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A Review Article of Comparative Analysis of Geotextile and Geojute Compressive Strength

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Abstract- This study covers a literature search and review to obtain information on geotextile applications related to pavement construction. Applicable information-from this study, if sufficient, would then be used to prepare guidelines on design application, material specifications, performance criteria, and construction procedures for improving subgrade support with geotextiles in general aviation airport pavements. The study revealed that there are numerous design procedures available for using geotextiles in aggregate surfaced pavements and flexible pavement road construction. However, there is no generally accepted procedure for either type construction. The state-of-the-art has not advanced to the point where design procedures for using geotextiles in paved airport construction are available. Construction/installation procedures are available for using geotextiles in aggregate surfaced pavements and flexible pavements for roads, and these may be used as an aid in recommending procedures for airport construction.

Keywords- Pavement deterioration, geosynthetics, pavement reinforcement, cracks, rutting, durability.

I. INTRODUCTION

Geosynthetics are an established family of geomaterials used in a wide variety of civil engineering applications. Many polymers (plastics) common to everyday life are found in geosynthetics. The most common are polyolefins and polyester; although rubber, fiberglass, and natural materials are sometimes used.

Geosynthetics may be used to function as a separator, filter, planar drain, reinforcement, cushion/protection, and/or as a liquid and gas barrier. The various types of geosynthetics available, along with their specific applications, are discussed in subsequent sections.

II. BACKGROUND AND MOTIVATION

Illinois Department of Transportation's (IDOT's) mechanistic-empirical (M-E) pavement design procedures have continually incorporated significant advances in material characterization, climate effects, performance prediction, and other elements of pavement design over the last few decades. However, the modernization of design and construction methods employed for foundation layers of pavements, including subgrade soils and base / subbase courses, has generally not kept up a similar pace.

One important aspect where IDOT's design and construction manuals are lacking modernization is the use of geosynthetics in highway and pavement projects. IDOT has kept up with technical advancements on the use of geogrids / geotextiles with regards to applications such as retaining walls. However, employment of and specifications for geotextile and geogrid products in highway design and construction has not kept pace. One of the objectives of this research project is to investigate proper usage of geotextiles and geogrids in pavement design and construction, to bring the most recent and up-to-date technologies and design methodologies to IDOT manuals, and to ensure proper use of geotextiles and geogrids in pavements.

This will result in more economical pavement structures with reliable performance and durability. Other geosynthetic products such as geocells will be also reviewed and recommended to be brought to the practice and specifications of IDOT.

III. GEOTEXTILE

Geotextile and geogrid materials are the most used geosynthetics in transportation. They provide reinforcement or stabilization to the aggregate layer by laterally restraining the base or subbase and improving the bearing capacity of the system, decreasing wheel load stresses on the subgrade. A geogrid with good interlocking capabilities with aggregate particles through its apertures or a geotextile with good frictional capabilities can provide tensile resistance to lateral aggregate movement.

The geosynthetic also increases the system bearing capacity by forcing the potential bearing surface under the wheel load to develop along alternate and longer mobilization paths.

Geotextile usage and properties have been widely investigated by researchers. Al-Qadi and Appea (2003) state that geotextiles are used between the aggregate layer (base / subbase) and subgrade and can decrease the required excavation depth on weak soil as they improve the performance of pavement sections constructed on weak soils.

According to Yeo (2008), geotextiles have four main functions for use in highway design and construction: separation, reinforcement, filtration, and drainage. Geotextiles can increase the interaction with soils to improve the shear capacity of the interface between aggregate layers and soils.

Thus, geotextiles for reinforcement can improve the mechanical properties of earth structures, which allows for the use of local weak soils. According to Alungbe (2004), geotextiles perform two main mechanical functions in conventional pavement systems. First, geotextiles provide a physical separation between two layers of different natural material, while allowing the water to freely flow through the interface.

IV. GEO-JUTE

Geo-jute or jute geotextile can be very effectively used in pavement structure as it has the advantage of being sustainable and cost-effective [1]. The application of jute materials in pavement engineering can both improve the performance of pavements as well as can flourish the jute industries. Singh and Sonthwal summarized the usefulness of jute as reinforcing materials for various projects [2]. It was observed that reinforcing of jute fiber into subgrade layer increases the California bearing Ratio (CBR) value of soil [3]. Hamid and Shafiq found jute fiber as a suitable material for improving the CBR of sub-base soil. It increases the CBR of sub-base soil up to 200% than the plain soil [4].

