27th Structural Engineering & Mechanics Symposium

Friday, March 3rd, 2023
9:30am - 5:45pm

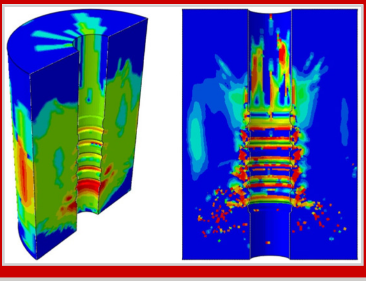
Department of Civil, Construction, & Environmental Engineering

NC STATE UNIVERSITY

SEM
STRUCTURAL ENGINEERING AND MECHANICS

Keynote Presentation

Computational Modeling of Interfaces in Complex Infrastructure Systems



Assoc. Prof. Ghadir Haikal, Department of Civil, Construction and Environmental Engineering, NCSU

Seminar Abstract

The field of computational mechanics has witnessed significant advancements that have greatly improved our ability to model complex phenomena, ranging from large-scale structures to nanoscale systems. With improved methods and more powerful computing, it has become possible to develop better design specifications for civil, mechanical and biomechanical systems under conditions that cannot be replicated in a laboratory, and often at reduced cost compared to experimental testing.

However, many challenges remain in the development of numerical models for complex infrastructure systems and composite materials where multiple components interact through an interface. Interfaces are critical pathways for load-carrying mechanisms that contribute to lifelong performance and structural resilience. Thus, it is crucial for the computational model to accurately capture the interface kinematics and force transfer processes, particularly in the presence of geometric and material nonlinearities, damage, friction and dynamics.

This presentation details the challenges and applications of interface modeling for coupled problems in engineering. I will introduce a new class of formulations that can efficiently handle complex interface interactions with large deformation, plasticity, friction and dynamics, that also support coupling structural elements (beams, plates) and meshfree discretizations. I will detail a physics-based model for accurate prediction of bond behavior in reinforced concrete (validated by experiments) that quantifies bond resistance from the material properties of steel and concrete constituents, as well as the mechanics of contact between them in the anchorage area. These new and robust interface formulations enable the modeling of complex structures for purposes of health monitoring and life-cycle management that also support the development of emerging materials and novel techniques for enhanced structural resilience.

Biography

Ghadir Haikal is an Associate Professor in Structural Engineering and Mechanics in the Department of Civil, Construction and Environmental Engineering at North Carolina State University. She holds a Bachelor's degree in Civil Engineering from Tishreen University, Syria and M.S. and Ph.D degrees from the University of Illinois at Urbana-Champaign, also in Civil Engineering. Prior to her current position, Dr. Haikal led the Computational Materials Integrity group in the Department of Materials Engineering at Southwest Research Institute (SwRI), and was an Assistant Professor of Civil Engineering at Purdue University. Dr. Haikal's research focuses on developing advanced computational models for structural integrity and lifetime prediction in complex structures and materials. She is a Fulbright Fellow and is a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the Society of Engineering Science and the United States Association for Computational Mechanics.

27th Structural Engineering & Mechanics Symposium

Friday, March 3rd, 2023

Location:

Duke Energy Hall, Hunt Library

Coffee and Conversation	9:30am - 9:45am
Opening Remarks and Keynote Introduction	9:45am - 10:00am
Keynote Seminar	10:00am - 11:00am
Morning Break	11:00am - 11:10am
Session I - Modern Modeling	11:10am - 12:30pm

Galib Muktadir, PhD with Drs. Kowalsky, Proestos, and Ranjithan
Design Optimization of Prestressed Concrete Bridge Girder-Systems

Abdelrahman Elmeliegy, PhD with Dr. Guddati
Multi-Resolution Imaging of Soft Tissue Viscoelasticity

Mrinal Mahanta, PhD with Dr. Gupta
Challenges in Simulation of Impact on Spent Nuclear Fuel Rack

Haritya Shah, PhD with Dr. Guddati
Homogenized Properties of Hepatic Lobule

Lunch	12:30pm - 1:30pm

Session II - Structuring with Composites 1:30pm - 2:30pm

Taylor Brodbeck, PhD with Drs. Seracino and Proestos
Strut-and-Tie Design of Disturbed Regions Utilizing Internal Fiber-reinforced Polymer Reinforcement

Jack Turicek, PhD with Dr. Patrick
Synchronal Toughening and in situ Self-healing of Laminated Fiber-reinforced Polymer Composites

Eman Abdullah, MS with Dr. Lucier
FRP Strengthening of Wall-to-Foundation Joints

Session III - Bridging the Gap 2:30pm - 3:30pm

Ariadne Palma Parra, PhD with Dr. Kowalsky
Multi-directional Seismic Response of Reinforced Concrete Bridge Structures

Rajprabhu Thangappa, PhD with Dr. Seracino
Performance Evaluation of Integral Bridges

Julio Samayoa, PhD with Dr. Kowalsky
Performance of External Socket Connections for Accelerated Bridge Construction in Seismic Regions

Afternoon Break — 3:30pm - 3:50pm

Session IV - Materials for Tomorrow — 3:50pm - 5:10pm

- **Hyunjun Choi, PhD with Dr. Pourghaz**
  Can the Deposition of CaCO3 Increase the Mechanical Properties of Wood?

- **Lucas Maciel de Andrade Lima, PhD with Dr. Hassan**
  Development of a High-temperature Creep Tester for Miniature Cladding Alloy Specimens

- **Francisco Javier Zapata, PhD with Dr. Pourghaz**
  The Effect of ITZ in Transport of Cement-based Materials

- **Zachary Phillips, PhD with Dr. Patrick**
  Opto-vascular Self-healing and Sensing in a Structural Thermoset

Judging/Certificates Break — 5:10pm - 5:30pm

Award Ceremony and Closing Remarks — 5:30pm - 5:45pm

CCEE

Special thanks to our students, faculty, and staff who were involved in the preparation of this event.

