CIES Quick Facts

• Founded in 1998
• 21-47 faculty members
• 5-12 departments
• CEC and CASB
• 2-3 staff members

Kamal H. Khayat
Vernon & Maralee Jones Professor of Civil Engineering
Director, Center for Infrastructure Engineering Studies

November 13, 2020

OUTLINE

• Research Themes
• Highlight work of some faculty
• Major initiatives led by Center
• Networking and TT activities
• Research infrastructure
Research Themes

• Advanced Materials for Sustainable & Resilient Infrastructure
• Advanced Design and Management Methods to Resist Extreme Events
• Asset Management and Data Analytics
• Advanced Construction Methods
• Novel Non-destructive Structural Health Monitoring

Addressing Nationally Recognized Grand Challenge

*Restore and improve urban infrastructure (NAE 2008)*
- Novel construction materials
- New construction and monitoring methods
- Automation in construction, repair, and maintenance
Advanced Construction Materials for Sustainable and Resilient Infrastructure

Design and Performance of Advanced Materials

- High-performance concrete (SCC, FRC, HSC, UHPC, LWC, etc.)
- Sustainable zero-CO2 emission binders, geopolymers, use of recycled materials, including municipal waste materials
- Smart, self-healing, PC, functionally graded, Nano materials
- Novel admixtures and surface modification of infrastructure mat.
- 3D printing – rheology and hydration control
- Asphaltic materials, asphalt cement, asphalt binders
- Environmental aspects of asphalt recycling
- Pavement preservation, repair, and rehabilitation
- Geomaterials
- Fiber-reinforcement and fiber-reinforced polymers
- Energy harvesting from geotechnical applications
- Constitutive modelling of multiphase materials
- Environmental aspects and contamination
DEPARTMENT OF CIVIL, ARCHITECTURAL, AND ENVIRONMENTAL ENGINEERING

Novel Materials Enhance Infrastructure Sustainability

Cement and Concrete Fundamentals
• Thermodynamics and Hydration Kinetics of Multi-Component Cementitious Materials
• Multiscale Characterization and Modeling (MD, ML, RW, FEM) of the Microstructure and Properties of Concretes

Novel Materials for Sustainable Infrastructure
• Phase Change Materials for Thermal Insulation in Building Envelopes, Thermal Crack Control in Massive Concrete, and Thermal Distresses Mitigation of Pavement
• Bacterial Carbonate and Silicate Precipitation in Concrete
• High-performance Construction/Repair Materials

Functional Composites
• Fast-Setting materials in special/extreme environments: extremely cold, underwater, acidic, etc.
• High-performance cements based on indigenous materials: waste slags, fly ash, MSWI ashes, lunar regolith, etc...
• Piezoelectric and fiber-optic sensing: cracking, strain, and temperature, applications of fiber-optic Raman/ph probes.

PoC: Hongyan Ma, Ph.D., Assistant Professor & CEC Dean’s Scholar
Civil, Architectural and Environmental Engineering
Center for Infrastructure Engineering Study
Email: mahons@mst.edu
Phone: (573)341-6250
Webpage: http://care.mst.edu/directory/profiles/ma/

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

Artificial Intelligence for Design and Discovery of Sustainable Materials

Sustainable Materials for Construction Infrastructure
• Microcalorimetry and ion chromatography methods to assess and enhance intrinsic reactivity of silicate and aluminosilicate waste materials
• Artificial intelligence, thermodynamic modeling, kinetic modeling, and virtual microstructure reconstruction techniques to design and discover novel, sustainable, and durable construction materials

Organic/Inorganic Additives for Reaction Control
• Microcalorimetry methods and Nucleation and growth models to characterize and regulate the influence of various organic and inorganic additives on reaction kinetics and microstructural development in cementitious systems

Fluid and Ion Transport in Porous Media
• Lattice Boltzmann models and experimental methods to estimate fluid/ion permeability & diffusivity in porous media

High-Fidelity Prediction and Optimization of Performance
• Development of machine learning tools for prompt and reliable prediction of performance of materials, including cementious systems, and optimization of material composition/mixture design

