Center for Integration of Composites into Infrastructure

2020 CICI- IAB Spring Virtual Meeting
Project Summaries

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TAMU Site Project Summaries

TAMU - 1: 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**: June 16, 2020
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 ~ crawl-space foundation systems (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 conducted. Also, the design of the dwelling prototype will be planned with the necessary instrumentation.		
Deliverables for the current proposed year: Paper 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 the majority of 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 pivot studies or future construction on thermal insulation of buildings with Geofoam-encapsulated foundation.	
Progress to Date: A preliminary plan for the laboratory scale study and a prototype house with Geofoam insulated foundation system has been prepared.	
Estimated Start Date: 09/01/2020	**Estimated Knowledge Transfer Date**: 08/31/2022

TAMU - 2: Utilization of Geocells in Pavement Infrastructure

Program Manager / PI: Dr. Anand J Puppala

Company / Sponsor: TxDOT

I / UCRC Executive Summary - Project Synopsis		**Date**: June 16, 2020
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 Md Ashrafuzzaman Khan (Doctoral Student)		**Proposed Budget**: $120k

Project Description: Geosynthetic composites made of polymeric sheets have been extensively used on earth structures including mechanically stabilized earth retaining walls and slopes to enhance their stability. Recent studies by the UTA research team involved soil reinforcement in the form of another innovative geosynthetic product, Geocell mattress has showed its efficacy in the fields of highway and embankment construction. Geocells are three dimensional, polymeric, honeycomb like structure of cells interconnected at joints. The cell walls keep the encapsulated material from being pushed away from the applied load and offer an all-around confinement by virtue of its three-dimensional nature. Additionally, the panel acts like a large mat which spreads the applied load over an extended area, instead of directing to the point of contact, leading to an improvement in the overall performance.

The main objective of the research is to address the efficacy of Geocell-reinforced base layer to provide stable and uniform support to pavement sections. Evaluations include laboratory studies under static and repetitive loadings, and field studies addressing full scale test sections. The performance characteristics of the Geocell sections will be addressed. Constructability evaluations along with cost benefit studies will be provided in the final report.

Experimental plan: Prior to the construction of test sections in the field, a series of large-scale laboratory tests were conducted to study the behavior of geocell-reinforced bases in flexible pavements. A parametric study has been performed by varying the experimental variables such as thickness of geocell, location of loading, type of loading and number of loading cycles. Based on the results of the large-scale laboratory tests and optimized pavement design, Geocell stabilized base layers are constructed for real field applications to harness its benefits in providing stable and uniform support to the pavement system. Instrumentation such as Micro-electro-mechanical system (MEMS), pressure cells, and temperature sensors was installed to obtain real-time data, where the deformations and loading responses are being monitored at regular intervals. Additionally, numerical analyses are being performed in finite element based software to simulate the performance of geocell-reinforced base layers in pavement system under static and repeated loads. Numerical models will be developed and validated against the experimental data obtained from the laboratory and field test sections. The results obtained from experimental and numerical studies will be used to develop design guidelines for enhancing the performance of geocell reinforced pavement system.

Related work elsewhere: The effect of geocell reinforcement on Reclaimed Asphalt Pavement (RAP) base course over weak subgrade was studied by Han et al. (2007) by performing Accelerated Pavement Testing (APT). Researchers like Pokharel et al. (2011), Yang (2012) and Bortz (2015) studied about the improvement in the performance of unpaved and low volume roads due to geocell reinforcement by performing APT. Sustainability aspects of geocell reinforced pavements were reported by Thakur et al. (2014).