We extend compassion to all those affected by the recent earthquakes in Turkey and Syria and hope that our dedication to structural engineering will help mitigate the impact from future natural hazards.

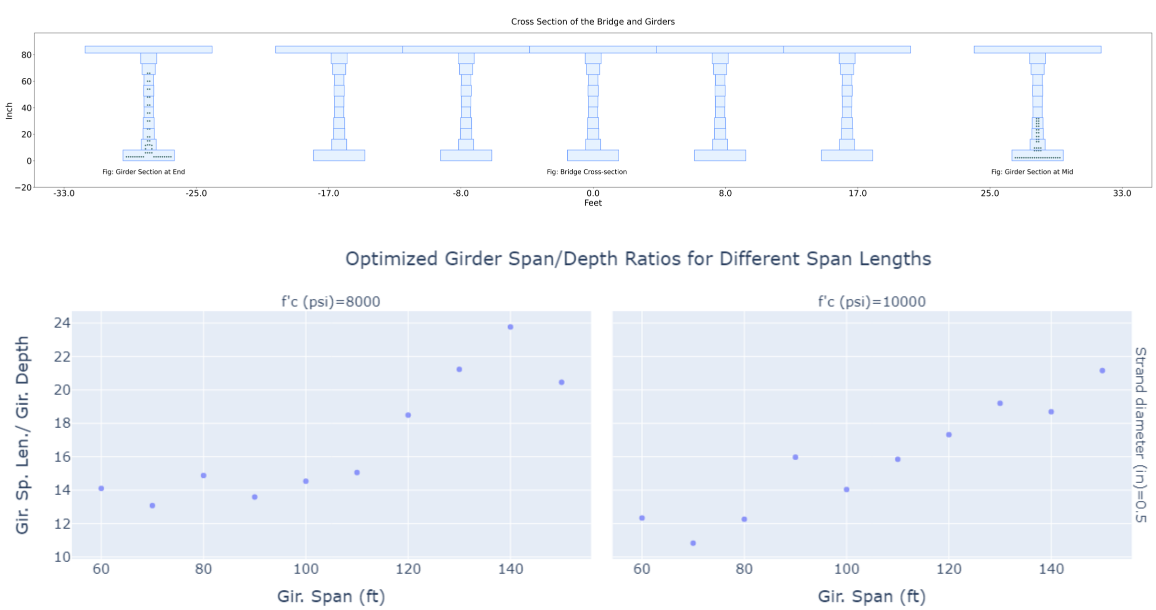
Design Optimization of Prestressed Concrete Bridge Girder-Systems

Muktadir, M.G.[1*], Kowalsky, M.J.[1], Proestos, G.T.[1], Ranjithan, R.S.[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

In the design of bridge structures engineers follow procedures guided by design codes. Traditionally designers use iterative trial-and-error methods to generate effective design alternatives based on their experience, intuition and ingenuity. However, formal optimization approaches are rarely used to identify alternative designs that simultaneously optimize cost, weight or volume of material, structural performance, and other parameters.

The research being presented describes a design optimization tool for prestressed concrete bridge girders that can be used to find optimized girder-system configurations including cross section shapes and reinforcement orientation. The tool implements a metaheuristic search procedure coupled with structural analyses to explore the multi-modal and highly nonlinear solution space of the bridge girder-system. For any defined girder span length and bridge width, the algorithm is capable of systematically and automatically changing the design variables to optimize cost while satisfying the structural performance limits and geometric feasibility criteria. Additionally, the optimization tool can identify a small set of maximally different, near-optimal design alternatives that practicing engineers can develop final designs from. The tool is also useful in providing insights on the inter-relationship between decision variables and design parameters for optimized design of girder-systems.



Sample Outcome from the Optimization Tool: Top figure showing optimized design of a 120 feet span pre-tensioned girder-system; Bottom figure showing span to depth ratio for optimized design of girder-systems for different span lengths.

Keywords (design optimization, prestressed concrete, highway bridge girder, metaheuristic global search algorithm, cost efficient design)

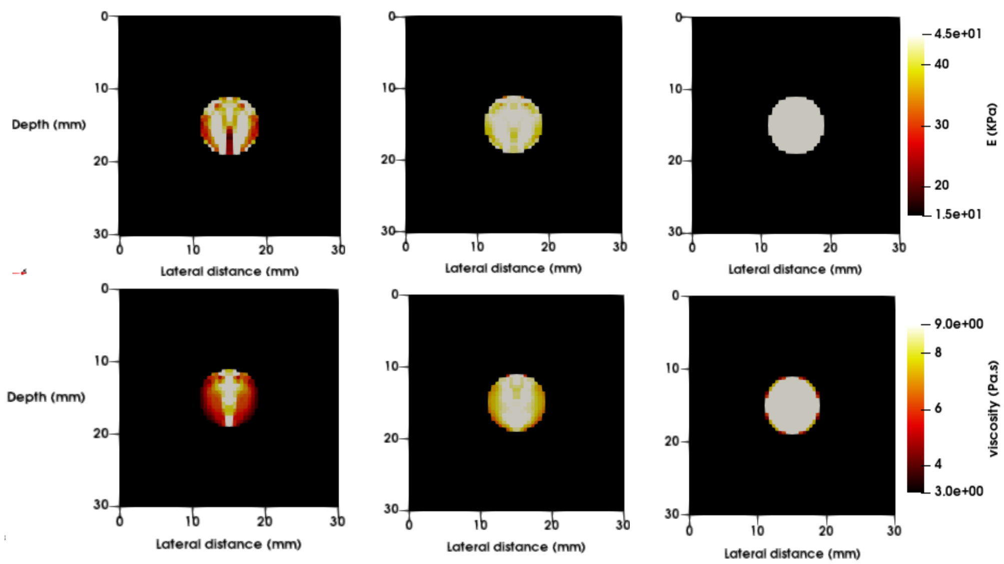
Multi-Resolution Imaging of Soft Tissue Viscoelasticity

Abdelrahman Elmeliegy*, Murthy Guddati

Department of Civil, Construction, and Environmental Engineering (CCEE)
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

Soft tissue elasticity and viscoelasticity are important biomarkers of many diseases including cancer. Shear wave elastography (SWE) is a method of reconstructing elasticity and viscoelasticity maps, by iteratively matching the observed and predicted propagation characteristics of waves generated by acoustic radiation force. Many established reconstruction algorithms are based on idealized wave physics in homogeneous media, resulting in erroneous elasticity maps. Recent methods that better capture the wave physics are limited to estimating the elasticity maps, ignoring tissue viscosity.