PoC: Aditya Kumar, Assistant Professor, Materials Science and Engineering
http://users.mst.edu/fluidstaf/facilities/kumarad/

Funding (Current and Prospective)
Dept. of Energy (DOE), National Science Foundation (NSF), U.S. DOT, Federal Highway Administration (FHWA)

Keywords
Sustainability; Novel/Smart/Functional Materials
• Cement Chemistry; Microstructure; Transport Properties; Multiscale Modeling
• Phase Change Materials; Bacterial Mineral Precipitation; Acid-base cements
• Fast repair materials; Indigenous raw materials
• Piezoelectric; Fiber-Optic; Chemical Sensing

Keynotes:
Sustainable Materials for Construction Infrastructure
• Microcalorimetry and ion chromatography methods to assess and enhance intrinsic reactivity of silicate and aluminosilicate waste materials
• Artificial intelligence, thermodynamic modeling, kinetic modeling, and virtual microstructure reconstruction techniques to design and discover novel, sustainable, and durable construction materials

Organic/Inorganic Additives for Reaction Control
• Microcalorimetry methods and Nucleation and growth models to characterize and regulate the influence of various organic and inorganic additives on reaction kinetics and microstructural development in cementitious systems

Fluid and Ion Transport in Porous Media
• Lattice Boltzmann models and experimental methods to estimate fluid/ion permeability & diffusivity in porous media

High-Fidelity Prediction and Optimization of Performance
• Development of machine learning tools for prompt and reliable prediction of performance of materials, including cementious systems, and optimization of material composition/mixture design

PoC: Aditya Kumar, Assistant Professor, Materials Science and Engineering
http://users.mst.edu/fluidstaf/facilities/kumarad/

Funding (Current and Prospective)
Dept. of Energy (DOE), National Science Foundation (NSF), U.S. DOT, Federal Highway Administration (FHWA)

Keywords
• #Cement, #Concrete, #Aluminosilicate, #GlassDissolution, #HighPerformanceConcrete, #DurableInfrastructure, #Sustainability

Recognitions
• Member: American Ceramic Society (ACerS), American Concrete Institute (ACI), RILEM
• Co-chair: Microstructural modelling chapter, ACI

Keynotes:
Sustainable Materials for Construction Infrastructure
• Microcalorimetry and ion chromatography methods to assess and enhance intrinsic reactivity of silicate and aluminosilicate waste materials
• Artificial intelligence, thermodynamic modeling, kinetic modeling, and virtual microstructure reconstruction techniques to design and discover novel, sustainable, and durable construction materials

Organic/Inorganic Additives for Reaction Control
• Microcalorimetry methods and Nucleation and growth models to characterize and regulate the influence of various organic and inorganic additives on reaction kinetics and microstructural development in cementitious systems

Fluid and Ion Transport in Porous Media
• Lattice Boltzmann models and experimental methods to estimate fluid/ion permeability & diffusivity in porous media

High-Fidelity Prediction and Optimization of Performance
• Development of machine learning tools for prompt and reliable prediction of performance of materials, including cementious systems, and optimization of material composition/mixture design

PoC: Aditya Kumar, Assistant Professor, Materials Science and Engineering
http://users.mst.edu/fluidstaf/facilities/kumarad/

Funding (Current and Prospective)
Dept. of Energy (DOE), National Science Foundation (NSF), U.S. DOT, Federal Highway Administration (FHWA)

Keywords
• #Cement, #Concrete, #Aluminosilicate, #GlassDissolution, #HighPerformanceConcrete, #DurableInfrastructure, #Sustainability

Recognitions
• Member: American Ceramic Society (ACerS), American Concrete Institute (ACI), RILEM
• Co-chair: Microstructural modelling chapter, ACI
DEPARTMENT OF CHEMICAL AND BIOCHEMICAL ENGINEERING

Developing Materials for Sustainable Infrastructure & Environment

Cement and Concrete Composites
• Coal-derived graphenemodified geopolymer cements
• Smart chemical admixtures for oil-well cement rheology control
• Hydration, microstructure, and durability of alternative eco-efficient concrete binders
• Nano-engineered cement and concrete systems

