Use of Fiber-Reinforced Polymer (FRP) Bars in Seismic Design of Building Structures

1. Proposal Information

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Proposal in Response to Nevada DOT, Topic ID #23-07-E2

Proposed Duration: 3 Years (August 01, 2024 – July 31, 2027)

Proposed Budget: $450,900

2. Problem Description

We propose a comprehensive experimental-analytical research program to develop seismic analysis and design guidelines for reinforced-concrete (RC) wall structures with fiber reinforced polymer (FRP) bars. The proposal is designed in direct response to NDOT problem statement ID #23-07-E2 and aims to create scientific knowhow to complete the current knowledge gaps in the literature and to enable advancing ACI CODE-440 toward seismic applications based on NDOT's vision.

The FRP material has emerged as an alternative for producing reinforcing bars (rebars) for RC structures. FRP rebars are noncorrosive and provide a suitable solution for construction of RC structures in highly corrosive environments, e.g., salt storage structures as envisioned by NDOT. Nevertheless, since mechanical behavior of FRP material is different from steel, unique procedure on the analysis, design, and construction of RC structures with FRP rebars is necessary.

Design and construction guidelines for FRP-reinforced concrete (FRP-RC) structures have been established in other countries such as Japan, Canada, and Australia. In U.S., ACI 440 provides general information and guidelines for the design and construction of structural concrete members reinforced with FRP bars, based on the worldwide state-of-knowledge. This guide, however, is limited to non-seismic applications. It, therefore, eliminates FRP-RC applications in most of the western U.S., including virtually most of Nevada, due to the high seismicity of the region. There is a need to advance research and to provide engineering guidelines that can enable application of FRP rebars in seismic design of RC structures.

Through this proposal, we will pursue a systematic research program to address the existing knowledge gaps regarding seismic behavior, failure modes, and design guidelines of FRP-RC structures. The focus will be on wall-type structures, as intended by NDOT, but the research will provide essential knowledge for other types of structural systems, enabling the broader applications that could serve NDOT's other structural needs. *Our unique competency to ensure the success of this project is our team, which is highly experienced in experimental structural mechanics, nonlinear mechanics of RC, and seismic design. We, moreover, benefit from state-of-the-art experimental facilities and experienced staff at the University of Nevada, Reno Earthquake Engineering Laboratories, which will be devoted to the success of this project.*

3. Background Summary

3.1. NDOT Current Practice

NDOT plans to construct at least three RC salt barn/storage structures with more than $12M estimated cost in the near future. Storing salt in humid conditions results in penetration of chloride and sulfate ions inside concrete and accelerated steel corrosion. The oxidized steel expands and leads to concrete cracking and delamination, and further exposure to corrosive materials and freeze-thaw effects, which all result in a rapid deterioration process and substantially reduced lifespan for the structure. The application of FRP rebars would eliminate this concern entirely and, therefore, represents a giant step forward in prolonging the lifespan of RC structures. The capital outlay saved by such an extension in useful life is of substantial value to NDOT.

3.2. Preliminary Literature Review

The application of FRP rebars in RC structural components has attracted attention in recent years. Several experimental and numerical studies have been performed to evaluate the behavior of the FRP-RC structural elements and systems, including culverts, piles, bridge decks, beams, slabs, bridge piers, and columns (e.g., [1]–[9] to name a few). Notably, the focus has been mainly on non-seismic applications until very recently that seismic performance of FRP-RC structural components has also gained some attention.

The stress-strain behavior of FRP rebars has been studied with monotonic (push) and half cycle (push-release) tensile tests for different types of FRP materials (e.g., [10]–[13]). Nevertheless, the tension-compression cyclic behavior and subsequent compression buckling of FRP rebars, which are important to understand ductility limits for seismic applications, has not been studied well in the literature.

The bond-slip behavior of FRP rebars within the concrete matrix has been investigated through experimental studies. Possible governing failure modes and bond strength have been suggested (e.g., [14]–[20]). Although most of the bond-slip tests have been carried out under monotonic loading, only a few studies considered and emphasized on half cycle and reversed cyclic loadings (e.g., [21]–[23]). The results of reversed cyclic tests show that bond-slip behavior of FRP rebars is significantly different under monotonic and cyclic loadings and depends on several factors such as the rebar surface and thread patterns. The FRP bar mechanical and bond-slip rate-dependency is another aspect of behavior that have not been thoroughly investigated while important for dynamic load cases such as seismic loads. Therefore, more experimental studies are needed to evaluate the mechanical and bond-slip behavior of the FRP rebars under reversed cyclic loadings and different loading rates.

