Center for Integration of Composites into Infrastructure

2024 NSF IUCRC CICI- IAB Spring Meeting
TAMU Site Projects' Summaries

2024 NSF IUCRC CICI- IAB Spring Meeting
TAMU Site Projects' Summaries

TAMU - 5: Application of Geofoam in Thermal Encapsulation of Foundations
Program Manager / PI: Dr. Anand J Puppala
Company / Sponsor: Thermafoam

I/UCRC Executive Summary - Project Synopsis		**Date**: May 23rd, 2024
Center/Site: Center for the Integration of Composites into Infrastructure (CICI) / TAMU		
Tracking No.:	**Phone:** ( ) -	**E-mail:** anandp@tamu.edu
Center/Site Director: Dr. Anand J Puppala		**Type:** Continuing
Project Leader: Hiramani Raj Chimauriya (Doctoral Student), Clay Caldwell (Doctoral Student), Gustavo Hernandez Martin (undergraduate student) and Dr. Anand J Puppala		**Proposed Budget**: $45,000
Project Description: The main objective of the research work in this project is to mitigate temperature fluctuations within dwellings by designing and using thermally insulated and energy efficient novel foundation systems. Temperature fluctuations inside the dwellings typically occur from advection, diffusion and radiation at foundation joints; therefore, an insulation material around dwelling foundation systems would help in reducing these temperature fluctuations. The proposed research plan will explore the use of expanded polystyrene geofoam material as a thermal insulating material for two foundation alternatives or systems to assist the building infrastructure in conserving energy. The proposed research study attempts to identify and optimize the design and construction of foundation insulation systems using geofoam materials, which are cost-effective and provide resilient support. The novelty of the proposed research lies in the use of geofoam for thermally encapsulating residential dwellings, at low additional cost and minimal deviation from the standardized structural and architectural design and construction of residential dwellings.		
Experimental plan: Two different types of insulated foundation systems, viz., (a) Geofoam blocks attached around the periphery of foundation (referred here to as GAF system), and (b) Geofoam slab placed underneath the foundation system (referred here to as GBF system) will be constructed in the laboratory. Temperature sensors will be installed both inside and outside of the structure to monitor the variation in temperature and heat transfer over time. The results will be compared with that of the control prototype to study the effect of thermal encapsulation and energy savings. The cost benefit analysis will also be conducted as a part of this study.		
Related work elsewhere: The insulating properties of EPS Geofoam have been studied earlier in brevity, however, its efficiency to provide thermal insulation to dwelling has not been evaluated in detail.		
How this project is different: The insulating properties of EPS geofoam are known, however, its application for saving energy consumption of dwelling needs to be evaluated. In this study, various sizes and types of EPS Geofoam blocks are being used for encapsulating the foundation of a dwelling prototype and evaluating its performance related to energy transfer.		
Milestones for the current proposed year: During this year, the lab scale studies for the 2-in., and 8-in. GAF R-130 geofoams were completed. The results showed the efficient mode of insulation as well as the influence of geofoam thickness and grade on thermal insulation performance of foundations.		
Deliverables for the current proposed year: Report with preliminary findings of the energy efficiency of the dwelling prototype with Geofoam-encapsulated foundation.		

How the project may be transformative and/or benefit to society: The energy savings from the insulation would allow the owner to recoup the cost of foundation insulation systems quickly. Subsequently, with a large number of dwellings adopting such a foundation system, the lower power consumption costs of each of these dwellings would collectively help in reducing the energy loads on the power grid. Supporting the reduced energy needs of these modified dwellings with other renewable energy sources such as solar energy will achieve net-zero energy status for most dwellings. Apart from the economic benefits of these foundation insulation systems, the foundation systems can also promote the development of sustainable infrastructure, namely green buildings and zero-energy ready homes.	
Research areas of expertise needed for project success: The knowledge of thermodynamics involved in evaluating the energy transfer in homes during warm and cooler climatic conditions and use of cost-effective construction materials and techniques is required for the study.	
Potential Member Company Benefits: The study on thermal encapsulation of the foundation using EPS Geofoam will be able to provide design guidelines for full-scale pilot studies or future construction on thermal insulation of buildings with Geofoam-encapsulated foundation.	
Progress to Date: First set of tests on geofoam insulated footing was performed for geofoam-below-footing (GBF) and geofoam-around-footing (GAF) configurations with an insulation grade of R-250. Numerical modeling of the control test was performed using COMSOL Multiphysics. Testing of GAF configurations using 8-inch and 2-inch thick R-130 grade geofoam was completed.	
Estimated Start Date: 09/01/2020	**Estimated Knowledge Transfer Date**: 05/31/2024

