Problem

An emerging field of research with intriguing potential to transform the entire engineering process is *biomimicry* – that is, researching bio-inspired materials and systems to learn from Nature’s often superior solutions to technological challenges and problems. Despite the considerable research effort into such systems, there have been no significant changes in either the materials or systems of our civil infrastructure, particularly in the field of large-scale structural engineering. Combining expertise in bio-inspired materials characterization and structural analysis along with design of structural systems in the built environment, one focus of our NICE Lab is to develop practical bio-inspired technology for viable and immediate structural applications. The fact that Nature achieves its goals with limited resources and energy suggests we can achieve engineering solutions by exploiting the opportunity of novel material responses and their synergistic response within a structural system.

Approach

Our lab’s approach is both cross-disciplinary and multi-scale, but follows a common “blueprint” consisting of:

1. Exploration, understanding and characterization of specific biological systems. Example systems investigated include spider silk webs and anchors, mussel byssus attachments, and gecko foot adhesion.
2. Theoretical description of the underlying physical phenomena and governing mechanistic principles.
3. Exploration of the effect of material and structural synergy on the systems *via* model materials, replacing the biologically constitutive law with an engineering material equivalent (e.g., a “silk to steel” or “bone to brick” paradigm).
4. Translation and application of the discovered principles to a practical engineered design.

Core Competencies

- Biomimicry
- Bio-inspired materials characterization
- Bio-inspired technology
- Exploration, understanding and characterization of specific biological systems

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Recent Findings

One of Nature’s damage and failure mitigating strategies (found in spider silk, cellular membranes, and arterial tissues, as examples) is materials which exhibit both hyperelastic stiffening and extreme extensibility. The root of these behaviors lies in the molecular “unfolding” of protein materials. We have developed a model embedded fiber composite system where the geometry of the fiber can be designed to tune unfolding and stiffening responses (see Figure). Using the same basic building blocks, the system can be “brittle” or “tough” by manipulating the curvature of the fiber. Current studies are exploring a homogeneous matrix reinforced with a single flexible fiber, with variable material properties. The next phase will be to extend the approach to structural materials such as concrete and steel.

Impact

A holistic knowledge of biological materials and systems (an emerging field known as materiomics) offers a unique opportunity to understand how complex materials science and engineering principles arise routinely in Nature. The underlying questions are not in how to design bio-like systems, but rather what material response could enhance structural performance. By considering the synergistic interaction of material and structure (a necessary biological constraint typically overlooked by engineering), not only can novel structures be developed, but also the potential to reinforce and retrofit existing infrastructure. The goal of our research is the shift from total mimicry (i.e., stealing) to an understanding of the process at its basic level, defining that process from an analytical perspective (e.g., mechanics and physics) and then exploiting the physical phenomena to ends that serve national needs such as increased sustainability and efficiency of physical infrastructure.

Selected Publications


Current Research Collaborations:

- Bio-Inspired Structural Anchorages (w/ Andy Myers, CEE NEU)
- Optimization of DNA-Based Biomarker Sensors (w/ Ming Wang, CEE, NEU)
- Bio-Inspired High-Performance CNT Fibers (w/ Marilyn Minus, MIE, NEU)
- Enhancing Thermal Properties of Asphalt (w/ Nima Rahbar, CEE, WPI)

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