Another study showed CBR value of cohesive soil is increased by 130.74% due to the application of jute geotextile [5]. Saride and Kumar studied the influence of geo-jute interlayers on the performance of asphalt overlays on pre-cracked pavements [6]. It was observed that geo-jute interlayers proved effective in controlling the reflection cracking and increasing fatigue life of the overlays. Evaluation of cracking resistance potential of geo-jute reinforced asphalt overlays using direct tensile test was also conducted [7-15].

The tensile strains in geo-jute reinforced specimens found lower than the unreinforced specimens. Considering the above literature review, this study focuses on the determination of stresses, strains and deflections of various layers of a flexible pavement under an instantaneous rectangular loading by 3-D finite element modeling due to geo-jute application. The objectives of this research are to determine the effects of geo-jute on stress-strain distribution and deformation characteristics of flexible pavement structure using finite element analysis. In order to assist in conventional design and construction process of flexible pavement, the study also investigates the effect of geo-jute on California Bearing Ratio (CBR) of subgrade soil.

V. LITERATURE REVIEW

Mehdi Zadehmohamad, Evaluating long-term benefits of geosynthetics in flexible pavements built over weak subgrades by finite element and Mechanistic-Empirical analyses: Finite element (FE) models were developed to evaluate the benefits of geosynthetic reinforcement in flexible pavements built over weak subgrades. The parametric study was conducted to evaluate the effect of different variables such as base thickness, geosynthetic type, geosynthetic stiffness, and double-geogrid layers.

FE analyses were performed for 100 load cycles, and the permanent deformation (PD) was used to calibrate the empirical parameters in MEPDG equations for each layer, which were used to extrapolate PD data for the service life of pavements. The PD curves for unreinforced and similar reinforced sections were used to evaluate the Traffic Benefit Ratios (TBR) at different rut depths.

The results showed that the inclusion of one geogrid/geotextile layer at the base-subgrade interface could significantly reduce pavement rutting. The use of geogrid is more effective than geotextile in reducing pavement rutting. The derived TBR values range from 1.91 to 8.9 for one geogrid layer and from 1.71 to 5.92 for one geotextile layer. The TBR values increase with increasing the rutting depth and geosynthetic stiffness. The TBR value demonstrates an optimum at a base thickness of 10 in. The results demonstrated the superior benefits of using double geogrid layers compared to single-layer cases.

C.Vivek Kumar, Pavement Subgrade Stabilized with Waste coal Ash and Geosynthetics: An Experimental Study and Multiple Regression Modelling: With expansive soils like black cotton soil, subgrade soil stabilisation is a critical step in the pavement construction process. The focus of this research is to use Multiple Regression Analysis (MRA) to evaluate the soil for the optimal addition of coal ash as well as geosynthetics, as well as to develop a model to forecast CBR values. For MRA, data analysis tool in Excel 2020 is used.

The input values for this study includes Atterberg's limits, Optimum Moisture Content (OMC) and percentage of coal ash added by weight which directly affect the CBR value. A model pavement subgrade with the stabilized soil characteristics is designed and economic analysis is done for the designed pavement subgrade.

W. Jeremy Robinson, Implications of incorporating geosynthetics in airfield pavements: A majority of literature indicates that geosynthetic inclusion in flexible pavement bases, subjected to highway loading, improves performance by reducing rutting or vertical pressure on weak subgrade layers. Instances where geosynthetics were less successful in highway pavements included strong subgrade soils and/or thick pavement layers. Thus, understanding the improvement that can be expected from geosynthetic inclusion in airfield pavements, that are often more substantial than highway pavements, requires an evaluation of existing airfield pavement assets and design methodology.

To achieve this objective, a number of tasks were performed: (1) review of in-service pavement thickness and subgrade strength to quantify military airfield pavement characteristics, (2) review of current Department of Defense (DOD) design methodologies to determine if geosynthetic inclusion can be adequately characterized in existing design procedures for new airfields, (3) evaluation to determine if (and in what conditions) an expected performance improvement is financially viable, and (4) implementation in military airfields in manners other than new construction.

Results indicated that airfield pavements were generally thicker and stronger than highway pavements, and that in-service airfield pavements exceeded the pavement characteristics where geosynthetics have been identified to provide a meaningful performance improvement. A review of the existing DOD design methodology indicated that any improvement from geosynthetic inclusion in thicker pavements was hidden within the variability of the data used to formulate the existing design methodology. An initial cost evaluation suggested that design life extension (if any) could be the preferred means of quantifying geosynthetic improvement and that the reduction in aggregate thickness attributed to geosynthetic inclusion did not seem to provide an initial cost savings for military airfields. Geosynthetic inclusion in airfield damage repair or as a crack mitigation technique may be more beneficial than aggregate base reinforcement in new construction.