In this work, we propose a robust approach to building complete viscoelasticity maps by matching the full wavefield that captures not only the wave propagation but also wave dissipation that is affected by viscosity. Further, in contrast to many existing methods, we utilize (partial) data obtained from single acquisition to invert for the full image of the tumor. Finally, we utilize multi-resolution imaging by sweeping through frequency windows to gradually refine the material property maps. We note that such an approach leads to robust images of not only elasticity but also viscoelasticity of the soft tissue. In this talk, we present the complete setup and detailed formulation of the proposed methodology, as well as several examples illustrating the effectiveness of the approach.



a) Inverted visco-elasticity (without multi-resolution)

b) Inverted visco-elasticity (with multi-resolution)

c) True visco-elasticity map

Elasticity maps (top) and viscosity maps (bottom): (a) without multi-resolution imaging, (b) with multi-resolution imaging and (c) ground truth.

Keywords (Elastography, Ultrasound Imaging, Viscoelasticity, Inverse modeling, Nonlinear Optimization)

NC STATE UNIVERSITY

2023 Structural Engineering and Mechanics (SEM) Symposium

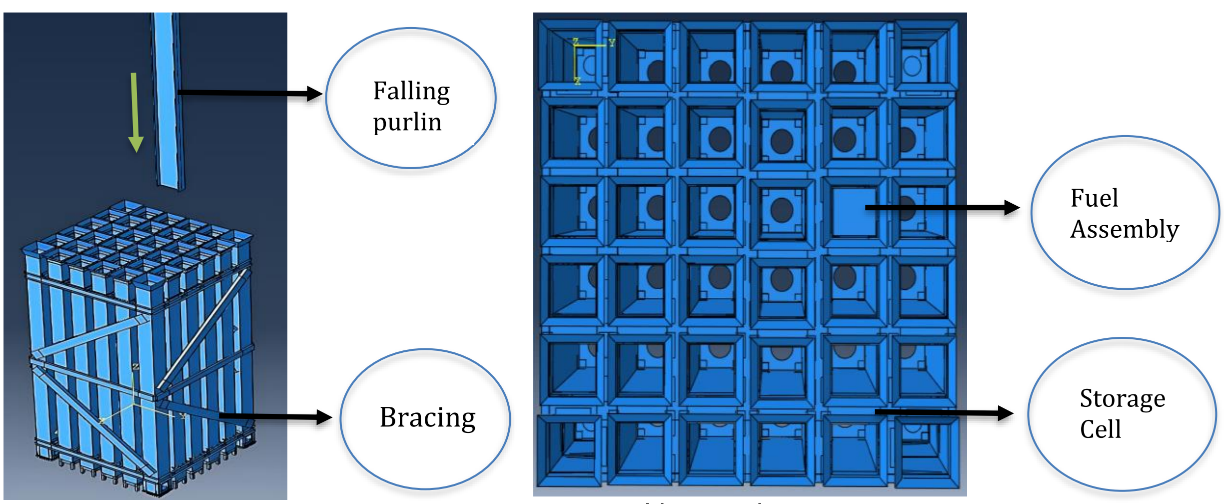
Challenges in Simulation of Impact on Spent Nuclear Fuel Rack

Mrinal Jyoti Mahanta[1], Parth Patel[1], Saran Srikanth Bodda[1], Abhinav Gupta[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

The structural integrity of spent fuel racks in a nuclear power plant is a key safety requirement as it ensures the safe storage and handling of highly radioactive materials. An unexpected impact event, such as a falling purlin from the roof during a tornado, has the potential to cause significant damage to the spent fuel rack and compromise its ability to securely hold the fuel assemblies. This could result in fuel spillage, radiation release, and other safety hazards that pose a threat to both the plant personnel and the surrounding community. The ability to precisely predict the response of the fuel assembly and storage cell to such an impact loading using finite element modeling can be quite challenging. Such a simulation is needed as it provides valuable insights into potential failure modes and assists with design improvements. Furthermore, finite element modeling allows for the exploration of the most critical impact loading scenarios that may not be feasible to study experimentally, offering a more comprehensive understanding of the behavior of the spent fuel rack under varying conditions.

In this study, we aim to gain an in-depth understanding of the response of spent fuel racks under such an impact using detailed finite element analysis. A realistic scenario is simulated, in which a purlin, dislodged from the roof, impacts the spent fuel rack. Moreover, this study outlines certain challenges that need to be considered for accurate finite element modeling. This presentation will also discuss a comparison of the deformed shape of the storage cell as evaluated from the analysis with that observed in an existing experimental study [1].



a) Elevation View b) Top View

graphical abstract title: Spent fuel rack assembly with a falling purlin from the roof

Keywords: Non-linear analysis, Simulation of impact, Plastic buckling, Spent-fuel rack

References

[1] Sobel, L. H., and Newman, S. Z. (1980). “Plastic Buckling of Cylindrical Shells under Axial Compression”. ASME Journal of Pressure Vessel Technology, Vol. 102, Feb. 1980, pp. 40-44.

