from stabilizer absorption (e.g., lime) into surrounding untreated soils when chemical stabilization is applied.

- The long-term deterioration rate of natural fibers (like bagasse) and the maintenance protocols required to achieve maximum material lifespan when used in stabilization.
- The deficiency of reported local Standard Penetration Test (SPT) data on expansive soils. Establishing a correlation between known index properties and bearing capacity through SPT testing is necessary for aligning local geotechnical practice with international standards.

## V. Conclusions, Recommendations and Future Work

This study successfully determined the performance, problems, and most feasible remedial measures for pavements constructed on expansive soils in Trinidad and Tobago. While pavement defects are consistent with expansive soil damage, the core mechanism of damage initiation is identified as structural failure due to pavement fatigue under heavy loading on the existing flexible pavement design. This structural breakdown facilitates moisture ingress, triggering the harmful shrink-swell cycle. Based on the quantitative feasibility assessment (Table 9), the following methods were deemed the most appropriate and sustainable for local implementation:

- The use of non-expansive soil as an embankment for major roadways requiring elevation change.
- The application of geosynthetic materials to function dualistically as pavement reinforcement (geogrids to increase strength and prevent heave) and moisture barriers (geomembranes for sealing shoulders).
- The fundamental importance of implementing proper drainage to control moisture fluctuations.

To effectively mitigate the effects of expansive soils, the following strategic measures are recommended to prevent initial structural failure and subsequent moisture seepage:

- **Pavement Design Modification:** Integrate a layer of geogrid reinforcement above the subgrade in the flexible pavement design. This intervention is critical for enhancing the structure's resistance to heavy traffic loads (fatigue prevention) and increasing resistance to soil heave.
- **Integrated Geosynthetic Barriers:** Mandate the dual application of geosynthetics for reinforcement and moisture control. Geomembranes should be applied as horizontal moisture barriers along pavement shoulders and embankments to prevent lateral seepage into the subgrade.
- **Mandatory Drainage Protocol:** Enforce the construction and regular maintenance of roadside drainage channels with specified sloping (12% minimum) to maximize water extraction and rapidly reduce the subgrade's swelling potential.
- **Routine Maintenance:** Implement regular maintenance schedules, including the application of epoxy in minor cracks, isolated patching for levelling distortions, and cleaning of drainage structures.

Future research should focus on three strategic areas to provide a complete, locally optimized solution set:

- **Local Material Stabilization:** Investigate the suitability and efficiency of local, readily available materials such as coconut shells and bamboo fiber as cost-effective, eco-friendly soil stabilization alternatives, thereby reducing reliance on expensive imported chemicals.
- **Targeted Treatment Protocol:** Conduct localized investigations to develop a prescriptive treatment protocol, allowing specific remedial methods to be implemented based on the varying levels of expansivity across different soil types and regions within Trinidad and Tobago.

**Structural Optimization:** Study the feasibility of optimizing existing pavement layer thicknesses and materials to intrinsically reduce or eliminate the need for geosynthetic reinforcement, thereby optimizing the total construction cost and complexity

## References

[1]. Chen FH. Foundations on expansive soils. Amsterdam: Elsevier Scientific Publishing Company; 1975.
[2]. Nelson JD, Miller DJ. Expansive soils problems and practice in foundation and pavement engineering. New York: John Wiley & Sons; 1992.
[3]. Seemungal J. Part 1: Billions spent repairing roads in T&T but we're still… Pothole nation [Internet]. Port of Spain: CNC3; 2021 Feb 20 [cited 2024 May 20]. Available from: https://www.cnc3.co.tt/part-1-billions-spent-repairing-roads-in-tt-but-were-still-pothole-nation/
[4]. Ramana KV. Humid tropical expansive soils of Trinidad: Their geotechnical properties and areal distribution [Thesis]. St. Augustine: The University of the West Indies; 1993.
[5]. Bandara N, Gunaratne M. Geotechnical aspects of pavement engineering. New York: Momentum Press; 2018.
[6]. Driscoll R. The influence of vegetation on the swelling and shrinking of clay soils in Britain. Geotechnique. 1983; 33: 93–105.
[7]. Vipulanandan C, Addison MB, Hansen M, editors. Expansive clay soils and vegetative influence on shallow foundations. Reston (VA): American Society of Civil Engineers; 2001.
[8]. Rao SM. Identification and classification of expansive soils. Bangalore: Indian Institute of Science; 2021.
[9]. Jones LD, Jefferson I. Expansive soils. In: Burland J, Chapman T, Skinner H, Brown M, editors. ICE manual of geotechnical engineering: Vol. 1. London: ICE Publishing; 2012. pp. 413–441.
[10]. Venkataramana KN. A hazard map for expansive soils of Trinidad. St. Augustine: The University of the West Indies; 2002.
[11]. Zumrawi MM. Geotechnical aspects for roads on expansive soils. Int J Multidiscip Sci Emerg Res. 2015; 4: 1018–1025.