C.Calvo-Jurado, Numerical computation of effective anisotropic elastic properties of geosynthetics-reinforced pavements: Although several numerical techniques have been recently developed for the prediction of the geosynthetic-reinforced pavements performance, it is often unclear how to quantify such properties, especially when the soil is anisotropic and highly heterogeneous. In this work, following Hashin-Shtrikman bounds, explicit expressions describing anisotropic linear elastic moduli of geosynthetic-reinforced soils are presented. Modelling the geosynthetic material by oblate spheroids with spheroidal distribution inside the matrix of asphalt, the derived expressions provide bounds as a function of laminated material geometry and first principles in the elastic setting. The scheme developed can straightforwardly be extended to multiphase composites. We illustrate the implementation of the model by showing reasonable predictions on the transversely isotropic behaviour of the heterogeneous pavement.

XiaohuiSun, Geosynthetic-stabilized flexible pavements: Solution derivation and mechanistic-empirical analysis: Geosynthetics have been widely applied in flexible pavements for decades. However, the mechanistic-empirical analytical approach for geosynthetic-stabilized flexible pavements based on the elastic solution derived from the layered elastic theory has not been established. In this study, the solution for a typical three-layer geosynthetic-stabilized flexible pavement was derived according to the layered elastic theory. In the derivation, lateral restraint and tensioned membrane effect of geosynthetics quantified in terms of layer permanent deformations were considered at the interface as a continuity condition.

The derived solution was then incorporated into the mechanistic-empirical approach for the calculation of pavement rutting and fatigue cracking. The result indicates that the solution derived in this study is capable of analyzing the geosynthetic-stabilized three-layer flexible pavement. The pavement elastic responses calculated using the solution obtained in this study is in line with those by the previously established solutions in the literature. The rut depths estimated using the proposed solution reasonably matches those measured in the previous study. For rut reduction, the geosynthetic placed underneath the base layer is more effective. For the tensile strain relief at the bottom of the asphalt layer, the geosynthetic placed at the bottom of the asphalt shows more benefit.

ThanongsakImjai, Performance of geosynthetic-reinforced flexible pavements in full-scale field trials: The paper presents the results of a series of full-scale trials carried out in Thailand examining the performance of geosynthetics as reinforcement for flexible pavements. The geosynthetics were embedded at different pavement depths and the structural response was monitored across four test sections by means of strain gauges, pressure sensors, deflection points and deflection plates. The results show that all reinforcement configurations helped reduce the vertical static stresses developed at the base of the pavement by up to 66% and by up to 72% for dynamic stresses. The performance enhancement expected to prolong the lifespan of the base layers.

The reinforcement layers closer to the base experienced the highest lateral strains of up to 0.13%, providing evidence that geosynthetics can also effectively reduce lateral spreading. All reinforcement configurations helped enhance rut resistance with maximum traffic benefit ratio (TBR) of 13.70, effectiveness ratio (EF) of 12.70 and minimum rutting reduction ratio (RRR) of 0.74. The best configuration included a geotextile within the asphalt concrete layer and a geogrid under the base layer. Non-linear finite element analyses of the test sections predicted very well the strains and stresses in the pavement. The study provides a benchmark for future studies in this field and concludes that geosynthetics can help increase maintenance periods and extend the lifetime of flexible pavements.

Thitapan Chantachot, Behaviours of geosynthetic-reinforced asphalt pavements investigated by laboratory physical model tests on a pavement structure: Damages of asphalt pavement are usually observed when the traffic volume and traffic load are excessive. There are, at least, two methods to improve the performance of the asphalt pavement. The first method is to modify the asphalt cement by polymer additive, while the second method is to reinforce the asphalt pavement with geosynthetic reinforcement. The combined effects of the two methods are of interest. In this study, a series of physical models of an asphalt pavement structure were performed to investigate behaviours of geosynthetic-reinforced asphalt pavements. Two types of pavements were prepared for modelling of new pavement and repaired pavement (i.e., overlay pavement).

Both normal asphalt cement and polymer-modified asphalt cement were used. Two types of geosynthetic reinforcements; i.e., (i) geogrid with apertures; and (ii) geocomposite (geogrid plus geotextile) without aperture, were used to reinforce the asphalt pavement layer. A uniform dense sand layer was used for preparation of foundation soil supporting pavement in a sand box. The pavements were vertically loaded by a footing.