Separations and Filtrations
• Coal-derived carbonaceous composites for sorption of organic and inorganic contaminants
• Carbon materials and microporous materials
• Nanocomposites and functional materials for water treatment

Carbon Capture and Storage
• CO₂ upcycling in cementitious materials
• Layered double hydroxide enhanced carbon capture and conversion

Oil-well cement rheology control by rational design of admixtures

Geopolymers

Geopolymer composites for sorption of heavy metal contaminants

Keywords:
• Cement and Concrete
• Materials
• Nanocomposites
• Sustainability
• Thermodynamics
• Admixtures
• Rheology
• Energy and Environment
• Wastewater/Water Treatment
• Waste immobilization
• Sorption
• Carbon capture

Recognitions
• Materials and Structures Outstanding Paper 2016
• Principals Research Excellence Award, Aberdeen 2013
• Best Graduating Student and University Valedictorian 2007

Department Of Geosciences And Geological And Petroleum Engineering

Wellbore Integrity, Hydraulic Fracture, and Enhanced Oil Recovery for Unconventional Reservoirs

Wellbore Integrity Research Topics:
• Modified Portland cement for long wellbore isolation
• Fly-ash cement for oil, gas, and geothermal wells applications
• Epoxy material for mitigating cementing failure

Key Words:
Experimental work is conducting to evaluate rheological and mechanical properties of the new developed cements.

Hydraulic Fracture Research Topics:
Characterize and evaluate fracture fluids including High Viscous FrictionReducers and linear gels:
• Rheological properties of fracture fluids
• Proppant static and dynamic settling velocity
• Proppant fracture conductivity

Key Words:
Experimental work is conducting to evaluate rheological properties of fracture fluids and their impact on proppant dune development inside fractures.

Enhanced Oil Recovery Research Topics:
Evaluate gas EOR in Unconventional reservoirs:
• Asphaltene precipitation, flocculation, and deposition
• Gas miscibility pressure
• Gas huff-n-puff
• Data analytics and management

Conformance Control:
• Gel injectivity through fractures, channels, and rock matrix
• Gel blocking Efficiency to water and oil
• Gel combination with polymer and low water salinity

Contact Information
Abdulmohsin Imam, Ph.D.
Assistant Professor
Petroleum Engineering Program
133 McKnight Hall
Email: simam@mst.edu
Phone: 573-341-4669
Funding:
NSF/CBT, asphaltene precipitation
Webpages:
https://sites.google.com/umystem.edu/abdulmohsin-imam/home
**Advanced Design and Management Methods to Resist Extreme Events**

- Evaluation of structural behavior
- Monitoring of long-term performance
- Development of sound design procedures
- Post-disaster response

**DEPARTMENT OF CIVIL, ARCHITECTURAL, AND ENVIRONMENTAL ENGINEERING**

**Sustainable Material and Resilient Infrastructure**

Vulnerability and resiliency of infrastructures under multi-hazard loads
- Diagnosis and retrofitting of existing infrastructures subjected to manmade and natural hazards such as earthquakes, wind, hurricane, and blast
- Developing innovative structural systems to increase the resilience of new infrastructure
- Using new materials to increase resilience of infrastructure

New material and systems for accelerating and sustainable construction
- Using innovative systems and materials to accelerate bridge construction
- Using more sustainable concrete and masonry using recycled materials such as shredded tires, mine tailing, and fly ash

**Keywords**
- #MultiHazard, #Deterioration, #Accelerated construction, #Recycled material, #Retrofitting, #Masonry, #Concrete, #Steel structures

**Recognitions**
- Board of Directors, The Masonry Society
- Associate Editor the American Society of Civil Engineering Journal of Bridge Engineering
- Chair American Concrete Institute Committees 441 and 341A
Asset Management and Data Analytics

• Sustainable infrastructure and resilient hazard management
• Risk, safety, and disaster management
• Transportation organizational decision-making tools, such as Big Data analytics, cloud computing
• Data-driven models for assets management and LCA to manage critical infrastructure systems
• Machine learning for Big Data management
• Dynamic modeling, transportation and construction management, and mobile data management, sensor computing, and cyber security

Smart Transportation Systems, Computing and Data Science

Smart Transportation Systems
• Connected and Autonomous Vehicles
• Electric Vehicles
• Active Traffic and Demand Management