[12]. Suryakanta. Linear shrinkage test of soil (IS-2720-PART-20-1966) [Internet]. CivilBlog.org. 2013 May 14 [cited 2024 May 20]. Available from: https://civilblog.org/2013/05/14/linear-shrinkage-test-of-soil-is-2720-part-20-1966/

[13]. Lucian C. Geotechnical aspects of buildings on expansive soils in Kibaha, Tanzania [Thesis]. Stockholm: Royal Institute of Technology (KTH); 2008.

[14]. Merwe DH van der. The prediction of heave from the plasticity index and percentage clay fraction of soils. Civ Eng S Afr. 1964; 6: 103–107.

[15]. U.S. Bureau of Reclamation. Earth manual: A guide to the use of soils as foundations and as construction materials for hydraulic structures. Washington (DC): Government Printing Office; 1974.

[16]. Ditzler C. Revision of the classification of soils of Trinidad and Tobago. Washington (DC): USDA NRCS; 2017.

[17]. Holden JC. Reduction of pavement damage from expansive soils using moisture barriers. Proceedings of the 6th Australia-New Zealand Conference on Geomechanics; 1992 Feb 3-7; Christchurch, New Zealand. pp. 83–88.

[18]. Ramana KV. Active soils of Trinidad: Their identification and classification. St. Augustine: The University of the West Indies; 1995.

[19]. Sebesta S. Investigation of maintenance base repairs over expansive soils. College Station (TX): Texas A&M Transportation Institute; 2002.

[20]. Scullion T, Guthrie S, Sebesta S. Field performance and design recommendations for full depth recycling in Texas. Austin (TX): Federal Highway Administration; 2003. Report No. FHWA/TX-03/3929-2.

[21]. Daniel CM. [Construction on expansive clay] [Image]. New York: Shutterstock; n.d.

[22]. Hearn G, Hunt T, Aubert J, Howell J. Landslide impacts on the road network of Lao PDR and the feasibility of implementing a slope management programme. Wokingham: TRL; 2008. Project Report No. PR/INT/346/08.

[23]. Britannica Kids. Road [Internet]. Chicago: Encyclopedia Britannica; n.d. [cited 2024 May 20]. Available from: https://kids.britannica.com/kids/article/road/390844

[24]. Vasudev D. Performance studies on rigid pavement sections built on stabilized sulfate soils [Thesis]. Arlington (TX): University of Texas at Arlington; 2007.

[25]. Chandra S. Flexible pavement versus rigid pavement [Internet]. New Delhi: NBM&CW Infra Construction & Equipment Magazine; n.d. [cited 2024 May 20].

[26]. The Constructor. Flexible Pavement vs Rigid Pavement [Internet]. [cited 2024 May 20]. Available from: https://www.google.com/search?q=https://theconstructor.org/transportation/flexible-pavement-vs-rigid-pavement/

[27]. Obinna U. Overexcavation and replacement of expansive soils [Internet]. Lagos: Structville Integrated Services; 2022 Mar 18 [cited 2024 May 20]. Available from: https://structville.com/2022/03/overexcavation-and-replacement-of-expansive-soils.html

[28]. Albuquerque FC. Review of expansive soil stabilization methods. Geotech Geol Eng. 2020; 38: 4523–4541.

[29]. Chamberlin KS, Rao MR. Influence of lime for enhancing characteristics of expansive soils in road works. Bristol: IOP Publishing; 2021.

[30]. Nai BM. Applications of bagasse in expansive soil stabilization [Thesis]. Nairobi: University of Nairobi; 2015.

[31]. Ravali B, Kumar V, Reddy MM, et al. An investigation of the cement and fly-ash impacts on flexible pavement in expansive soils. Int J Sci Technol Res. 2020; 9: 4479–4482.

[32]. Dessouky S, Lee SI, Yang M, et al. Pavement repair strategies for selected distresses in FM roadways. Austin (TX): Texas Department of Transportation; 2012. Report No. 0-6616-1.

[33]. Demirdogen S. Vertical barriers and numerical analysis of their effectiveness on flow under dams [Thesis]. Ankara: Middle East Technical University; 2018.

[34]. Chen L, Bulut R. Numerical analysis of vertical moisture barriers in controlling expansive soils in presence of soil cracks. Int J Geomech. 2015; 15. doi: 10.1061/(ASCE)GM.1943-5622.0000414.

[35]. Uba B. Performance, problems and remedial measures for roads constructed on expansive soil in Ethiopia – A review. J Civ Environ Eng. 2017; 7: 1-10.