2021 CICI- IAB Fall Virtual Meeting
TAMU Site Projects' Summaries

Center for Integration of Composites into Infrastructure

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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**: November 14, 2021
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. Anand J Puppala and Dr. Surya S.C. Congress		**Proposed Budget**: $20,000
Project Description: The main objective of the research work in this project is to mitigate temperature fluctuations within dwellings by designing and using thermal insulate 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 innovation research plan will explore the use of expanded polystyrene geofoam material as a thermal insulating material for two foundation alternatives or systems to support building infrastructure. 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 lab. Temperature sensors would be installed both inside and outside the structure to monitor the variation in temperature and heat transfer over time. The results would be compared with that of the control prototype to study the effect of thermal encapsulation and energy savings. The cost benefit analysis would 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: As the insulating properties of EPS geofoam are known, its application for saving energy consumption of dwelling will be evaluated. In this study, EPS Geofoam is being used for encapsulating the foundation of a prototype of a dwelling and its performance related to energy transfer will be studied.		
Milestones for the current proposed year: During this year, the lab scale study will be continued for different thicknesses, configurations, and grades of geofoam. Numerical simulations will also be conducted in conjunction with the experiments to model a wider range of scenarios of thermal encapsulation using Geofoam material.		
Deliverables for the current proposed year: Report with preliminary findings of the energy efficiency of the prototype dwelling 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 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 would 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: Preliminary testing has started and control tests have been done to obtain a baseline behaviour of the test setup. Testing using various configurations and grades of geofoam is ongoing.	
Estimated Start Date: 09/01/2020	**Estimated Knowledge Transfer Date**: 08/31/2022

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**: November 14, 2021
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. Anand J Puppala, Md Ashrafuzzaman Khan (Doctoral Student), and Ramineni Krishneswar (Doctoral Student)		**Proposed Budget**: $120k

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 performances. However, there are no such guidelines available regarding the design of such product. Giroud and Han (2004) provides 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.

Part I: Performing repeated load tests on geosynthetic reinforced 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

Part II: Developing various design charts and methods for IFI, Inc Geosynthetic Products based on the results and calibration studies from Part I

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 will be performed on the base material and subgrade soils. Both these materials will be selected based on the recommendation by IFI, Inc. For subgrade selection, the subgrades with different CBR values (1 and 3) will be 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 layer of select CBR will be prepared using selected material at target dry density and moisture content.

Test results will be 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.

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: Subgrade and base materials were characterized before the construction of the large test sections. California Bearing Ratio (CBR) tests were conducted for both the base and subgrade materials. Dynamic cone penetrometers along with handheld cone penetrometer devices were used to ensure the quality of the test sections. Four types of geosynthetics products were tested for two different types of subgrade soils (CBR 1 & 3).
Deliverables for the current proposed year: Base and subgrade material characterization, quality control report of the test sections, load-deformation characteristic curves of the unreinforced and reinforced sections will be reported
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 mechanism with different combination of HDPE products.
Potential Member Company Benefits: Development of design guidelines for foundation systems with different combinations of HDPE materials.
Progress to Date: Assembled test box and installed hydraulic load frame along with data acquisition system. Performed material characterization of base and subgrade materials in the laboratory. Performed large-scale repeated load tests for geosynthetic products with different aperture stability modulus.

Estimated Start Date: 9/1/2020	**Estimated Knowledge Transfer Date**:8/31/2022

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

I/UCRC Executive Summary - Project Synopsis		**Date**: November 14, 2021
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. Anand J Puppala and Nripojyoti Biswas (Doctoral Student)		**Proposed Budget**: $160,000

Project Description: Expansive soils are found in various regions around the globe. In 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 which integrates the features of traditional woven geosynthetics like strength, separation, and puncture resistance to an additional water wicking technology due to the presence of hydrophilic and hygroscopic fibers. These woven geotextiles have the capability to be utilized in varying applications including pavement sections, where it can be used as a separation between the base and subgrade, while providing drainage through the geotextile.

The main objective of the proposed project would be to study the separation and drainage characteristics of woven geotextile Mirafi H2Ri when introduced between base and subgrade layers of the pavement section. A full-scale field implementation of the geotextile on the eastbound FM 1807 in Venus, Texas was constructed. In addition, small scale laboratory test will be performed to understand the moisture movements in subsoil due to the placement of H2Ri in a controlled environment. Numerical model will be developed to compare experimental data obtained from the laboratory and field test sections with the model predictions. Additionally, the life cycle cost analysis (LCCA) will be performed and compared with other traditional materials used for construction of a pavement section. 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.

Experimental plan: The study focuses on 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 is compared with a control section. Instrumentation such as moisture probes, pressure cells, and Shape Array Accelerometer (SAA-MEMS) has been installed for continuous monitoring of the test section. The influence of variation in moisture, traffic loads on the stresses developed on top of the subgrade layer was carried out and is expected to continue in the coming years.

Furthermore, the wicking action of the TenCate Mirafi H2Ri, when embedded in an expansive soil subgrade, is being studied by performing small-scale laboratory tests. Numerical models will be developed and validated against the experimental data obtained from the laboratory and field test sections. LCCA will be performed and compared with pavement sections built with conventional construction materials.

