Graduate Opportunities in Safe Transportation and Resilient Systems

GAANN- GOSTARS Fellowship Project

Adviser: Islam M. Mantawy, Ph.D., PE

Title: Topology Optimization and Additive Construction toward Sustainable, NetZero Carbon Infrastructures

Description: For decades, concrete structures are constructed using cementitious based materials using conventional methods through formworks (either cast-in-place or precast). Concrete with sufficient slump is needed to fill up the formworks. This approach results in significant material wastage (where the material is placed at areas with low to very low stresses) and increases carbon footprint. Additive construction (3D printing) provides unique opportunities to build form-free structural elements and can enable topology and structural optimization. This project aims at developing concrete mixes without cement (either geopolymer or polymer concrete) and adapting these mixes for additive construction and topology optimization toward sustainable, NetZero carbon structural elements. Several green concrete will be examined such as geopolymer concrete, polymer concrete, etc. The project will include 1) mix design, 2) numerical modeling for optimized structural elements, 3) 3D printing of structural elements, and 4) experimental testing.

Impact on GAANN: The study attempts to address a national need to reduce construction wastage of materials and utilize greener materials toward the reduction of carbon footprint and emissions. The success of this project will open a new horizon for more structurally and topological optimized structures using sustainable materials. The goal of this project is to construct and test structural elements (truss-like structures to form beams and columns) using both innovative formwork and additive construction.

Impact on GOSTAR: This proposed GAANN project prepares a graduate student to be able to develop different sustainable concrete mixes (geopolymer or polymer concrete) for both conventional and additive construction. The graduate student will also be able to develop numerical models to optimize structure elements and will lead the construction of the structural elements (through both innovative formworks and additive construction), experimental testing, and numerical model calibration. The graduate student will be qualified to join industry, academia, or growing business in (3D printing of concrete structures as a major impact of this project after graduation.

Tentative Plan

Semester	**1**	**2**	**3**	**4**	**5**	**9**	**7**	**8**	**9**
Task 1: Literature Search	✓	✓	✓						
Task 2: Development of Mix Design	✓	✓	✓			✓			
Task 3: Numerical Modeling for Topology Optimization			✓	✓	✓	✓			
Task 4: Construction and Testing of Specimens				✓	✓	✓	✓	✓	
Task 5: Final Deliverables								✓	✓
Outcome	Learning the basic mix designs for different construction methods			Development of numerical modelling for topology and structural optimization			Learning skills of new innovative and emerging construction techniques		
Deliverable	Publish in refereed conference proceedings and journals			Publish in refereed conference proceedings and journals			Publish in refereed conference proceedings, journals, and final report.		
Graduation									**Summer 2025**