Development of Roller Compacted Geopolymer Concrete Using Recycled Aggregates

**Advisor/Mentor:** Mohammad Jamal Khattak, PhD, P.E.

**Project Summary:** Every year large quantity of recycled aggregate (RA) such as reclaimed asphalt pavements (RAP) and recycled concrete aggregate (RCA) is generated in USA. Utilization of RA can solve the storage problem, prevent the environmental pollution and reduce the construction costs. The proposed study focuses on the strength characteristics of RA mixtures by introducing the concept of roller compacted fly ash-based geopolymer concrete (RCGPC). Geopolymer materials represent an innovative class of “green” technology that is gaining popularity in the construction industry due to emphasis on sustainability. Geopolymer systems mainly rely on industrial by-products to significantly reduce its carbon footprint. Geopolymer utilize aluminosilicate rich industrial by-products and natural materials including fly ash, furnace slag and clays, etc. Several selected RCGPC mixtures will be investigated to evaluate the effect of mixture variables, including sodium hydroxide (NaOH) molarity, sodium silicate (Na$_2$SiO$_3$) to sodium hydroxide (NaOH) ratio on the strength and modulus characteristics. The effects of different curing temperature and curing duration, and curing conditions will also be investigated. Based on the results and analysis recommendations for the use of RCGPC using RA as a cost-effective solution for the construction of pavement structures will be provided.

Development of High Performance Hot mix Asphalt Mixtures

**Advisor/Mentor:** Mohammad Jamal Khattak, PhD, P.E.

**Project Summary:** This study focuses on the development of high performance asphalt composite for mitigating flexible pavement cracking such as fatigue, transverse and reflective cracks. Long-term performance and sustainability of the pavements could be achieved by augmenting asphalt mixtures with optimum dosages of microfiber. Addition of the fibers will significantly increase the stiffness, strength, and fracture toughness under traffic loading. Such novel composites could enhance the life-cycle cost of pavements and save taxpayers money. The asphalt mixtures are used over 94% of all pavements in US, and accounts for $45 billion/year of national transportation spending. The potential economic impact is significant if the pavement life-cycle cost could be decreased due to the high performance asphalt mixture. In order to develop advanced high performance asphalt composite, several mix parameters will be studied and optimized in relation to mechanical and durability characteristics. The developed the mixture will hold high prospective of commercialization and implementation potential by federal, state, and private industry due to the following characteristics:

- Enhanced stiffness, strength, and fracture toughness due to microfiber addition (*High Performance, Durable, Sustainable*)
- Reduced life-cycle costs of pavement due to high performance and low maintenance costs
  *(Economical)*

**Improved Flexure Capacities of Cross Laminated Timber (CLT) Beam Structures Using Fiber Reinforced Plastic (FRB)**

**Advisor:** Dr. Trung Do, Civil Engineering

**Project Summary:** CLT is a new construction material which has been used in today construction of buildings with height challenging up to 18 stories. In bridge constructions, CLT has been used for small span bridges or bridge deck only due to the low strength comparing to other convention materials. Numerous consolidation techniques for wooden elements by reinforced with other material have been proposed recently. In which FRB-reinforced wood with very thin layer of fiber composite sheets boned on tension face is a promise solution for improving ductility, stiffness, and strength of construction wood material. This experiment study investigates the potential of applying FRB reinforced technique for CLT beam to improve the bending capacity. A series of CLT beams with and without FRB reinforcement will be tested to investigate the effectiveness of FRB in different configurations for optimizing the cost and resilience of reinforcement. The bending tests will show the deflection ductility and load-carrying capacity of CLT beam to investigate the ability of using reinforce CLT beams for longer span range and the feasible alternative material for used in designing bridges.

**Evaluate the Restrained Shrinkage during Early Hardening Period of Concrete**

**Advisor:** Dr. Li Hui, Civil Engineering

**Project Summary:** Cracking in concrete bridge decks has been identified as one of the major issues on infrastructures for departments of transportation throughout the United States. These cracks allow harmful substances such as salts to penetrate concrete decks, which can initiate the corrosion of the reinforcing steel and leading to many safety concerns and economic losses by requiring more frequent rehabilitation and reconstruction. Previous researches indicate that the restrained shrinkage causes most of the cracks formed in concrete bridge decks during the early hardening period. The shrinkage during the curing of concrete can cause significant stress along with the reinforcing steel, resulting in small cracks developed on the contacting surface of steel bar and concrete. These micro-cracks grow inside the concrete and propagate to the deck surface. In this study, the free and restrained shrinkage of concrete during the early hardening period will be evaluated and compared based on the laboratory testing results. Several groups of concrete specimens with steel bars embedded as well as plain concrete cylinders will be cast, and the strain gauges will be installed on steel bars and different layers of concrete to evaluate the changes of stress caused by early shrinkage. This study will provide students a general idea on the effects of restrained shrinkage which may cause cracks on concrete decks. Also, the data collected in this study can be used to calibrate the material behaviors for computer simulation using the finite element method.
Development of Proteinaceous Structural Composites