Transportation Big Data Analytics
• Mobility Behavior Modeling and Analytics
• Machine Learning and Optimization
• Multi-Source Transportation Data Mining

Traffic Flow and System Modeling
• Traffic Flow Modeling and Applications
• Dynamic Traffic Assignment
• Origin-Destination Demand Calibration

XianBiao(XB)Hu, Ph.D.
Assistant Professor
Civil, Architectural & Environ. Eng.
xhu@mst.edu (+1)573-341-6176

Funding
• US Department of Transportation, Department of Energy, Department of Education, Federal Highway Administration, Missouri Department of Transportation, Colorado Department of Transportation

Keywords
• Smart Transportation Systems, Connected and Autonomous Vehicles, Electric Vehicles, Big Data, Artificial Intelligence, Computational Intelligence;
• Mobility Modeling, Traffic Flow Theory, Dynamic Traffic Assignment, Traffic Operation and Safety;

Recognitions
• Excellent Paper Award, 2018 World Transport Convention
• ASCEExCEEd fellowship
Novel NDT and SHM

- Evaluation of structural behavior
- Evaluation of constructability and safety
- Structural health monitoring
- NDT
- Simulation & analysis of failure

Acoustic, Microwave, Ultrasonic
LIDAR technology
Radar thermography, etc.
Sensors: embedded and remotely interrogated for SHM
Research on Concrete Applications for Sustainable Transportation

Research Theme Areas

- Innovative Materials for Accelerated Construction and Sustainable Construction

- Durable and Resilient Materials for Rehabilitation of Transportation Infrastructure

$4.2M from U.S. DOT
$3.2M non-Fed agencies + industry
Total: $7.4M
Match: 1:0.75

Advanced Materials for Sustainable Infrastructure Strategic Area

AMSI involves construction and rehabilitation of urban/mass transport systems, rail, airports, ports, water navigation channels, nuclear structures, as well as utility infrastructure.
Advanced Materials for Sustainable Infrastructure Development

GRC: Cutting-Edge Development and Characterization of Cement-Based Materials

Topics of Interest
- Alternative Binders
- Nanostructure of C-S-H and Hydration
- Advances in Chemical Admixtures
- Measurement and Control of Rheology
- Corrosion Science and Mitigation
- Sustainability and Life Cycle Assessment
- Durability and Service Life
- Emerging Technologies for Performance Prediction of Concrete
- Specialty Materials

Bringing together materials professionals, researchers and representatives from infrastructure owners to engage with leading edge experts

Ventura Beach Marriott – Ventura, CA

Gordon Research Conference
Frontiers of Science
Feb. 22-27, 2020

Chairs: Kamal H. Khayat, Missouri S&T
R. Doug Hooton, University of Toronto

Gordon Research Seminar
Graduate Research
Feb. 22-23, 2020

Chairs: William Wilson, École Polytech. Fédérale de Lausanne
Nima Farzadnia, Missouri S&T

The Use of Energy-Dense Isothermal Still Mineral Dissol... Dr. Gunev Oke

Thursday, October 29
4 p.m. | 124 Butler-Carlton Hall

Dr. Gaurav N. San... Associate Professor
Henry Samueli School of Engineering, University of California, Los Angeles (UCLA)

Thursday, February 21
2 p.m. | 317 Butler-Carlton Hall

Dr. Gaurav N. San... Associate Professor
Henry Samueli School of Engineering, University of California, Los Angeles (UCLA)

Thursday, November 14
4 p.m. | 124 Butler-Carlton Hall

Abstract:
Extensive winds, such as tornadoes and hurricanes, have induced substantial structural damage, injuries and deaths in the USA. Tornadoes occur in mainland America, mainly "Tornado Alley", and they contribute $12 billion annually to the nation’s losses. Hurricanes occur in coastal areas, and the governmental costs for hurricane damage are still billions of dollars. This talk will focus on the following cutting-edge research: 1) Tornado Alley: Tornado Alley is a region that experiences a significant number of tornadoes and severe thunderstorms. 2) Numerical simulations: Numerical simulations are used to predict the path and intensity of tornadoes and hurricanes. 3) Stormwater management: Stormwater management strategies are implemented to reduce the impact of storms on infrastructure. 4) Tornado Alley: Tornado Alley is a region that experiences a significant number of tornadoes and severe thunderstorms.
Sustainable development transportation, building, and energy infrastructure