TAMU - 6: Design and Testing of IFI Geosynthetic Products

Program Manager / PI: Dr. Anand J Puppala

Company / Sponsor: Industrial Fabrics (IFI)

I/UCRC Executive Summary - Project Synopsis		**Date**: May 23rd, 2024
Center/Site: Center for the Integration of Composites into Infrastructure (CICI) / TAMU		
Tracking No.:	**Phone:** ( ) -	**E-mail:** anandp@tamu.edu
Center/Site Director: Dr. Anand J Puppala		**Type:** Continuing
Project Leader: Krishneswar Ramineni (Doctoral Student), Avinash Gonnabathula (Doctoral Student),Dr. Nripojyoti Biswas (Post Doc)and Dr. Anand J Puppala		**Proposed Budget**: $245,000

Project Description: The application of geosynthetic products can provide an effective solution for the earth retaining systems as well as different foundation systems by reinforcing the earth materials. These products include, but not limited to, geocells, geogrids, and laminated geogrid products. The combination of these products has been used in the field for quicker construction and better performance. However, there are no such guidelines available regarding the design of such products. Giroud and Han (2004) provide a design methodology for geogrid reinforced pavement structures. The objective of this study is to expand on those methods by improving the study behind the theories and/or incorporating new concepts and methods of calculations. There are two major objectives in this study:

- Phase 1 Part I: Performing repeated load tests on geosynthetic reinforced 12-inch base layers built on different weak subgrades and then use the test data to calibrate parameters that can be used with Giroud and Han (G&H) designs.
- Phase 1 Part II: Developing various design charts and methods for IFI, Inc Geosynthetic Products based on the results and calibration studies from Part I.
- Phase 1 Part III: Perform non-destructive tests on geosynthetic reinforced base layers built on weaker subgrades and then use the test data to determine the stiffness properties of different pavement layers in the field.
- Phase 2 Part I : Performing repeated load tests on geogrid reinforced 6-inch base layers built on different weak subgrades.
- Phase 2 Part II: Developing various design charts and methods for IFI, Inc Geogrids Products based on the results and calibration studies from Phase 1 Part 1 and phase 2 Part 1

Experimental plan: Physical and engineering soil testing including grain size distribution, standard Proctor test, Atterberg's limit, resilient modulus, shear strength and undrained strength tests, and California Bearing Ratio (CBR) test has been performed on the base material and subgrade soils. Both these materials were selected based on the recommendation by IFI, Inc. For subgrade selection, the subgrades with different CBR values (1 and 3) were prepared by adjusting the moisture content. A large-scale test setup is available at the Center for Infrastructure Renewal (CIR), Texas A&M University, which was designed and constructed to facilitate a wide range of static and repeated load testing to evaluate the behavior and performance of the geosynthetic reinforced soils. The large-scale test setup consists of a steel testing box, loading frame, actuator, along with a data acquisition system. The steel testing box has dimensions of 6 ft x 6 ft x 5 ft (1.83 m × 1.83 m × 1.52 m). In the test box, subgrade layers of select CBR were prepared using selected material at target dry density and moisture content.

Test results were analyzed and calibrated to determine various parameters for both geocell and Fabgrid (geocomposites) reinforced soils. Test results from the repeated load tests would be used to generate 1/tan α vs log N plots. This information could be used to calibrate the performance of the section as a function of the Aperture Stability Modulus (J) for proposed Fabgrid. Analyses of these results would provide calibration parameters that will be useful for designing reinforced base/subbase systems using IFI geosynthetic products.