The lateral cyclic behavior of flexural-dominated FRP-RC columns (with circular and rectangular cross sections) has been investigated through experimental and numerical studies (e.g., [24]–[28]). According to the test results, the FRP-RC columns with well-distributed longitudinal reinforcement that are laterally supported through closely spaced stirrups show stable hysteretic behavior up to failure. However, the shear behavior of FRP-RC elements under cyclic loading has not been investigated well in previous studies.

The in-plane seismic behavior of FRP-RC walls (slender and squat) has also been investigated through experimental and numerical studies. For instance, Hassanein et al. [29], [30] tested shear walls under quasi-static cyclic loadings, with an emphasis on the configuration of the boundary-element confinement. In another study, the behavior of squat shear walls has been assessed through a series of experimental and numerical investigations [31], [32]. In these studies, the in-plane shear stiffness, and shear and flexural strengths of the squat walls were investigated under quasi-static cyclic tests. Nevertheless, the existing works in the literature mainly present isolated case studies without a comprehensive understanding of the different failure mechanics and performance levels, which is essential for developing seismic analysis and design guidelines.

Due to the growing interest, different guidelines and specifications have been developed to standardize the design and construction of FRP-RC structures. In North America, American Concrete Institute (ACI), the Association of State Highway and Transportation Officials (AASHTO), the Canadian Standards Association (CSA), and the International Code Council (ICC) provide guidelines for design and construction of FRP-RC structures. However, considering the lack of knowledge on the behavior of FRP-RC members under cyclic loading and the system-level energy dissipation capacity of these structures, the existing design guides mentioned above are mainly silent about seismic applications.

The common perception is against the seismic applications of FRP rebars due to their brittle behavior. Nevertheless, the results of recent member-level experimental studies suggest potentially promising seismic behavior of FRP-RC structures. This is because the characteristics of RC members and systems are not fully controlled by the behavior of FRP rebars. In conclusion, a systematic research program is required to address existing knowledge gaps at different scales, from component to structural scales, to enable future seismic applications of FRP-RC structures.

3.3. Knowledge Gaps

As briefly reviewed in the previous section, although valuable research has been performed on the FRP-RC applications so far, several remaining fundamental questions should be answered to enable developing seismic design procedures for these structures. These questions are summarized below and form the basis and logic for the research program outlined in this proposal.

- How does low cycle fatigue affect the behavior of FRP-bars under cyclic loadings?
- What is the compression buckling/failure mechanism of FRP rebars under cyclic loadings?
- What is the shear failure mechanism of FRP rebars under dowel action?
- What is the bond-slip behavior and failure mechanism of commercially available FRP rebars under reversed cyclic loadings and different strain rates?
- How the response behavior and failure modes of flexural- and shear-dominated FRP-RC members is different from traditional RC members? How the design and detailing of FRP-RC members can be adjusted to enhance the member-level displacement ductility and cyclic energy dissipation capacity?
- How the seismic analysis (e.g., as in ASCE-7), design (e.g., as in ACI-440), and detailing guidelines should be adjusted to ensure achieving proper seismic performance-objectives for different FRP-RC structures?

4. Proposed Research

We present a systematic research process to address the knowledge gaps and create engineering knowledge that can be integrated to develop seismic design guidelines for FRP-reinforced concrete structures. The proposed research program includes complementary experimental testing and numerical modeling (see Figure 1). The experimental research is designed to address critical scientific questions from the component-level to member-level behavior, and to provide essential data for building and validating numerical models. Through numerical analyses, we plan to perform extensive parametric studies to understand the effects of different design assumptions on the member- and system-level seismic behavior of the FRP-RC structures. The resulting design assumptions and guidelines will be finally validated through shake-table testing of structural assemblies. This section outlines the proposed work scope where seven research tasks are defined and outlined along with the objective, research process, and expected outcomes for each task.

Different types of FRP bars are commercially available including carbon, glass, aramid, and basalt FRP, while the glass FRP (GFRP) is the most common and cheapest option. The FRP materials in general have a linear elastic behavior with brittle failure in tension. The elastic modulus is comparable with concrete, while the tensile/rupture strength varies among the different material types and manufacturing processes. For the experimental research in this proposal, we plan to focus on the GFRP rebars manufactured commercially in U.S., while other FRP types may also be considered depending on the NDOT's preference. We will focus on the materials that are domestically available to facilitate future application and adoption by NDOT. We will reach out to the handful of U.S. FRP rebar manufacturers and invite them to participate in the research progress, to benefit from their technical and practical knowhow, and moreover, to facilitate the future buy-ins and adoption of the research outcomes by the broader industry.