- Challenges in arctic construction - geotechnical, mining, environment, procurement, materials, labor force, monitoring, asset management, etc.
- Exploitation and use of indigenous materials for built systems – new materials, recycled materials, LCA driven tools
- Modular construction (prefab elements, 3DP technology, ...)
- Energy harvesting: on-shore and off-shore structures
- Prefabricated wind
- Monitoring and protection stations
- Semi-submersible, floating airports, stations, camps, fishing farms, ...

Promote technology transfer to the engineering community and industry

Sixth Annual
Transportation Infrastructure Conference

Rolla, December 8, 2017

Amr Elnashai
V-P/VCR&TT
University of Houston

David Lange
Director, Center of Exc. for Airport Technology, UIUC

Peter Taylor
Director, Nat. Concrete Pavement Center, Iowa State University

William Stone
Research Administrator
Missouri DOT
Phase I: Secure and operate state-of-the-art equipment to conduct cutting edge of research

$2.8M from U.S. Department of Transportation in 2012 Advanced Construction & Materials Laboratory (ACML)

Phase II: Butler-Carlton Hall Expansion: Clayco ACML ($7M)

- 16,000 ft² of new state-of-the-art research infrastructure
- space
- CIES will provide online inventory tool
- Web-based system to facilitate access to equipment
- Launch user fees
- Provide safety directives and training
Concrete Batching System (concrete à la carte)

Fully automated planetary motion high shear concrete batching plant with dual-mixers: 750-L (1-yd³) and 250-L (1/3-yd³) outputs

Ultra-High-Performance Concrete
Rheometers

- ConTec 5: Concrete and mortar
- ConTec 6: Micro-mortar
- Factors on flow properties
- Static/dynamic stability
- Pumping issue
- Quality control

Heat of cement hydration and activation energy:

Calorimeters (Isothermal/semi-adiabatic)
Material Characterization

Pycnometer measures true volume/density of solids

Mercury Intrusion Porosimeter

4D X-ray micro-CT – time-resolved characterization of microstructure evolution of in situ (T, R.H., and loading) samples

Air-void analyzer

Environmental Chambers

ASR

Frost durability

Carbonation

Deicing Salt Scaling
Two-dimensional (2D) materials are thin films with one or a few-atom layer thickness. Due to their 2D nature, the electron mainly transports in the 2D space, allowing them to have superior electrical properties. In addition, being ultra thin, their mechanical strength-to-thickness ratio is much higher than steel (10 times) even when subjected to defects and out-of-plane loading. In this talk, we will illustrate the fundamental mechanical and electrical properties of 2D materials including graphene and 2D transition metal carbides (MXenes). In addition, we will also illustrate how these materials can help in manufacturing super-strong structural armors, ultra-sensitive fiber-optic sensors, and compact bio-chemical sensors. In addition, we will show the relative low cost-to-effectiveness ratio of using 2D materials and discuss future opportunities.

Biographical Sketch

Chenglin (Bob) Wu received his bachelors degree in civil engineering from Tongji University in 2006 and his PhD degree in Civil, Architectural, and Environmental Engineering from Missouri S&T in 2011. He obtained his PhD in Engineering Mechanics in 2014 from the Department of Aeronautics and Engineering Mechanics, at UT Austin. Dr. Wu joined the Department of Civil, Architectural, and Environmental Engineering at Missouri S&T in spring 2017.

Dr. Wu’s research interests focus in the area of engineering mechanics with a particular emphasis on materials and structures at different dimensions (from macro to nano scale) and having multi-physics related problems. His research is motivated by practical applications in civil, mechanical, geo-mechanical, microelectronics, micro-electromechanical systems (MEMS), and emerging nanotech technologies. The objective of his research are to provide fundamental understandings and solutions to problems encountered in such applications.

http://cies.mst.edu/
khayatk@mst.edu