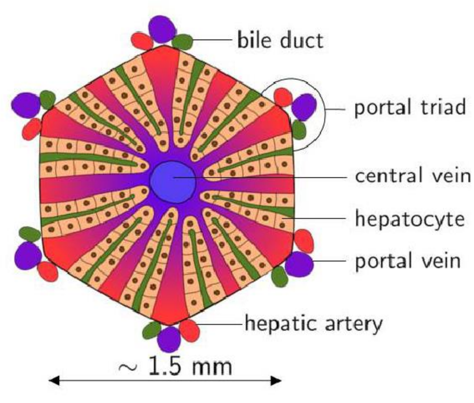
Homogenized Material Properties of Liver and it's relation to histopathology

Haritya Shah[1*], Murthy Guddati[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

Mechanical properties of liver tissue are affected by different pathological processes and histology. Thus, making them important biomarkers, which can used to diagnose different diseases and their progress. For example, shear wave elastography is being widely used by hospitals in Europe to diagnose and track the progression of fibrosis, which is formation of connective tissue due to necrosis and regeneration caused by different histological conditions. However, not enough data exists to effectively use mechanical properties of the liver for a wide range of pathological conditions. Namely, pathological conditions as Non-Alcoholic Fatty Liver Disease (NAFLD) and Non-Alcoholic Steatohepatitis (NASH) do not have significant onset of connective tissue formation inside the liver matrix. They result in the accumulation of fat in macro or micro vesicles inside the hepatocytes or in the interstitial spaces. This results in changes in the viscoelastic properties of the liver matrix.

In this work, we aim to study the changes in the homogenized viscoelastic properties due to histological changes in the liver matrix, such as the accumulation of fat. In contrast to the current approach, which models liver as a homogeneous viscoelastic material, we aim to account for the heterogeneity in the distribution of fat within a hepatic lobule, the basic unit cell of the liver matrix. Then, using the heterogeneous model, we calculate the equivalent properties macro properties through the process of homogenization. In this talk, we present the approach of homogenization and modelling of liver unit cells to capture the effects of tissue level heterogeneity and its effect on the homogenized properties at the macro scale.



Representation of heterogeneity of hepatic lobule (structural unit cell of liver matrix)

Keywords Homogenization, Viscoelasticity, Soft tissue

Strut-and-Tie Design of Disturbed Regions Utilizing Internal Fiber-Reinforced Polymer Reinforcement

T.J. Brodbeck[1*], R. Seracino[1], G.T. Proestos[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

As fiber-reinforced polymer (FRP) reinforcing bars become more widely used as a cost effective and corrosion resistant alternative to traditional steel reinforcement, it is important that practicing engineers are provided with the necessary tools to design structures that utilize internal FRP. The recently published ACI 440.11-22 “Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars – Code and Commentary” struck six of the 27 Chapters of the ACI 318-14 dependent code, including Chapter 23 – Strut-and-Tie Models [1]. In conventionally reinforced structures, strut-and-tie models have been widely used in the design of disturbed regions. Strut-and-tie models more accurately characterize the load transfer in disturbed regions, such as deep beams, and have shown to give reasonable predictions of structural capacity. However, research is needed to establish that designs based on the strut-and-tie method perform adequately in situations where internal FRP reinforcement is used. This presentation summarizes the results of strut-and-tie models from different codes, finite element models created using VecTor2 compared to published results of experimental deep beam tests, and the experimental test matrix developed to address their shortcomings.

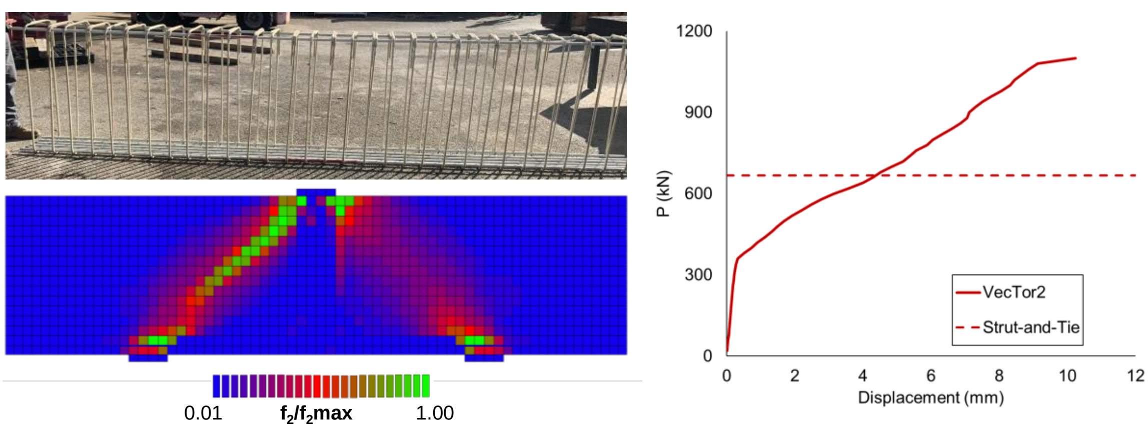


Figure: FRP reinforcement of a deep beam and analytical predictions.

Keywords (reinforced concrete, deep beams, fiber-reinforced polymers)

References

[1] American Concrete Institute, *Building Code Requirements for Structural Concrete Reinforced with Glass Fiber‐Reinforced Polymer (GFRP) Bars*, ACI 440.11, 2022.

FRP Strengthening of Wall-To-Foundation Joints

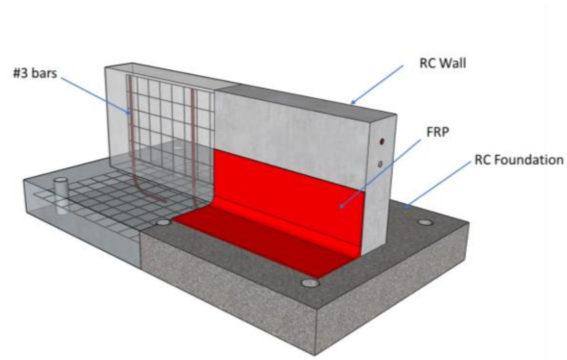
Eman Abdullah[1], Advisor Dr. Gregory Lucier[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

In some buildings, the connection between reinforced concrete shear wall and foundation is deficient and requires strengthening. Literature related to this problem focuses mainly on strengthening the wall itself [1] [2], with few studies strengthening the connection [3]. Our current research aims to study the effects of Fiber-Reinforced Polymer (FRP) strengthening systems on the behavior of wall-to-foundation connections subjected to in-plane loading. The experimental study examines various factors such as the type and configuration of FRP strengthening, the presence and absence of internal steel bars, and the use of fiber anchors. The research was completed in two phases with a total of 10 specimens tested.