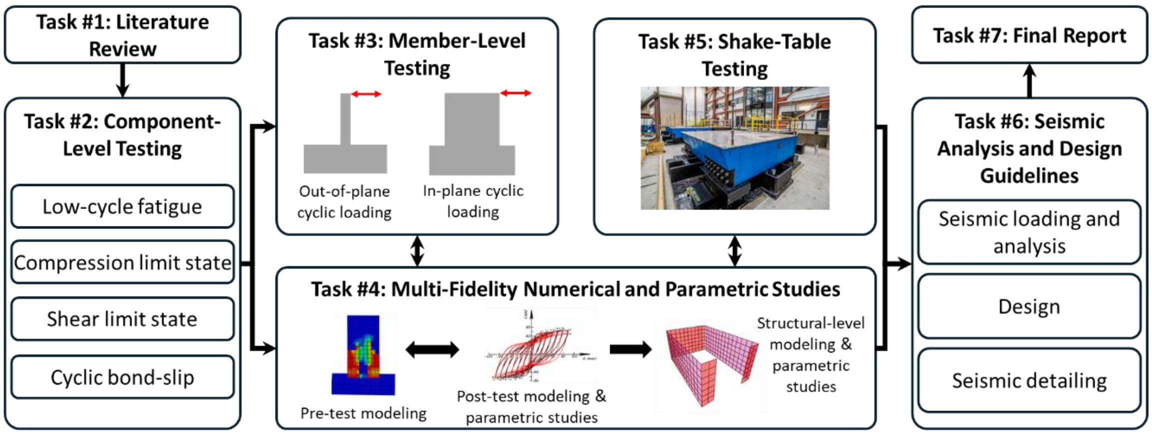

Figure 1: The proposed research includes a systematic experimental-analytical program to address existing knowledge gaps toward developing seismic design guidelines for FRP-RC shear wall structures.

Task #1: Comprehensive Literature Review

Objective: Although we have a fair understanding of the state-of-the-knowledge, in this task we plan to pursue an updated comprehensive literature review to synthesize the relevant research performed in the literature, collect test data, and compile a summary report/publication. The ultimate objective is to use the information and guide the next steps of the project and avoid duplication of research.

Methodology: The graduate student in charge of the project will be guided and tasked with performing a thorough literature review. The existing scholarly works will be reviewed and categorized based on objectives, application, research approach, and quality. We will, furthermore, communicate with the corresponding researchers – both nationally and internationally – to collect relevant available research data and metadata to the extent necessary for the proposed study. The project PIs will work with the graduate student to compile the information into useful knowledge that can be summarized to inform the following experimental tasks of the project.

Deliverables include a state-of-the-art review report that will be shared with NDOT and published as part of the project outcomes.

Task #2: Component-Level Testing

Objective: The component-level testing is focused on the response behavior of FRP rebars as pertain to seismic loading in RC structures. Here we plan to pursue an experimental campaign to investigate the following knowledge gaps: (1) the potentials of low-cycle fatigue in FRP rebars under cyclic tensile loadings; (2) compression limit state of FRP rebars under cyclic tension-compression loadings; (3) shear limit state of FRP rebars under cyclic loadings for dowel action; and (4) bond-slip behavior of FRP rebars in concrete under cyclic tension-compressions loading. Different strain rates will be considered for the relevant mechanical testing to complete the understanding pertaining to dynamic loadings such as earthquakes.

Methodology: Four different experimental programs will be pursued through this task as explained below. Each program will address a specific question that will affect the seismic response behavior of FRP-RC structures and the consequent design process.

Task 2.1 – Low-cycle fatigue under cyclic tensile loadings: We will use an Instron Universal Testing Machine (UTM) to test FRP rebar samples under cycles of tensile loading and unloading with large stress amplitude varying between 50%-90% of the tensile strength. Each test will be repeated multiple times depending on the results. The objective is to observe if the material strength and/or stiffness can be affected under cyclic loadings. The hypothesis is that as the material is loaded, the small imperfections in the bonding agent and fibers will result in micro-level debonding and ruptures that propagate upon subsequent loading cycles, resulting in premature failure. The tensile strength after cyclic loadings will be compared with samples that are monotonically pulled until failure. The so called "low-cycle fatigue" is a critical issue that determines the design strength limits for the material under seismic loading. Moreover, the variability of the material strength under monotonic tests will be used to evaluate the current suggested values for the strength reduction ϕ-factor.

Task 2.2 – Compression limit state under cyclic loading: This task is focused on understanding the failure limit state in tension-compression loading cycles. Since the elastic modulus of FRP material is comparable with the concrete, FRP-reinforced flexural concrete members usually experience earlier and more extensive spalling under cyclic loading compared to steel-reinforced counterparts. This will result in loss of lateral support and potential compression buckling of the longitudinal FRP rebars within the lateral bar spacings. Unlike steel rebars, FRP bars will likely disintegrate under cycles of tension-compression loading.

Here, we will again use UTM to test FRP rebar samples with different lengths under cycles of tension-compression loading at different target displacements. By processing the results, we will conclude the failure mechanism of FRP rebars in compression. The findings will be used in the next steps to guide the lateral reinforcement spacings and to develop member- and structural-level displacement ductility capacity for seismic design.