Field studies include performing non-destructive tests like Lightweight deflectometer (LWD), Dynamic Cone Penetrometer (DCP) and Variable Energy Dynamic Cone Penetrometer (VE-DCP) tests on different geosynthetic reinforced unpaved field sections. Perform Laboratory tests on base and subgrade materials to develop co-relationship between surface modulus, tip resistance and CBR. Develop a geosynthetic reinforced unpaved section numerical model and validate the model with field data.	
Related work elsewhere: The longevity and performance of the pavement sections on problematic soils including soft and expansive subgrades, has been a major concern for transportation practitioners (Puppala et al. 1996; Puppala and Pedarla 2017). Flexible pavements and unpaved roads constructed on problematic soil suffer from different failures such as cracking, rutting, and depression (George et al. 2019; Khan et al. 2020; Puppala et al. 2017). The reasons for such failure may be attributed to fatigue, temperature changes, moisture ingress and egress, and softening caused by surface layer cracking (Han et al. 2011, Pokharel et al. 2018). The use of geosynthetics as an additional supporting layer to the existing subsoil might help the agencies and organizations to eliminate the distress problems associated with the problematic soils (Giroud and Noiray 1981).	
How this project is different: In the previous studies, researchers used planar geosynthetic products or the combination of two/three different geosynthetic products; however, there is very little information available about the utilization of combined products such as FabGrid. This study focuses on the utilization of different combinations of high-density polyethylene (HDPE) products for different types of foundation systems.	
Milestones for the current proposed year: Completed 6-inch base large-scale repeated load testing.Developed the design equation for geogrid reinforced pavement structures based on 6-inch and 12-inch base large-scale repeated load test results.	
Deliverables for the current proposed year: A Final report with Design charts for different IFI products based on field testing and a Layer coefficient table for the design of unpaved road-based large-scale repeated load tests will presented	
How the project may be transformative and/or benefit society: This study mainly focuses on the utilization of new combinations of HDPE products (e.g.,Fabgrid and Fabgrid+GeoCell). This study aims to develop design charts for different HDPE products/combinations of HDPE products for different stiffnesses of foundation materials. The outcome of this research will help to ensure the safety and reliability of the geotechnical structures by providing the design charts.	
Research areas of expertise needed for project success: A thorough knowledge in foundation design using geosynthetics reinforcement, pavement engineering and load transfer mechanisms with different combinations of HDPE products.	
Potential Member Company Benefits: Development of design guidelines for foundation systems with different combinations of HDPE materials.	
Progress to Date: Performed material characterization of base and subgrade materials in the laboratory. Performed large-scale repeated load tests for 20 reinforced and 4 unreinforced with 6-inch and 12-inch base sections. Developed the analytical models to accommodate the stiffer geogrid materials.Developed layer coefficient chart for different IFI products. Performed field studies and developed a numerical model for geosynthetic reinforced unpaved sections.	
Estimated Start Date: 9/1/2020	**Estimated Knowledge Transfer Date**:03/31/2024

TAMU - 7: Performance of Pavement Sections with Wicking Geosynthetics
Program Manager / PI: Dr. Anand J Puppala
Company / Sponsor: TenCate/Solmax

I/UCRC Executive Summary - Project Synopsis		**Date**: May 23rd, 2024
Center/Site: Center for the Integration of Composites into Infrastructure (CICI) / TAMU		
Tracking No.:	**Phone:** ( ) -	**E-mail:** anandp@tamu.edu
Center/Site Director: Dr. Anand J Puppala		**Type:** Continuing
Project Leader: Dr. Nripojyoti Biswas (Post Doc) and Dr. Anand J Puppala, Avinash Gonnabathula (GAR), Krishneswar Ramineni and Gustavo Hernandez Martin (undergraduate student)		**Proposed Budget**: $310,000

Project Description: Expansive soils are found in various regions around the globe. In the US itself, expansive soils cover a vast stretch in western and southwestern states. The seasonal moisture variation leads to a large volume change in these soils causing alternate swelling and shrinkage. As a result, this induces significant surficial distress in the form of heaving and cracking. The Mirafi H2Ri is an innovative geosynthetic product that integrates the features of traditional woven geosynthetics like strength, separation, and puncture resistance to an additional water-wicking capability with the presence of hydrophilic and hygroscopic fibers. These woven geotextiles have the capability to be utilized in various applications including pavement sections, where they can be used as a separation between the base and subgrade while providing drainage through the geotextile.

The main objective of the proposed project is to study the separation and drainage characteristics of woven geotextile Mirafi H2Ri when introduced between base and subgrade layers of the pavement section. Full-scale field implementation of the geotextile on the eastbound FM 1807 in Venus, Texas was constructed. In addition, small-scale laboratory tests in a controlled environment will be performed to understand the moisture movements in subsoil due to the placement of H2Ri. A large-scale repeated load pavement tests will be performed using the geotextile under different moisture conditions of the subgrade. Additionally, the Life Cycle Analysis (LCA) will be performed and compared with other traditional materials used for the construction of pavement sections. Finally, the benefits of using the H2Ri geosynthetic in pavement sections having high plasticity soils as subgrades will be evaluated and summarized in the final report. Currently additional studies to investigate the performance of RS580i geosynthetics are also considered.