The findings show that FRP strengthening can be effective at increasing the load-carrying capacity of the connection when FRP is applied to the full length of one or both sides of the wall. The use of FRP anchors greatly improves the ability of the system to remain bonded under reverse cyclic loads and enables strengthening with partial-length coverage of the connection. Uplift of the wall appears to be a major factor in initiating the debonding failure mode observed with many of the specimens. The study provides a viable proof of concept for fiber strengthening at the wall-to-foundation joint.

Strengthened specimen in the experimental setup



Schematic of the test specimen

Keywords (reinforced concrete, shear wall, connection, FRP, in-plane shear)

References

[1] A. Delnavaz and M. Hamidnia, “Analytical investigation on shape configuration of CFRP strips on lateral loading capacity of strengthened RC shear wall,” Structural Concrete, vol. 17, no. 6, pp. 1059–1070, Dec. 2016, doi: 10.1002/SUCO.201500196.
[2] S. Altin, Ö. Anil, Y. Kopraman, and M. E. Kara, “Hysteretic behavior of RC shear walls strengthened with CFRP strips,” Compos B Eng, vol. 44, no. 1, pp. 321–329, Jan. 2013, doi: 10.1016/J.COMPOSITESB.2012.05.009.
[3] A. Chalot, N. Roy, L. Michel, and E. Ferrier, “Mechanical behavior of a full-scale RC wall-slab connection reinforced with frp under cyclic loading,” Engineering Structures, vol. 239, p. 112146, Jul. 2021, doi: 10.1016/J.ENGSTRUCT.2021.112146.

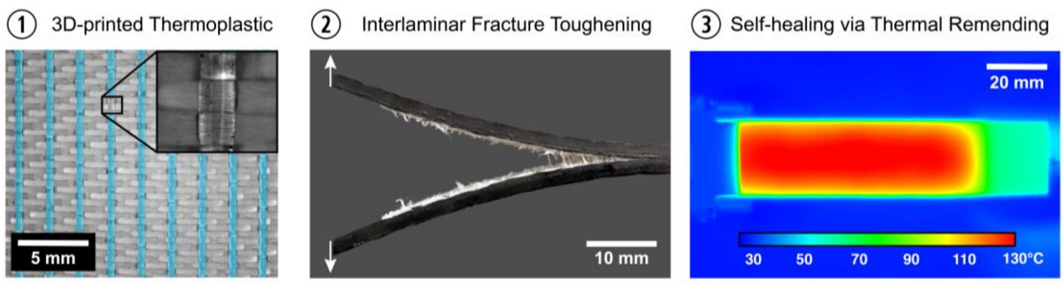
Synchronal Toughening and in situ Self-healing of Laminated Fiber-reinforced Composites via Copolymer Interlayers

J.S. Turicek[1*], A.D. Snyder[1], J.F. Patrick[1,2]

[1] *Department of Mechanical and Aerospace Engineering (MAE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA
[2] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

Fiber-reinforced polymer (FRP) composites are attractive materials for weight-critical applications due to their high specific strength and stiffness. However, the lack of through-thickness reinforcement in laminated FRP composites renders them susceptible to interlaminar delamination (*i.e.,* matrix-fiber debonding). This internal damage is often undetectable and irreparable using conventional techniques, thus remaining one of the most life-limiting factors for composite structures [1].

Here we detail a novel solution to mitigate delamination via proactive toughening by the addition of a 3D-printed poly(ethylene-co-methacrylic acid) (EMAA) thermoplastic interlayer. When damage occurs, embedded textile resistive heaters provide energy for *in situ* self-healing via thermal remending of EMAA [2]. Up to 450% increase in mode-I fracture resistance is achieved compared to an unmodified laminate, with 100% restoration of the enhanced fracture resistance over ten consecutive heal cycles. The addition of the copolymer interlayer has an insignificant effect on the mechanical properties of the composite laminate, with structural integrity maintained during thermal remending that is below the glass transition temperature of the epoxy matrix. The areal density of printed EMAA serpentine patterns is found to govern global toughening/healing performance, while pattern orientation dictates local crack-propagation behavior. The proposed pre- and post-damage mitigation strategy improves structural reliability and increases service lifetime while reducing the overall risk of catastrophic failure.



Concurrent Toughening and Self-healing: (1) 3D-printed thermoplastic enables (2) interlaminar toughening and (3) *in situ* thermal remending when coupled with embedded textile resistive heaters.

Keywords self-healing, 3D-printing, thermal remending, multifunctional

References

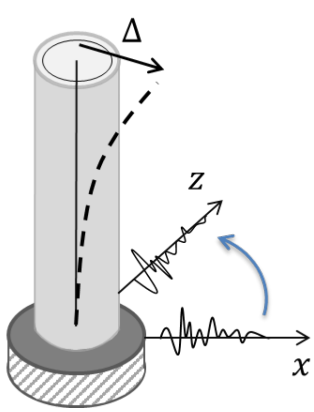
[1] M. R. Wisnom, The role of delamination in failure of fibre-reinforced composites, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*: **370** 1850–1870 (2012).
[2] A. D. Snyder, Z. J. Phillips, J. S. Turicek, C. E. Diesendruck, K. B. Nakshatrala, J. F. Patrick, Prolonged in situ self-healing in structural composites via thermo-reversible entanglement, *Nature Communications*: **13** 1–12 (2022).