Task 2.3 – Shear limit state under cyclic loading: In this task, we will focus on the dowel-action behavior of the FRP rebars and their potential failure mechanism. Upon large-amplitude cyclic loading of shear- and/or flexural-dominated RC members, the longitudinal rebars bridge the concrete cracks as they open and limit the widening gaps. The shear-load transfer capacity in the rebar is a critical mechanism that prevents failure and enables life-safety performance of RC structures after large seismic events. The shear behavior of FRP rebars for dowel action has not been studied before and will be investigated in this task. For this purpose, we will design a specific test fixture to load the rebars in shear. The fixture will be installed in one of the available UTMs in our lab. Different rebar sizes will be tested to understand the shear failure mechanism and limit state. The findings will be used in the next steps to guide the lateral reinforcement design and spacing and to develop displacement ductility capacity at the member- and structural-levels.

Task 2.4 – Bond-slip under cyclic loading: While the bond-slip behavior of the FRP rebars have been studied under monotonic as well as loading-unloading cycles, the cyclic tension-compression bond-slip behavior of FRP rebars has not been extensively studied. The thread configuration and strength of FRP rebars is different from steel rebars. In this task, we will design a test fixture based on state-of-the-art methods in the literature (e.g., the beam-end test [33]). Different rebar sizes with different thread and surface conditions will be tested under variable concrete strength and confinement. The design of the test fixture and experimental parameters in this task will be decided based on the literature review outcomes of Task #1. The findings will be used to guide the anchoring mechanism of FRP rebars at the end zones, and to suggest specific seismic detailing.

Deliverables: An interim progress report will be prepared and submitted to NDOT after the completion of the component-level experimental campaign. NDOT comments on the findings will be sought and practical implications of the findings will be noted. We will, moreover, publish the outcomes in reputable peer-reviewed journals, and present at conferences and committee meetings as in ACI Conventions for example, to disseminate the new knowledge while soliciting feedback from the broader technical and scientific communities to enable future adoption of the research outcomes.

Task #3: Member-Level Testing

Objective: While the component-level testing provides insights into the key failure mechanisms of the FRP rebars inside concrete matrix, the integrated member-level response behavior of the FRP-RC subassemblies needs to be investigated. The resulting data will be essential to investigate the system-level response and failure mechanism and to calibrate and validate numerical models that will be used in the next step for further parametric studies.

Methodology: Here, we plan to perform two types of tests to explore the flexural (out-of-plane) and shear (in-plane) responses of wall-type FRP-RC subassemblies under quasi-static cyclic loadings as explained below. The tests will capture the general features of structures used in salt barns and storage buildings. Preliminary designs of the test specimens will be presented to NDOT, and feedback will be sought. The models will be modified based on the feedback as necessary.

Task 3.1 – Flexural (out-of-plane) cyclic loading of wall members: We propose to build cantilever beam/wall members and test under quasi-static cyclic loadings to understand the main failure mechanism of FRP-RC flexural members. One or two specimens will be built and tested with different configurations to be decided. The specimens will be heavily instrumented with load cells, strain gauges, linear variable differential transformers (LVDTs), and cameras, and will be loaded under several out-of-plane push-pull cycles until failure. The measured responses will be processed to correlate different observable failure modes to the level of force, rebar strain, and section curvature. The data will be valuable to understand the internal distribution of forces, different seismic performance levels, and failure mechanisms.

Task 3.2 – Shear (in-plane) cyclic loading of wall members: Similar to the previous task, wall members will be tested under cyclic quasi-static loading to investigate in-plane shear behavior and failure mechanisms. One or two specimens will be tested – details will be decided based on the findings of previous research steps and will be consulted with NDOT.

Deliverables: An interim progress report will be prepared and submitted to NDOT after the completion of the member-level experimental campaign. The tests and measured data will be processed, documented meticulously, and stored to become available for possible future NDOT use. The outcomes of the experimental campaign will be published in reputable peer-reviewed journals and will be presented at ACI conventions and conferences to enable future adoptions of the research outcomes to advance ACI design guides.

Task #4: Multi-Fidelity Numerical and Parametric Studies

Objective: The experimental tests need to be accompanied with extensive numerical analyses to enable parametric studies beyond the limited test cases. Thus, Tasks #3 and #4 will be running in parallel such that each test protocol will be designed through "pre-test modeling," which will be further calibrated and validated using collected experimental data in high-fidelity "post-test modeling" phase. The process will result in a reliable modeling framework that can then be used to study the effects of other design parameters not considered in the tests. We will then use the experience to develop refined models of FRP-RC structural assemblies and systems to answer critical questions regarding seismic analysis (e.g., response modification *R*-factor), seismic design (e.g., ultimate strength methods), and seismic detailing.