Advisor: Dr. William M. Chirdon

Project Summary: This research project focuses on the invention and development of novel, sustainably-sourced composites utilizing waste proteins from a variety of industries including biodiesel production, wastewater treatment, and other bioprocessing industries. This project hopes to develop new composite materials that are more sustainable in their sourcing from waste proteins and from waste material aggregates. The objectives also include creating structural materials that have a sustainable fate in that they can be naturally degraded by the environment. We hope that these materials can be used for temporary infrastructure, where the materials will intentionally degrade after their use by design, which may allow for the minimization of environmental damage caused by the need for creating temporary roadways for industries including oil & gas as well as forest products.

While this research group has a US Patent (#10,023,778) on a successful binder that has been derived from algal biomass, the participant would be encouraged to further develop this technology by optimizing the binder formulation and process as well as the composite formulation and process. The composites will be evaluated by mechanical testing so that their suitability for various applications might be assessed.

Development of a High-Quality Green Adhesive from Waste Biomass Derived from Large Municipal Wastewater Treatment Plants and/or Algae-to-Biofuels Production Facilities

(2 REU Students will be working on this project)

Advisor: Dr. Mark E. Zappi, PE – BORSF Chair in Processing, Professor of Civil Engineering, Professor of Chemical Engineering (jointly appointed), and the Executive Director of the Energy Institute of Louisiana, UL College of Engineering

Project Summary: Algae to biofuels is a fastly developing process that uses algae oil to produce biodiesel. The residuals from the algae currently do not have a significant value-added component. Biosolids represent wasted sludge produced at wastewater plants with over 8 million dry tons being generated in the US each year that require disposal at costs often far exceeding $50/ton. This project will capitalize on recent discoveries at UL on how to process biosolids and deoiled algae cake to produce an adhesive capable of being used to produce construction materials, such as fiber and ply boards. The process involves the cross-linking of protein strands within the algae and/or bacteria from the biosolids to produce a strong adhesive using a heated, elevated pH processing system. Results to date indicate that this green adhesive has strengths similar to currently available commercial adhesives made from animal protein and/or phenolics. Challenges to be overcome include the impact of the differing chemistries of the mixed protein sources on the final adhesive properties; the impact of complex protein matrices on rate and extent of the functioning process mechanisms; and the
expected increase in chemical use for processing that more complex feedstock and the resulting impact on overall economics. Benefits will be a commercially viable use for both algae cakes and biosolids. In the case of the algae, this will add more value to the overall biofuels process. With the biosolids, this envisioned process will eliminate costly sludge disposal issues. In either case, the developed processed will produce a new green, sustainable commercial adhesive. This timely project integrates construction materials research with green production of chemicals from waste feedstocks which is a popular research topic for achieving a more sustainable infrastructure.

Interdisciplinary Project-Based Hands-On Training on Green Concrete Reinforced with Renewable Fibers

Advisor: Dr. Dilip Depan, Chemical Engineering Department

Project Summary: Research on “Green Concrete” has experienced an explosive growth in recent years because of the unique combination of their properties such as nontoxicity, biocompatibility, and high strength. Further, Green Concrete is extremely important from environmental perspective, as it does not leach out toxic substances and pollutants with aging. Various renewable source based nanofillers have been added to concrete owing to their low weight, high strength and modulus, and high surface area. Further, superplasticizers (SPs) or water reducers have been used to improve the fluidity of cement, because they can reduce the water-to-cement ratio. However, conventional SPs are toxic and have negligible impact to reinforce concrete. “Green concrete” needs adaptive green SPs, and the preparation of green SPs using modified renewable natural materials is an important pathway. So, we propose to fabricate next generation of SPs for the development of high-performance green concrete with superior strength, and improved fluidity. Thus, the focus of this study is to investigate the utilization of functionalized cellulose nanofibers (CNFs) as a potential green SP, in such a unique way that the CNFs will offer mechanical reinforcement, while functionalization with sulfonate will provide super-plasticity to the concrete.

Furthermore, CNFs have been widely used as reinforcing materials for various construction materials. However, complete utilization of CNFs to improve the physical properties of cement is still difficult due to the following attributes: first, it is difficult to disperse CNFs in cement; second, the agglomeration of CNFs during cement hardening.

The objective of the proposed work is to study the effect of size and chemical functionalization of CNFs to improve the strength of cement. For this CNFs will be synthesized, functionalized, and characterized in terms of chemical structure, crystal structure, crystallinity, and aspect ratio. The proposed research will provide a deeper understanding of the interaction between CNFs and cement and promote the development of new synthetic strategies for reinforced cement.
The objective of the project is to build an inter-disciplinary team of undergraduate and graduate students, and junior researchers to fabricate CNFs-cement nanocomposites and study physical properties using scanning electron microscopy, X-ray diffraction, differential scanning calorimetry, and Fourier infrared transform spectroscopy.