Experimental plan: The study focuses on the installation and monitoring of TenCate Mirafi H2Ri between the subgrade and the base layers on the eastbound FM 1807 in Venus, Texas. Field data for the past year was obtained from two test sections, (i) RAP aggregate as a base layer, and (ii) traditional flex-base aggregate as a base layer and their performance was compared with a control section. Instrumentation such as moisture probes, pressure cells, and Shape Array Accelerometer (SAA-MEMS) were installed for continuous monitoring of the test sections. The influence of variation in moisture, traffic loads on the stresses developed on top of the subgrade layer was measured and evaluated and is expected to continue in the coming years. Furthermore, the wicking action of the TenCate Mirafi H2Ri, when embedded in expansive soil subgrade, is being studied by performing small-scale laboratory tests. LCA will be performed and compared with pavement sections built with conventional construction materials. Additional monitoring will be performed for another year on the test sections. Some studies will be performed on the benefits of RS580i geosynthetics in synchronous with the H2Ri geosynthetics. Laboratory studies, using large-scale pavement simulator will be performed in the final phase to simulate the pavement performance under flooded conditions.

Related work elsewhere: The effectiveness of wicking geotextile in reducing soil moisture for roadway application was studied in a laboratory model by Wang et. al. (2017). Zhang et.al. (2014) studied the effect of wicking fabric to prevent the effect of frost boil on Alaskan pavements by performing full-scale field implementation of the woven geosynthetics. The rate of water removal under controlled temperature and humidity using wicking was studied by Guo et.al. (2016).
How this project is different: In the previous studies, H2Ri geotextile was used to mitigate the effects of frost-heaving. This study primarily focuses on the improvement in the drainage of pavement sections by using H2Ri and its application in high plasticity subgrade soils. In addition to the enhancement of drainage coefficient, H2Ri is a high-strength material that would provide adequate support for the base layer. Similarly, RS580i geotextiles is a high-strength woven fabric whose application could be beneficial for long-term serviceability of pavement sections.
Milestones for the current proposed year: Performance analyses of the test sections constructed with RS580i and compared with H2Ri sections. Performed field test using falling weight deflectometer and compared performance between sections. Started data collection for robust LCA analyses of the H2Ri geotextiles. Started constructing large-scale laboratory-based repeated load test sections.
Deliverables for the current proposed year: Perform large-scale repeated load testing to simulate different moisture conditions. Develop an LCA framework for the wicking geotextiles.
How the project may be transformative and/or benefit society: This study mainly focuses on the drainage improvement of pavement which will enhance the structural capacity of the pavement system. This new technology will not only increase the drainage coefficient but also enhance overall stiffness which will reduce the required pavement thickness. This project will contribute to enhanced safety for the traveling public and reduce construction costs. It also increases the resiliency and longevity of the pavement systems, thereby contributing to a higher return on investment. Additionally, the use of RAP material can make pavement structures more sustainable and cost-effective as it will decrease the demand for virgin aggregate.
Research areas of expertise needed for project success: A thorough knowledge in pavement design using Geosynthetics reinforcement, advanced numerical modeling of H2Ri/RS580i reinforced pavements under static and repeated loadings, sustainability of RAP bases with H2Ri/RS580i in the pavement construction, and the estimation of cost-effectiveness of pavement constructed with RAP material on expansive subgrade soil.
Potential Member Company Benefits: Development of design and construction guidelines for H2Ri supported pavements with RAP base in areas where the subgrade soil is expansive. Pavement structures will be resilient and will have lesser distress during their service life.
Progress to Date: Test setup is prepared and waterproofed for large-scale laboratory tests with H2Ri and RS580i geotextiles. Field monitoring has been performed using the Falling Weight Deflectometer tests. The cradle-to-gate + construction boundary condition was identified, and data collection is in progress for the comprehensive Life Cycle Analysis (LCA). Life Cycle Cost Analysis was performed using the market costs with the determined boundary conditions. For the sustainability analysis, the environmental impact factors i.e. embodied energy and various categories of emissions were determined for the different sections in the field using OpenLCA software.
Estimated Start Date: 5/1/2018   **Estimated Knowledge Transfer Date**:07/31/2024