Methodology: Here, we will pursue high-fidelity pre- and post-test modeling to study the effects of different design and detailing assumptions. The experience will then be used to develop structural models to perform parametric studies and inform seismic analysis and design guidelines. The suggested guidelines will be validated through shake table testing in the next task.

Task 4.1 – High-Fidelity Pre-Test Modeling: Each of the tests in Task #3 will be designed and studied *a-priori* through pre-test models. We will use refined finite element (FE) models with continuum elements using advanced simulation platforms such as LS-DYNA [34] to explore the response sensitivities to different design parameters. This will inform the most informative specimen designs and test protocols.

Task 4.2 – High-Fidelity Post-Test Modeling and Parametric Studies: The pre-test models include inherent sources of uncertainty, variability, and error. After collecting experimental data, we will calibrate our pre-test models, reduce the uncertainties in the material models, and investigate and enhance the various sources of error in the modeling assumptions and procedure. The outcome will be a validated modeling platform that can be used for parametric studies at the member- and subassembly-levels to guide the phenomenological structural-level modeling in the next step.

Task 4.3 – Structural-Level Modeling and Parametric Studies: In this step, we will build structural models of shear-wall building structures representing NDOT's salt barns and storages and investigate the seismic behavior of the systems under earthquake excitation. Through this process, we will study the failure mechanism, energy dissipation capacity, seismic performance levels, and the effects of different design parameters. The outcomes will be utilized to develop preliminary seismic analysis and design guidelines for FRP-RC structures for future NDOT use.

Task #5: Shake-Table Testing

Objective: While the proposed research in Tasks #1-4 provides fundamental scientific knowledge on the seismic behavior of FRP-RC structures and proposes guidelines on the seismic analysis and design process, the proposed guidelines need to be validated through a structural-level shake table testing. The shake table test will validate the system-level performance and the proposed guidelines toward achieving the seismic design targets set forth by the current practice.

Methodology: We will design one reduced-scale structural assembly to be tested on one of the shake tables at the UNR Earthquake Engineering Laboratory incrementally under increasing seismic intensities with ground motion input ranging from serviceability, and design, to maximum credible earthquake levels. The specimen will be designed based on the preliminary seismic analysis and design guidelines developed in the previous tasks. The specimen design and test protocols will be decided through pre-test models built on the collective outcomes of the previous tasks and will be consulted with NDOT. The specimen will be heavily instrumented, and the collected data will be used to further validate the modeling schemes developed in the previous task and the preliminary seismic analysis and design guidelines.

Deliverables: An interim progress report will be prepared and submitted to NDOT after the completion of the shake table test. The tests and measured data will be cleaned, documented meticulously, and stored to be shared with NDOT. The outcomes of the shake table test along with accompanied numerical studies will be published in peer-reviewed journals.

Task #6: Seismic Analysis & Design Guidelines

This task is focused on processing all the research outcomes to summarize seismic analysis, design, and detailing guidelines that can be used by NDOT and shared with code committees such as ACI 440. The proposed guidelines will be accompanied with step-by-step illustrative design examples that NDOT engineers can use in future design of salt-barns and storage structures. Upon NDOT review of the work and feedback, we will effectively work with the ACI 440 committee to share the research outcomes and address any remaining questions and concerns toward updating the existing guidelines and design practices with the new knowledge for seismic applications.

Task #7: Final Report

While interim progress reports will be prepared and shared with NDOT at the conclusion of Tasks #1, #2, #3, and #5, we will compile the whole research process and findings into a final draft report that will be submitted to NDOT for review and comments. The comments and other issues important to NDOT will be addressed, and the report will be finalized and submitted to NDOT. The final report will, moreover, study potential implementation costs of FRP in RC structures for NDOT, including material cost, equipment, and construction staff training. The objective is to provide actionable information for NDOT management to make informed decisions on the adoption and application of FRP-RC structures in future.

5. Data Management and Dissemination

All project data including raw and processed experimental data, computer codes, FE model input files, resulting data related to verification and validation studies, and publications, presentations, and reports will be archived redundantly through cloud storage and external hard drives. The data will be stored with extensive instructions in data memo to ensure accessibility and usability by NDOT staff and engineers. We recognize and respect the benefits of freely sharing the data products with the research community, as well as archiving data in a format that provides maximum interoperability between our team as well as outside users. Public release of data will take place immediately after publication of the related results in peer-reviewed journals, which will take place in a timely manner.