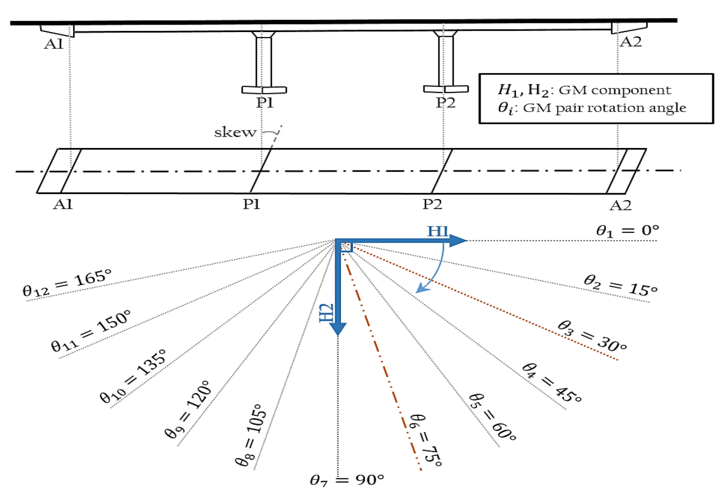
Multi-directional Seismic Response of Reinforced Concrete Bridge Structures

A.L. Palma Parra[1*], M.J. Kowalsky[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE) North Carolina State University (NCSU), Raleigh, NC, 27606, USA*

Recent developments in seismic bridge hazard maps and ground motion directionality motivate the need to assess the implications of directionality on the seismic design and performance of bridge structures. Seismic analysis in engineering practice, as well as research, has mostly focused on conducting separate analyses in each principal direction of the structure (i.e., longitudinal direction and transverse direction of a bridge). However, during earthquakes, bridges are subjected to a multidirectional demand, which does not always align with the principal axes of the structure. This fact, combined with a lack of experimental data, motivates the need to evaluate potential structural modeling approaches and their shortcomings to simulate bidirectional inelastic response of reinforced concrete (RC) structures. To fill this gap, we first need to understand the interaction between the bidirectional demands through experimental research, specifically shake table tests, as well as identify the limitations of various computational approaches. This presentation compares different approaches to model the 3D response of a bridge structure, including the simple case of a RC cantilever column and a RC bridge when subjected to a rotated pair of earthquake motions.





Keywords (ground motion; directionality; bridge design; RC column; structural modeling)

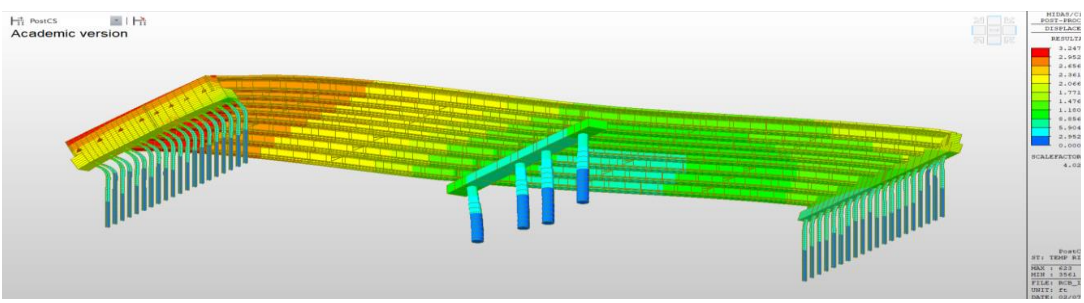
Performance Evaluation of Integral bridges

Rajprabhu Thangappa[1], Rudolf Seracino[1], Amin K Aknoukh[2]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA
[2]*Department of Construction Management*
East Carolina University (ECU), Greenville, NC, 27858, USA

The US Department of Transportation has favored Integral Abutment (IA) bridges for some time now. The North Carolina Department of Transportation (NCDOT) has been building IA bridges since 2006 due to the lower costs for construction and maintenance, which are made possible by monolithically connecting the girder to the end bents without expansion joints or bearings. IA bridges also have a longer service life, better performance, and are easier to construct. However, the NCDOT has encountered some maintenance problems with IA bridges such as minor cracking in the bridge deck, end bent walls, and approach slabs, and settlement of the backfill affecting the approach slab alignment.

To address these observation, this project aims to conduct a thorough investigation of the construction and design practices of IA bridges in North Carolina. To do this, a field monitoring of a prestressed concrete IA bridge has been carried out to gather real-time data. The data collected will be compared to 3-D FEM models built with MIDAS Civil to calibrate the models and further investigate the parameters affecting the bridge performance. The project will also make recommendations regarding geometric limitations of IA bridges, such as length and skew, by determining the appropriate limit states.



Deformation of the instrumented bridge under Positive Thermal load using MIDAS Civil

Keywords Integral abutment bridges, field monitoring, 3-D FEM, parametric investigations

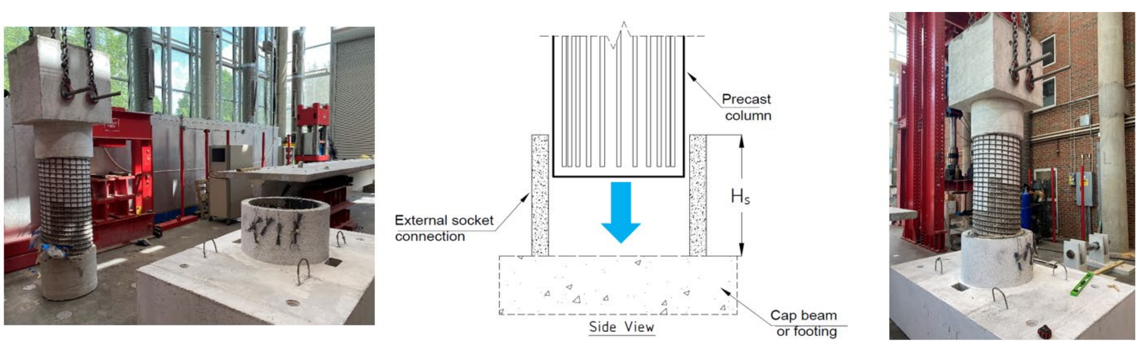
Performance of External Socket Connections for Accelerated Bridge Construction in Seismic Regions

Julio A. Samayoa, Ph.D. Student [1*], Mervyn J. Kowalsky, Ph.D.[1], Giorgio T. Proestos, Ph.D.[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

The use of innovative construction and design techniques such as accelerated bridge construction (ABC) is growing worldwide due to the benefits in total delivery time, improved quality, traffic impact, and reduced on-site construction time. One of the critical aspects of accelerated bridge construction is the design of columns to adjoining member connections. Through an analysis of the existing literature, at least ten variables have been identified that may influence the performance of external socket connections. While some experimental work has been conducted [1, 2, 3], there is limited understanding of the fundamental behavior of socket connections, resulting in little guidance for their design.