A photogrammetric analysis was performed to determine strain field mobilised in the sand layer. It was found that: (i) the pavement surface settlement was decreased and the maximum shear strain was less localised by reinforcing effects; (ii) distortional permanent deformation of asphalt was decreased by the improvement in asphalt cement used; and (iii) geogrid is preferable to be installed inside the asphalt so that its aperture would be beneficial by interlocking, while geocomposite is appropriate when it has to be installed at the bottom of asphalt pavement.

JoséNeves, A Numerical Study on the Implications of Subgrade Reinforcement with Geosynthetics in Pavement Design: The main purpose of this paper is to present a numerical study to demonstrate the implications of subgrade reinforcement with geosynthetics in road pavement design. A parametric analysis was carried out with the finite element program ADINA using two-dimensional modeling. This analysis considered different pavement materials and structures, traffic conditions and subgrade soil quality. The pavement reinforcement effect was analyzed in terms of fatigue and rutting design criteria. Overall, the results of numerical modeling confirmed the reinforcement effect and pointed out the most important factors influencing the use of geosynthetics at the subgrade level for this purpose.

Andrzej Pożarycki, Laboratory Testing of Fatigue Crack Growth in Geosynthetically Reinforced Large Scale Asphalt Pavement Samples: While using the geosynthetics for pavement reinforcement the proper role and designed application is often misunderstood by engineers and constructors of such technology in asphalt road structures. The efficiency of reinforcement is erroneously identified with increasing the AC stiffness rather than fatigue life of reinforced pavement system.

The original laboratory method is developed here in order to check the influence of selected reinforcing geosynthetic type on a fatigue life of asphalt pavement samples. To simulate real pavement conditions the research laboratory set-up scale was fit to large size samples cut from asphalt pavement layers. Two types of commonly used in Poland geosynthetic materials were tested in order to evaluate the reinforcement efficiency on inhibition of crack propagation. Test results also gave some indications on numerical model simulation parameters.

J.Norambuena-Contreras, Influence of geosynthetic type on retarding cracking in asphalt pavements: Geosynthetics are one of the most popular anti-reflective cracking systems used in asphalt pavements, although it is not clear how this reinforcement works and what are the optimum materials and installation process needed in order not to have a negative impact on the materials and consequent reinforced pavement. For these reasons, an experimental evaluation of the influence of geosynthetic type on retarding reflective cracking in asphalt pavements has been developed in this paper. With this purpose, eight different geosynthetics commonly used as anti-reflective cracking systems have been studied using a dynamic test in order to evaluate their contribution to the cracking resistance.

Additionally, their mechanical and thermophysical properties and deterioration effect due to the installation and compaction conditions have also been measured with the aim of evaluating the real behaviour of the geosynthetics under experimental conditions. Results show that a geosynthetic that presents a good tensile behaviour does not necessarily present a high contribution on retarding the crack propagation in asphalt pavements. Finally, it has been found that the resistance to deterioration is a decisive factor on the behaviour of geosynthetics.

J.Norambuena-Contreras, Mechanical damage evaluation of geosyntheticsfibres used as anti-reflective cracking systems in asphalt pavements: Geosynthetics are composite materials usually employed as anti-reflective cracking systems in asphalt pavements. However, materials that compose geosynthetics can be damaged due to mechanical and thermal effects produced during the installation process under Hot Mix Asphalts (HMAs). Although different studies have been carried out with the aim of evaluating the damage due to installation on geosynthetics, it is still not clear which variables have more influence on the deterioration of these materials and on the reduction of their properties.

Therefore, the main objective of this paper was to evaluate the physical and mechanical damage produced on fibres of geosynthetics used as anti-reflective cracking systems in asphalt pavements. With this purpose, a new procedure to simulate in laboratory conditions the damage produced by the spread and compaction of a HMA on geosynthetics has been developed, by using dynamic compaction of aggregates at high temperatures. Thus, this procedure experimentally simulates the thermal and mechanical loads that geosynthetics undergo when they are used as anti-reflective cracking system.

Thereby, different synthetic fibres such as polyester, polyvinyl-alcohol and glass fibres have been evaluated under the developed procedure. Finally, the reduction of physical and mechanical properties has been evaluated by using contrast tests, quantifying the damage produced on the fibres of geosynthetics after different deterioration procedures. Main conclusions of this research established that damage procedure using dynamic compaction of aggregates did not significantly reduce mechanical properties of the fibres strings evaluated by tensile tests on the studied geosynthetics. However, these results were different depending on the material that composes the geosynthetics.