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 drainage improvement of pavement section by using H2Ri and its application in high plasticity subgrade soils. In addition to the enhancement on drainage coefficient, H2Ri is a high strength material which would provide adequate support for the base layer.
Milestones for the current proposed year: The test and control sections were monitored at regular intervals for deformation, stress distribution, and moisture variation over the past year. Nondestructive tests such as Light Weight Deflectometer and Automated Plate Load Testing were performed over the test and control sections to compare their performance. Fabrication of a small-scale laboratory box to study the moisture redistribution capacity of the geotextile in a controlled environment.
Deliverables for the current proposed year: Construction and instrumentation report on sections with H2Ri geosynthetics. Performance evaluation pavement sections with H2Ri geosynthetics. Construction and monitoring of a small-scale laboratory model.
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 increase overall stiffness which will reduce the required pavement thickness. This project will not only provide and enhance safety to the traveling public and reduce construction costs, but also increase the resiliency and longevity of the pavement systems. Additionally, the use of RAP material can make the pavement structures more sustainable and cost effective as it will decrease the demand on virgin aggregate.
Research areas of expertise needed for project success: A thorough knowledge in pavement design using Geosynthetics reinforcement, advanced numerical modeling of H2Ri reinforced pavements under static and repeated loading, sustainability of RAP bases with H2Ri 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: Performed material characterization of base and subgrade materials in the laboratory. Construction of two pavement sections with H2Ri (one section with RAP as base layer and the other with aggregate). Instrumentation of the sections with pressure cells, moisture sensors and SAAs (Shape Array Accelerometers) to monitor its performance. Initial performance monitoring is currently underway. Construction of small-scale laboratory models to understand the wicking action in a controlled environment

Estimated Start Date: 5/1/2018	**Estimated Knowledge Transfer Date**:8/31/2022

TAMU - 8: Mitigating Sulfate Heaving Using Novel Admixtures
Program Manager / PI: Dr. Anand J Puppala
Company / Sponsor: HVJ Associates and Terracon

/UCRC Executive Summary - Project Synopsis		Date: November 14, 2021
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. Anand J Puppala and Nripojyoti Biswas (Doctoral Student)		**Proposed Budget**: $ 20,000

Project Description:
Sulfate-rich expansive soils treated with traditional calcium-based stabilizers such as lime or cement exhibit deleterious sulfate-induced heave, due to the formation of highly expansive minerals Ettringite and Thaumasite. These minerals expand in the presence of water and hamper the performance of overlying infrastructure. Alternative forms of sustainable additives are being sought after to address sulfate heaving. Silica-rich quarry fines produced during the crushing of rocks is one such additive. Millions of tons of quarry dust material are produced extensively around the world, and this material has excellent potential to be used for engineering purposes. This material often poses a geoenvironmental problem as fine dust needs to be disposed of as waste material. The crystalline silica particles present in quarry fines may serve the purpose of reacting with calcium-based stabilizers to form C-S-H phases. These cementitious phases can increase the strength and stiffness properties and potentially counteract the ettringite-induced heaving, provided the specific surface area of the particles is large enough to accommodate their participation in the chemical reactions and consequently expedite the pozzolanic reaction. The presence of silica from crystalline silica admixture can potentially suppress the availability of alumina leached from clay minerals, and this can suppress ettringite formation and associated heaving.

Experimental plan:
Extensive laboratory tests have been conducted on control high-sulfate expansive soils and soils treated with the novel additives to evaluate the improvements in engineering properties, including swell strain, shear strength, and resilient moduli properties. The mechanisms responsible for the observed improvements in the engineering properties have been studied based on supplementary mineralogical and microstructural analyses using X-Ray diffraction, scanning electron microscope imaging, and differential scanning calorimetry.

Related work elsewhere:
Admixtures and industrial by-products such as ground granulated blast furnace slag and fly ash usually are often used to reduce the sulfate-induced heaving. Micro-silica and nano-silica have shown promising results in enhancing the engineering properties of problematic soils when used as an additive/co-additive.

How this project is different:
The potential for utilizing crystalline silica-rich quarry fines for mitigating sulfate heaving in soils treated with calcium-based stabilizers has not been explored. The sustainable utilization of crystalline silica-rich waste products for civil infrastructure works is expected to be beneficial to the civil engineering community.

Milestones for the current proposed year:
During this year, the admixture dosage will be optimized, and life cycle cost analysis studies will be performed.

Deliverables for the current proposed year: The findings of the research project, emphasizing on the improvements in engineering properties, the mechanisms responsible for the observed improvements, will be presented.
How the project may be transformative and/or benefit society: The findings of this project are expected to highlight the applicability of utilizing these sustainable non-traditional soil additives for treating problematic soils.
Research areas of expertise needed for project success: The research team has extensive experience in ground improvement techniques, chemical stabilization of soils, and different mineralogical and microstructural techniques suitable for studying the properties of chemically treated soils.
Potential Member Company Benefits: The utilization of these novel additives to reduce ettringite-induced heaving in lime-treated sulfate soil will be of immense value to the geotechnical and transportation engineering fraternity as these materials, if effective, will provide sustainable utilization of wastes in civil infrastructure works.
Progress to Date: Extensive laboratory tests were performed to study the swelling characteristics, shear strength, and resilient moduli properties of the sulfate-rich expansive soil treated with lime and lime-crystalline silica additives. The influence of crystalline silica admixture as a co-additive with lime was studied for different additive dosages and various curing periods. Microstructural analyses were performed using X-Ray diffraction, scanning electron microscope imaging, and differential scanning calorimetry.

Estimated Start Date: 07/01/2020	**Estimated Knowledge Transfer Date**: 08/31/2022