Based on a proposed model, it is possible to relate socket height to an applied moment and critical stresses within the connection. To explore the boundaries where the external socket connections are feasible and considering the outputs of the proposed model for different failure modes, three large-scale experiments were performed. The experiments and model have provided a better understanding of the behavior of external socket connections and provides a rational methodology for their design.



Accelerated Bridge Construction Connection: A precast column connected to a foundation using an external socket connection

Keywords: Accelerated Bridge connections, Seismic design, Bridges, Seismic performance, Large-scale test

References

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Can the Deposition of $CaCO_3$ Increase the Mechanical Property of Wood?

H. Choi[1*], L. E. Dalton[2], I. Peszlen[3], M. Pourghaz[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE) North Carolina State University (NCSU), Raleigh, NC, 27606, USA*
[2] *Department of Civil, and Environmental Engineering Duke University, Durham, NC, 27708, USA*
[3] *Department of Forestry and Environmental Resources North Carolina State University (NCSU), Raleigh, NC, 27606, USA*

According to a report published by the United States Census Bureau in 2021, 92% of American homes built that year are made of wood-frame structures [1]. The National Fire Protection Association estimates that property loss from house fires in 2021 was $8.4 billion, with 2,580 reported civilian deaths [2]. Studies have shown that depositing calcium carbonate ($CaCO_3$) in wood can increase its fire retardancy without the use of chemical treatments [3–5]. As wood is an organic anisotropic solid, it is hypothesized that depositing $CaCO_3$ in wood will not only enhance its mechanical properties, but also create an organic-inorganic composite with self-adapting properties. This research examines $CaCO_3$ deposition methods and resulting 3D morphologies using X-ray computed tomography and uses dynamic mechanical analysis to investigate the impact of CaCO3 deposition on the mechanical properties of two types of wood.

(a) (b) (c) (d)

Graphical abstract title: X-ray CT scans of solution-exchange cycled (aqueous $CaCl_2$ + aqueous K_2CO_3) samples: (a) control, (b) 1 cycled, (c) 2 cycled, and (d) 3 cycled.

Keywords Calcium carbonate, Dynamic mechanical analysis (DMA), Thermogravimetric analysis (TGA), Wood, X-ray CT

References

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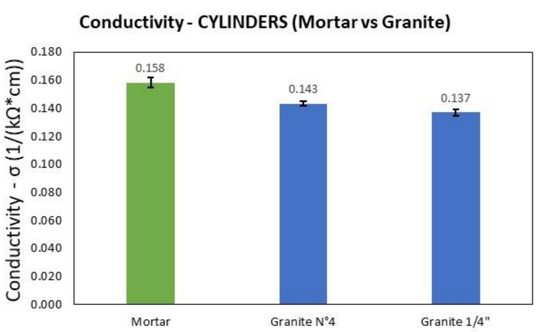
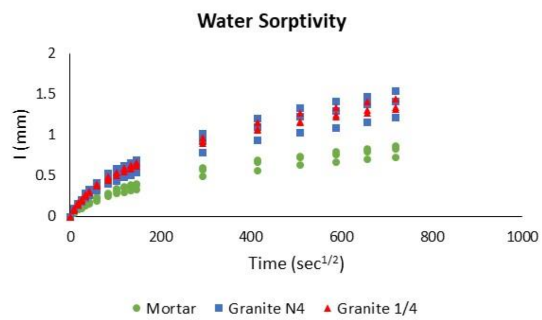
The Effects of ITZ on the transport properties of cement-based materials

Francisco Javier Zapata[1*], Dr. Moe Pourghaz[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

The Interfacial Transition Zone (ITZ) between aggregates and cement paste has been the subject of study by many researchers. Some have suggested that ITZ adversely affects the mechanical and durability properties of concrete while others have suggested ITZ does not influence these properties, leading to ambiguous understanding of the role of ITZ. In this study, samples with identical volume fraction of aggregates but different maximum aggregate sizes were produced, resulting in different volume fraction of ITZ. A series of 10 concrete and mortar mixtures were cast, using ordinary portland cement, with two different water to cement (w/c) ratios, calcium-based (limestone) and silica-based (granite). Standard test method for measuring the rate of absorption was used to evaluate the rate of water sorption. Electrical Impedance Spectroscopy (EIS) was used to evaluate the electrical conductivity of cement-based specimens. In addition, mechanical tests were performed to determine the compressive strength and dynamic elastic modulus through both destructive and non-destructive testing methods. The electrical conductivity results indicate a higher conductivity for mortar than concrete specimens meaning, confirming the presence of a higher volume fraction of ITZ. On the other hand, absorption results indicate a higher water sorptivity for concrete than for mortar, indicating a higher volume fraction of ITZ in concrete.





Keywords: Compressive strength, Electrical methods, Interfacial Transition Zone, Mass transport, Non-Destructive Testing, Sorptivity.