Sireesh Saride, Influence of geosynthetic-interlayers on the performance of asphalt overlays on pre-cracked pavements: The functions of geosynthetic-interlayers in retarding reflection cracking and improving fatigue performance of hot mix asphalt (HMA) overlays in flexible pavements are evaluated in this study. The delamination or debonding mechanisms of the overlays are studied when geosynthetic-interlayers are adopted. A polyester grid coated with polymer modified binder (G1), a woven geo-jute mat (G2), and a bi-axial polypropylene grid (G3) interlayer are examined based on their adhesion properties.

A two stage experimental program, in which, during the first stage, the performance of the geosynthetic-interlayers sandwiched between the pre-cracked old pavement and new asphalt layers are evaluated using flexural fatigue testing. A digital image correlation (DIC) technic was employed to record the failure modes and the corresponding tensile strains in the overlay system. During the second stage, the effect of interlayers on the interface bond strength was evaluated with the help of shear and tensile bond strength tests. The results show that the inclusion of interlayers retards the propagation of reflection cracking, however, results in the delamination of overlays. The debonding effect is prominent in G3 interlayers due to their high initial stiffness. Overall, interlayers with high interfacial shear and pull-off tensile bond properties proved effective in controlling the reflection cracking and increasing fatigue life of the overlays.

NGurung, A laboratory study on the tensile response of unbound granular base road pavement model using geosynthetics: Traditional flexible pavement design emphasizes pavement layer fatigue under repeated traffic loading, but the majority of Australian rural roads consist of bituminous surfaced unbound granular base. The performance of such pavements depends upon complex environmental factors including shrinkage and swelling of the subgrade. This paper briefly explains the structural response of a pavement base layer under applied tensile forces in a laboratory set-up.

The research involves a 100mm thick fine crushed rock pavement layer, which has been stretched horizontally by the opening of a crack in the underlying subgrade and the tensile force–displacement responses were observed in the laboratory. Experimental results show higher tensile resistance of geosynthetics (geotextile, geogrid) inclusion in the pavement base and such high tensile responses will significantly influence the behavior of the pavement surfaces.

Lilian R.de Rezende, Chapter 26 The use of alternative and improved construction materials and geosynthetics in pavements: Traditional construction materials can be scarce or very expensive for several civil engineering works. Nowadays, significant increases in the cost of construction materials can also be a consequence of environmental restriction to their exploitation. Thus, there is an increasing interest on the use of low grade construction materials in pavements and other earth works. This work deals with the use of alternative materials for the construction of pavements in association with low cost geosynthetics.

Field test sections in a highway were constructed and monitored to evaluate the performance of the following pavement solutions: fine-grained soil stabilised with lime, quarry waste, poor quality fill material enveloped by a nonwoven geotextile impregnated with asphalt, geotextiles as separation between the pavement base and the subgrade and between the base and the asphalt cap. A control test section where the pavement was constructed using good quality gravel was also monitored. Several laboratory and field tests were performed throughout the research, such as laboratory tests under unsaturated conditions, field plate load tests, field CBR and pressuremeter tests. The results obtained show the potentials of the use of low grade construction materials when appropriate construction procedures and geosynthetics are employed.

HaoFang, Analytical solutions of the dynamic response of a dual-beam model for a geosynthetic reinforced pile-supported embankment under moving load: To analyze the dynamic response of geosynthetic-reinforced pile-supported (GRPS) embankment, a dual-beam model that includes an upper Euler-Bernoulli beam under moving concentrated load and a lower Euler-Bernoulli beam to simulate pavement structure and geosynthetic reinforcement respectively are established in this paper. Furthermore, the embankment fill layer is idealized as continuous spring-dashpot systems supporting the pavement structure. The pile improved foundation is idealized as a series of periodically distributed pile-soil spring-dashpot systems supporting the geosynthetic reinforcement. The governing equations of the dual-beam system are derived based on the assumptions above.

The steady-state solutions are solved by Fourier series and verified by periodicity condition and Finite Difference Method. A detailed parametric study has been performed to analyze the effects of load velocity, pile stiffness and reinforcement moduli. The results show that the deflection and stress distribution of GRPS embankment are related to the load location. The influence of load velocity on deflection and stress distribution cannot be ignored. The deflection and stress increase as load velocity increases. Increasing pile stiffness and reinforcement modulus can reduce the influence of load velocity on the GRPS embankment. Piles and geosynthetic reinforcement play a significant role in GRPS embankment deflection and making GRPS embankment more stable.