**Cysteine Modified Graphite Oxide for Pb(II) Removal: Characterization, Adsorption, and Adsorption Mechanism**

**Advisor:** Dr. Daniel Gang, Civil Engineering

**Project Summary:** This study is aimed at developing a novel material which can remove Pb(II) efficiently from drinking water. Pb(II) issue has gained great attention due to its oncogenicity, bio-accumulation, non-biodegradability and virulence. Available techniques for remediation of Pb(II) from water include adsorption, chemical precipitation, membrane separation, ion-exchange, and reverse osmosis. Among these technologies, adsorption techniques have gained a lot of attention due to its effectiveness for Pb(II) removal, low cost, and simple operations. Various adsorbents have already been reported for Pb(II) removal such as chitosan–tripolyphosphate, modified lignin, phosphorylated bacterial cellulose, carbon aerogel, carbon nanotubes, and ordered mesoporous carbon. However, these materials have not been widely used due to the limited adsorption capacity. In this study, cysteine will be used to modify graphite oxide to increase the adsorption capacity. The objectives of this study are to: (1) demonstrate the concept for removing Pb(II); and (2) to understand the effects of adsorption time, pH, and background cations on the adsorption. The results will prove the concept and possibly provide highly efficient adsorbent for Pb(II) removal from drinking water.

**Urbanization and the Hydraulic Failure Potential of Roadway Drainage Structures**

**Mentor:** Dr. Robert Miller

**Project Summary:** The objective of this project is to conduct a case study which informs the development of a methodology aimed at quantifying the impact of urbanization on the hydraulic failure potential of roadway drainage crossings. The student working on this project will participate in field visits to inspect and document hydraulic conditions at various culvert and bridge locations in the study area. The student will also be introduced to basic design concepts including advanced hydraulic analysis procedures, flood risk assessments, and regulatory requirements.
Activities

Seminar series and an educational field trip will be offered during the 10-week program to help participating students learn how to conduct research, improve their presentation and writing skills, and prepare them for graduate school and advanced career in the engineering field.

Seminar Series:

**Grand Challenges of US Infrastructure** - An half-hour presentation will be given to the participating students to introduce them the current status of US infrastructure, the grand challenges our infrastructure is facing, and the importance of research in infrastructure materials to overcome these difficulties.

**Research Methods and Ethics** – 1-2 1-hr seminars will be given to the participating students to introduce them the basics of the research process. The seminar will introduce what research is, safety procedures and required training for working in different labs, literature search tools, and the importance of research ethics.

**Technical Writing and Presentation Skills** – 1-2 1-hr seminars will be offered by an experienced tutor from the Writing Center at UL Lafayette on technical writing and presentation tips and advice.

**Graduate School Life and Application Process** – A 1-hr seminar on graduate school application followed by a 1-hr panel discussion on graduate school life and experience will be offered to the participating students during the REU program. Past and current graduate students with diverse backgrounds from both engineering and science disciplines will share their experience with participating students on graduate school application process, life as a graduate student in STEM and discuss why they chose to attend graduate school.

**Careers in STEM** – A 2-hr seminar on potential career paths and development in STEM fields will be given. Senior engineers from industries will be invited to speak at the seminar and offer their advice to participating students on career development. Recent graduates from UL Lafayette will also be invited to share his/her experience as a young engineer.

Field trips:

Two field trips will be help during the 10-week program.

**LUMCOM Trip**: A two-day weekend field trip to Louisiana Universities Marine Consortium (LUMCON, Figure 1) will be organized during the REU program. LUMCON was formed in 1979 to increase society’s awareness of the environmental, economic and cultural value of Louisiana’s coastal and marine environments by conducting research and education programs directly relevant to Louisiana’s needs in marine science and coastal resources and serving as a facility
for all Louisiana schools with an interest in marine research and education. Part of LUMCON’s mission is to increase society’s awareness of important Louisiana coastal issues. LUMCON is located within the coastal landscape and is close to the Mississippi and Atchafalaya rivers, where a number of largest Louisiana’s coastal bridges are located. LUMCON is in possession of multiple vessels, Marine Center, Library and Environmental Monitoring Stations which will be available for use to the REU site. The Marine Center is a modern, 75,000 square foot complex of research, instructional, housing, and support facilities completed in 1986. The Center includes 26,000 net usable square feet of laboratory, classroom, office, and library space. Eight laboratories are equipped with running seawater. Six additional laboratories are reserved for dry applications and instrumentation and are used for both research and teaching.

LTRC trip: Another educational field trip will be a tour to Louisiana Transportation Research Center (LTRC) research lab to learn about the advanced research conducted by Louisiana Department of Transportation related to advanced infrastructural materials.