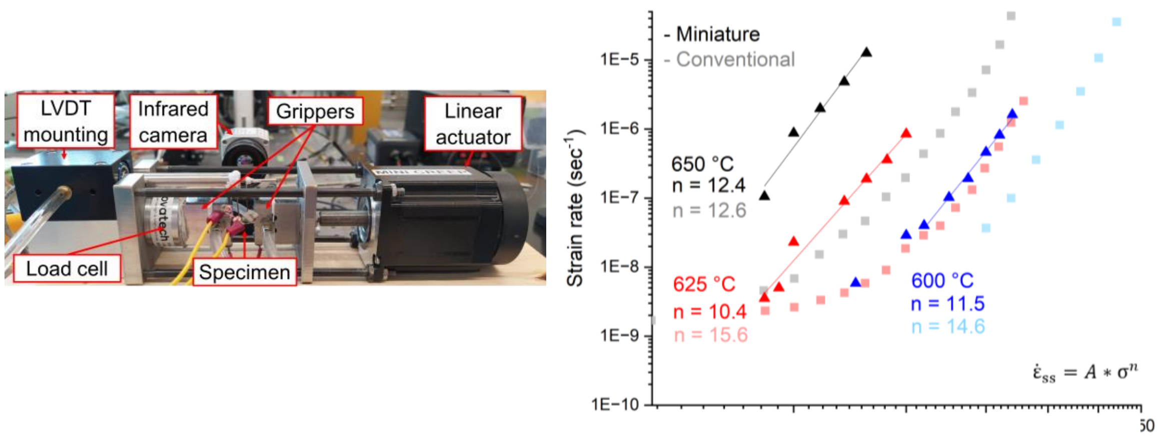
Development of a High-Temperature Creep Tester for Miniature Cladding Alloy Specimen Testing

L.M.A. Lima[1*], T. Hassan[1]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE)*
North Carolina State University (NCSU), Raleigh, NC, 27606, USA

The nuclear industry boosted the development of miniature sample test techniques due to the necessity of developing new alloys for `the cladding of nuclear reactors. These materials are exposed to the reactor fuel and subjected to radiation damage and temperatures up to 1000 °C. The limited amount of material during the development of new alloys and the volume limitations on radiation experiments hinder the use of standard specimens [1]. At these temperature levels, failure by creep mechanisms is critical for the structure's life. However, there is no commercially available test system for creep tests on miniature samples. The systems found in the literature have limitations, such as approximations in the strain measurement and non-uniform temperature profiles [2], [3]. Furthermore, none of the systems can perform in-situ tests inside a scanning electron microscope (SEM) for real-time monitoring of microstructural events.

In this work, we discuss the challenges of the development of a novel high-temperature creep tester that can be used for ex-situ and in-situ tests and present the advantages and disadvantages of such a system. The results of creep tests performed on miniature specimens of alloy Kanthal APMT are compared to the results of standard samples.



Mini Creep test system: the test rig (left) is developed from scratch and used to perform high temperature creep tests on miniature specimens of a cladding alloy.

Keywords: Creep test, miniature specimen, test system development, high-temperature alloys

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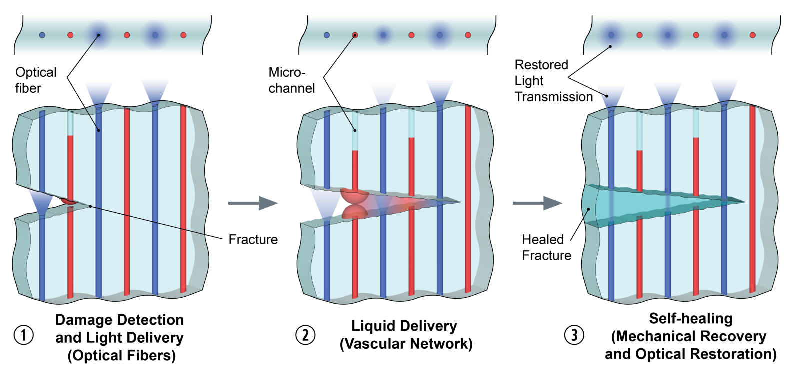
Opto-vascular Self-sensing and Self-healing in a Structural Thermoset

Z.J. Phillips[1*], A.D. Snyder[2], J.F. Patrick[1,2]

[1] *Department of Civil, Construction, and Environmental Engineering (CCEE) North Carolina State University (NCSU), Raleigh, NC, 27606, USA*
[2] *Department of Mechanical and Aerospace Engineering (MAE) North Carolina State University (NCSU), Raleigh, NC, 27606, USA*

The susceptibility of fiber-reinforced composites to brittle fracture undercuts their high specific-strength advantage. Locating and manually repairing internal damage is difficult and costly — often requiring over-engineering to ensure reliability — thus offsetting weight savings. Various self-healing strategies have been proposed to engender self-repair and mitigate fracture before catastrophic damage occurs [1]. Bioinspired vascular healing based on auto-release of reactive agents from hollow conduits hold promise for repairing internal cracks and extending lifetimes of structural polymeric materials. However, difficulties in achieving *in situ* mixing of two-part agents, polymerization times on the order of hours/days, and propensity for flow blockages from cross-contamination are research challenges limiting adoption of this technology [2].

Here we describe the development of a microvascular-based, self-healing and self-sensing thermoset epoxy. This new materials system employs internal micro-channels for fracture-induced liquid photo-chemistry transport to the crack plane, in combination with embedded optical fibers for rapi light-activated healing and damage detection **(Fig. 1)**. The one-part photo-chemistry formulated for visible light (405 nm) polymerization is 50 times faster than existing two-part epoxy/amine chemistries [3,4] and achieves nearly full (~90%) recovery of mode-I fracture toughness. A 660 nm light source, outside photo-chemistry absorption, provides orthogonal and reliable fracture monitoring where optical feedback control renders autonomic repair. This transferable self-healing/sensing implement is well-posed to eliminate routine inspection and manual repair of structures to enhance reliability and resilience.



Opto-vascular self-healing: ① Internal fracture of optical fibers (blue) diverting light and sensing damage; ② Simultaneous rupture of micro-channels (red) releasing one-part liquid photo-chemistry; ③ Photonic energy delivered via fractured optical fibers polymerizes healing agent, restoring mechanical integrity and transmission via index matching.

Keywords (self-healing, microvascular, self-sensing, fiber optics)

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