How this project is different: In the previous studies, researchers used novel polymeric alloy (NPA) geocell for reinforcing the base layer of unpaved and low volume roads. This study mainly focuses on the widening of highways with limited ROW and high volume roads by using high density polyethylene (HDPE) geocell. Additionally, in this research, repeated load tests are performed to determine the resilient modulus of the geocell reinforced base layer in a large-scale laboratory setup.	
Milestones for the current proposed year: The test and control sections were monitored at regular intervals for deformation, stress distribution, and temperature 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. Development of a finite element model for the parametric study.	
Deliverables for the current proposed year: Performance monitoring of the pavement sections reinforced with Geocells. Analysis of deformation, stress distribution and temperature data for the previous year. Perform numerical analysis to verify the strength and stiffness responses obtained from the non-destructive field testing.	
How the project may be transformative and/or benefit society: This study mainly focuses on the increase robustness of high volume roads by using high density polyethylene (HDPE) geocell. This technology will not only provide and enhance safety to the traveling public, but also increase the resiliency and longevity of the pavement systems. Additionally, the use of RAP as the geocell infill material leads to sustainability and cost effectiveness for pavement construction.	
Research areas of expertise needed for project success: A thorough knowledge in pavement design using Geosynthetics reinforcement, advanced numerical modeling of geocell reinforced pavements under static and dynamic loading, sustainability of geocell reinforced RAP bases in the pavement construction and the estimation of cost effectiveness of geocell reinforced RAP in pavements.	
Potential Member Company Benefits: Development of design and construction guidelines for Geocell supported pavements in areas where ROW is restricted (most urban environment) and pavement structures will be resilient and will have lesser distress during service life.	
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 from the new site. Static and repeated load studies have been performed on unreinforced, 4 in., and 6 in. geocell base layers with RAP infill for varying number of loading cycles. Construction of 3 test sections in the field for monitoring the performance of Geocell-reinforced test sections. Numerical models were developed and validated for static loading in a finite difference software to perform parametric studies. Non-destructive cyclic tests were conducted in the field to determine the stiffness of different test sections.	
Estimated Start Date: 9/1/2019	**Estimated Knowledge Transfer Date**:8/31/2022

TAMU - 3: 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**: June 16, 2020
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 south western 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 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 expansive soil subgrade, will be studied by performing small-scale laboratory study. 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. A fabrication plan was developed for building a small-scale laboratory box.

Deliverables for the current proposed year: Construction and instrumentation report on sections with H2Ri geosynthetics. Performance evaluation pavement sections with H2Ri geosynthetics.

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 its 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.

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

TAMU - 4: Mitigating Sulfate Heaving Using Novel Soil Stabilizers
Program Manager / PI: Dr. Anand J Puppala
Company / Sponsor:

/ UCRC Executive Summary - Project Synopsis		**Date**: June 16, 2020
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:** New
Project Leader: Dr. Anand J Puppala and Dr. Sayantan Chakraborty		**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 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. In recent years, Geopolymer has received much attention as an alternative to Ordinary Portland Cement (OPC) and lime for soil stabilization, and other applications for pavements, bridges, and other transportation structures. This is because they show comparable mechanical properties to traditional stabilizers but are more eco-friendly and sustainable since Geopolymers can be processed at room temperatures from aqueous solutions of waste materials (e.g., fly ash) or abounded natural sources (e.g., clay) and thus reduce significant CO_2 production associated with the processing of OPC or lime. Although significant progress has been achieved over the last couple of decades on developing Geopolymers with desired properties, their applicability for stabilizing sulfate-rich expansive soils is relatively unknown.

Experimental plan:
Extensive laboratory tests will be conducted on the control soil and soil 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 will be studied based on supplementary mineralogical and microstructural analyses using X-Ray diffraction and scanning electron microscope imaging.

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, nano-silica, and geopolymers 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. Although significant advances have been made over

the last couple of decades on developing Geopolymers with desired properties, their applicability for stabilizing sulfate-rich expansive soils is relatively unknown.	
Milestones for the current proposed year: During this year, the engineering tests, and microstructural and mineralogical studies will be tentatively completed.	
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, and sustainability and resiliency aspects of using the novel stabilizers, 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: This is a new project.	
Estimated Start Date: 07/01/2020	**Estimated Knowledge Transfer Date**: 08/31/2022

The Executive Summary is used by corporate stakeholders in evaluating the value of their leveraged investment in the center and its projects. It also enables stakeholders to discuss and decide on the projects that provide value to their respective organizations. **Ideally, the tool is completed and shared in advance of IAB meetings to help enable rational decision making.**