6. Urgency and Anticipated Benefits

Different studies have been devoted to predicting service life of RC in corrosive environments. Depending on the environmental conditions, concrete material mix, reinforcement detailing, and loading conditions, the effective useful life of RC – defined as the time required for penetration of chloride ions to the depth of reinforcement matrix at a threshold concentration – can be 10 to 30 years in corrosive environments [35]. Considering a normal lifespan of 60 years, it can be concluded that corrosive environments can reduce the lifespan of RC structure by 50% or more. NDOT plans to invest more than $12M to build three RC salt storage structures. Based on the provided simple logic, NDOT can save at least $12M or more in the next 30-60 years on these structures by adopting FRP-RC design practices. Nevertheless, the overall benefits of this research to the broader civil engineering industry, both nationally and internationally, is much more than these numbers as the research aims to develop guidelines that enable seismic application of FRP-RC structures. This can enable construction of corrosive-resistant critical civil infrastructure in seismically active regions across U.S., which enhances the durability and return-on-investment in new constructions. Moreover, the collaboration with U.S. FRP rebar manufacturers enables the introduction of new markets to the domestic producers. In summary, the research will be pioneering in advancing the resilience and durability of our infrastructures and increase U.S. economic competency by developing and spearheading new engineering knowledge.

7. Implementation Plan

Nevada is a growing state, and with the recent infrastructure bill and U.S. administration investment, many new civil infrastructures are likely to be constructed in Nevada in the next decade. As such, there will be implementation opportunities of the proposed research outcomes in actual new salt barn/storage and other structures across the state. Nevertheless, the research results from the proposed study will be at Stage 2 (Laboratory Prototype Stage) but will help NDOT get through Innovation Stages 3 and 4. The results will be translated into step-by-step design procedures and examples to help facilitate their implementation by NDOT in design of new barn and storage structures. Task #6 described in the Proposed Research will provide the seismic design guidelines, and the final report in Task #7 will include evaluation of the potential implementation costs to make future applications possible.

Another major aspect of facilitating future implementation of the results of this project is our representation at the ACI to join the efforts of ACI Committee 440 such that the research outcomes can make their way to the future ACI 440 design guides. Co-PI Moustafa is an active ACI member and has been working with several ACI committees, such as ACI 239 on ultra-high-performance concrete, to develop ACI design guides. This expertise and capacity will be leveraged to ensure a seamless outreach to the FRP-concerned ACI community in general and ACI 440 committee, in particular. A successful pathway for integrating seismic design guidelines of FRP-RC structures is another means of facilitating future implementation.

8. Project Schedule

The project will support one postdoctoral scholar and one Ph.D. student. The technical, budgetary, and timeline of the project will be supervised and managed by the project PIs. The project is expected to take three years to complete. The proposed project timeline is shown in Table 1.

Table 1: Project schedule.

Tasks	Y1 (2024)		Y2 (2025)				Y3 (2026)				Y4 (2027)	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Task 1: Literature Review	■											
Task 2: Component-Level Testing		■	■									
Task 3: Member-Level Testing				■	■							
Task 4: Numerical Studies				■	■	■	■	■	■	■		
Task 5: Shake Table Testing						■	■	■				
Task 6: Design Guidelines									■	■	■	■
Task 7: Final Report												■

9. Facilities and Expertise

Research Team: The project will be directed by Dr. Ebrahimian (PI) in collaboration with Dr. Moustafa (Co-PI) and Dr. Saiidi (Co-PI). The resumes for the PIs are included in an appendix, and a brief overview of PIs expertise is provided here.

Dr. Ebrahimian has extensive experience in nonlinear mechanics of RC, computational structural mechanics, methods for integrating experimental data with computational models, as well as large-scale experimental testing including shake table tests. He has several years of structural design and consulting experience before joining UNR. Dr. Ebrahimian has more than 70 published journal and conference papers, and research reports. Dr. Moustafa's relevant expertise is in multi-scale experimental testing of advanced construction materials and structural systems as well as computational finite element modeling of RC structures. Dr. Moustafa has about 15 years of experience in structural and earthquake engineering research and has published more than 90 journal and conference papers. Dr. Saiidi is a world-renowned earthquake engineer and researcher with extensive experimental and analytical experience in RC structural systems. Dr. Saiidi has over 40 years of experience in earthquake engineering research and has published more than 500 technical papers and reports. His projects have been funded by NSF, FHWA, NCHRP, NDOT, Caltrans, and WashDOT.