VI. CONCLUSION

This paper presented the benefits of applying geosynthetics in pavement structures. Therefore, it was revealed that geosynthetic materials are commonly utilized in pavements for three dissimilar purposes, namely, waterproofing, strain absorbing, and reinforcement.

Waterproofing function is affected highly by tack coat and bitumen impregnation of geosynthetic materials. Furthermore, it may also be inferred that the main difference between strain reinforcing and reinforcing action of geosynthetic is in its elastic stiffness, meaning that as a strain absorbing agent, the stiffness of the geosynthetic is less than its surrounding materials, whereas in reinforcing role, its stiffness is higher than stiffness of adjacent materials.

Generally, geosynthetics when used in AC layer can change the stiffness, durability, reflective cracking, fatigue, and rutting resistance of AC, as well as surface deformation, and applied stress on subgrade. Moreover, it was indicated that in reinforcing behaviour, stiffness of geosynthetics, cross-sectional area, pavement structure composition, and layer thickness are decisive factors.

REFERENCE

[1] **MehdiZadehmohamad,** Evaluating long-term benefits of geosynthetics in flexible pavements built over weak subgrades by finite element and Mechanistic-Empirical analyses, Geotextiles and Geomembranes, Available online 1 February 2022.
[2] C.Vivek Kumar, Pavement Subgrade Stabilized with Waste coal Ash and Geosynthetics: An Experimental Study and Multiple Regression Modelling, Materials Today: Proceedings, Available online 24 December 2021.
[3] W. JeremyRobinson, Implications of incorporating geosynthetics in airfield pavements, Transportation Geotechnics, Volume 28, May 2021, 100533.
[4] C.Calvo-Jurado, Numerical computation of effective anisotropic elastic properties of geosynthetics-reinforced pavements, Applied Mathematical Modelling, Volume 96, August 2021, Pages 719-732.
[5] XiaohuiSun, Geosynthetic-stabilized flexible pavements: Solution derivation and mechanistic-empirical analysis, Geotextiles and Geomembranes, Volume 48, Issue 4, August 2020, Pages 468-478.
[6] ThanongsakImjai, Performance of geosynthetic-reinforced flexible pavements in full-scale field trials, Geotextiles and Geomembranes, Volume 47, Issue 2, April 2019, Pages 217-229.
[7] ThitapanChantachot, Behaviours of geosynthetic-reinforced asphalt pavements investigated by laboratory physical model tests on a pavement structure, Transportation Geotechnics, Volume 8, September 2016, Pages 103-118.
[8] JoséNeves, A Numerical Study on the Implications of Subgrade Reinforcement with Geosynthetics in Pavement Design, Procedia Engineering, Volume 143, 2016, Pages 888-895.
[9] AndrzejPożarycki, Laboratory Testing of Fatigue Crack Growth in Geosynthetically Reinforced Large Scale Asphalt Pavement Samples, Procedia Engineering, Volume 57, 2013, Pages 922-928.
[10] J.Norambuena-Contreras, Influence of geosynthetic type on retarding cracking in asphalt pavements, Construction and Building Materials, Volume 78, 1 March 2015, Pages 421-429.
[11] J.Norambuena-Contreras, Mechanical damage evaluation of geosyntheticsfibres used as anti-reflective cracking systems in asphalt pavements, Construction and Building Materials, Volume 109, 15 April 2016, Pages 47-54.
[12] SireeshSaride, Influence of geosynthetic-interlayers on the performance of asphalt overlays on pre-cracked pavements, Geotextiles and Geomembranes, Volume 45, Issue 3, June 2017, Pages 184-196.
[13] NGurung, A laboratory study on the tensile response of unbound granular base road pavement model using

geosynthetics, Geotextiles and Geomembranes, Volume 21, Issue 1, February 2003, Pages 59-68.

[14] Lilian R.de Rezende, Chapter 26 The use of alternative and improved construction materials and geosynthetics in pavements, Elsevier Geo-Engineering Book Series, Volume 3, 2005, Pages 765-786.

[15] HaoFang, Analytical solutions of the dynamic response of a dual-beam model for a geosynthetic reinforced pile-supported embankment under moving load, Computers and Geotechnics, Volume 142, February 2022, 104563.