Research Facilities: The current structural testing facility at UNR consists of two labs: (a) Large-Scale Structures Laboratory (LSSL), which is 150' by 56' (45m by 17m) in plan; (b) Earthquake Engineering Laboratory (EEL), which is 120' by 80' (36m by 24m) in plan. This study is planning to use the LSSL to conduct mechanical characterization and member-level testing. Several UTMs are available and will be used in this project including an Instron 50 kips machine and an MTS 500 kips machine for the cyclic testing and bond-slip tests of FRP bars. Ten hydraulic actuators and several jacks are available and capable of delivering a range of forces and displacement strokes up to 700 kips and +/- 24 inches, respectively. The lab is equipped with strong floor and reaction walls besides a large number of modular reinforced concrete blocks with 4'x4'x8' (1.2m x 1.2 x 2.4m) dimensions to allow for large- and full-scale testing of structural members and walls as desired for this project. Two 25-ton overhead cranes in the LSSL allow for the handling of large specimens. The shake table tests will be conducted at the EEL, which is one of the world's most renowned earthquake engineering laboratories. The EEL is equipped with four large shake tables that include three identical bi-directional MTS shake tables. One of those shake tables will be used in Task #5 of this project for the final stage of the proposed experimental testing. Our labs own three different National Instrument data acquisition systems that collectively provide over 400 instrumentation channels of force, displacement, and strain data for both static and dynamic tests.

10. NDOT Champion, Coordination, and Involvement

We plan to have regular (once or twice a year) progress meetings with NDOT champions and technical staff to provide updates on the research progress and collect feedback. No other specific commitment is expected from NDOT. Throughout the project, we will establish connection to the U.S. manufacturers of FRP rebars to engage them through the research process as the industry steering committee. Moreover, we will engage with ACI 440 committee to integrate their technical feedback within the research process and facilitate the future adoption of research outcomes. NDOT project champions include:

- Ross Baker, Assistant Chief Maintenance Engineer, Architecture
- Jessen Mortensen Chief Structural Engineer, Structures
- Nathan Morian Administrator 1 PE, Maintenance & Asset Management
- Pete Schmalzer Administrator 1 PE, Materials

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Hamed Ebrahimian, Ph.D., P.E.
Assistant Professor, Department of Civil and Environmental Engineering
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Education

University of California, San Diego, CA

2015	Ph.D., Structural Engineering
2013	M.S., Mechanical Engineering (Dynamic Systems and Control)

Shiraz University, Shiraz, Iran

2006	M.S., Structural Engineering (Summa Cum Laude)
2004	B.S., Civil Engineering (Summa Cum Laude)

Appointments

Assistant Professor, University of Nevada, Reno, NV (*tenure-track)*	2019 - Present
Senior Engineer, SC Solutions, Sunnyvale, CA	2017 - 2019
Scientific Research Assistant, Caltech, Pasadena, CA	2017
Postdoctoral Scholar, Caltech, Pasadena, CA	2015 - 2017
Graduate Student Researcher, UC San Diego, CA	2010 - 2015
Founding Principal, In Responsible Charge, Ebrahimian Structural Engineers, Shiraz, Iran	2008 - 2009
Freelance Consultant and Structural Designer, Shiraz, Iran	2004 - 2007

Research Experience

- PI/Co-PI on 13 funded research projects in past 5 years (about 6.3 million USD in funding) sponsored by federal and state agencies and private sector (e.g. NSF, DOE, USGS, FHWA, Charles Pankov Foundation) in the areas of computational modeling, data analytics, digital twinning, and structural mechanics.

Certifications

- Professional Civil Engineer (P.E.), License # C84371, Board for Professional Engineers, Land Surveyors, and Geologists, CA, USA (Since 2015).

Selected Relevant Publications

1. M. Vahedi, S. ZolfagharySaravi, **H. Ebrahimian**, M.S. Saiidi, "Experimental-Analytical Investigation of Accelerated Bridge Construction Concrete Columns with Self-Centering Fe-SMA Bars Subjected to Near-Fault Ground Motions," *Engineering Structures*, 2024, 299, 117127, https://doi.org/10.1016/j.engstruct.2023.117127.
2. M. Vahedi, **H. Ebrahimian**, A. Itani, "Full-Scale Testing and Analytical Modeling of Rebar Cages Reinforced with Mechanical U-Bolt Connectors," *Applied Science*, 2023, 13(14), 8113, https://doi.org/10.3390/app13148113.
3. A.J. Romero, M.A. Moustafa, M.S. Saiidi, **H. Ebrahimian**, "Shake Table Testing of Out-of-Plane Response of Repaired Bridge Subassembly with Simplified ABC-Inspired Cast-in-Place Joints," *Engineering Structures*, 2023, 285, 116064, https://doi.org/10.1016/j.engstruct.2023.116064.
4. M. Vahedi, **H. Ebrahimian**, A. Itani, "Experimental Investigation of U-Bolt Connectors for Application in Rebar Cages," *ASCE Journal of Structural Engineering*, 2022, 149(1), https://doi.org/10.1061/JSENDH.STENG-11381.
5. F. Ghahari, N. Malekghaini, **H. Ebrahimian**, E. Taciroglu, "Bridge Digital Twinning Using an Output-Only Bayesian Model Updating Method and Recorded Seismic Measurements," *Sensors*, 2022, 22(3), 1278, https://doi.org/10.3390/s22031278.
6. R. Astroza, J.P. Conte, J.I. Restrepo, **H. Ebrahimian**, and T.C. Hutchinson, "Seismic Response Analysis and Modal Identification of a Full-Scale Five-Story Base-Isolated Building Tested on the NEES@UCSD Shake Table," *Engineering Structures*, 2021, 238, 112087, https://doi.org/10.1016/j.engstruct.2021.112087.

7. **H. Ebrahimian**, R. Astroza, J.P. Conte, and R.A. de Callafon, "Nonlinear Finite Element Model Updating for Damage Identification of Civil Structures using Batch Bayesian Estimation," Special issue on Nonlinear System Identification, *Mechanical Systems and Signal Processing*, 2017, 84(B), 194–222, https://doi.org/10.1016/j.ymssp.2016.02.002.
8. **H. Ebrahimian**, R. Astroza, J.P. Conte, and T.C. Hutchinson, "Pre-Test Nonlinear Finite Element Simulation of Five-Story Reinforced Concrete Building Tested on the UCSD-NEES Shake Table," *ASCE Journal of Structural Engineering*, 2018, 144(3), https://doi.org/10.1061/(ASCE)ST.1943-541X.0001963.
9. M.C. Chen, E. Pantoli, X. Wang, R. Astroza, **H. Ebrahimian**, T.C. Hutchinson, J.P. Conte, J.I. Restrepo, C. Marin, K. Walsh, R. Bachman, M. Hoehler, R. Englekirk, and M. Faghihi, "Full-scale Structural and Nonstructural Building System Performance During Earthquakes: Part I – Specimen Description, Test Protocol and Structural Response," *Earthquake Spectra*, 2015, 32(2), 737–770, https://doi.org/10.1193/012414eqs016m.
10. E. Pantoli, M.C. Chen, X. Wang, R. Astroza, **H. Ebrahimian**, T.C. Hutchinson, J.P. Conte, J.I. Restrepo, C. Marin, K. Walsh, R. Bachman, M. Hoehler, R. Englekirk, and M. Faghihi, "Full-scale Structural and Nonstructural Building System Performance during Earthquakes: Part II – NCS Damage States," *Earthquake Spectra*, 2015, 32(2), 771–794, https://doi.org/10.1193/012414eqs017m.

Other Selected Publications

1. M. Song, N. Partovi-Mehr, B. Moaveni, E. Hines, **H. Ebrahimian**, A. Bajric, "One Year Monitoring of an Offshore Wind Turbine: Variability of Modal Parameters to Ambient and Operational Conditions," *Engineering Structures*, 2023, 297, 117022, https://doi.org/10.1016/j.engstruct.2023.117022.
2. N. Malekghaini, F. Ghahari, **H. Ebrahimian**, M. Bowers, H. Azari, E. Taciroglu, "Time-Domain Finite Element Model Updating for Operational Monitoring and Damage Identification of Bridges," *Structural Control and Health Monitoring*, 2023, 4170149, https://doi.org/10.1155/2023/4170149.
3. M. Song, B. Moaveni, **H. Ebrahimian**, E. Hines, A. Bajric, "Joint Parameter-input Estimation for Digital Twinning of the Block Island Wind Turbine using Output-only Measurements," *Mechanical Systems and Signal Processing*, 2023, 198(1), 110425, https://doi.org/10.1016/j.ymssp.2023.110425.
4. M-S. Nabiyan, M. Sharifi, **H. Ebrahimian**, B. Moaveni, "A Variational Bayesian Inference Technique for Model Updating of Structural Systems with Unknown Noise Statistics," *Frontiers in Built Environment*, 2023, 9, https://doi.org/10.3389/fbuil.2023.1143597.
5. N. Malekghaini, F. Ghahari, , **H. Ebrahimian**, M. Bowers, E. Ahlberg, E. Taciroglu, "A Two-step FE Model Updating Approach for System and Damage Identification of Full-Scale Prestressed Bridge Girders," *Buildings*, 2023, 13(2), 420, https://doi.org/10.3390/buildings13020420.
6. **H. Ebrahimian**, R. Astroza, and J.P. Conte, "Extended Kalman Filter for Material Parameter Estimation in Nonlinear Structural Finite Element Models using Direct Differentiation Method," *Earthquake Engineering and Structural Dynamics*, 2015, 44(10), 1495–1522, https://doi.org/10.1002/eqe.2532.

Selected Synergistic Activities

1. Editorial board member, Fire Journal, MDPI (Since 2022).
2. Chair (Since September 2023), former Vice Chair (2020-2023), and former Chair of Student Paper Competition (2018-2020), ASCE EMI Dynamics Committee.
3. WRF-Fire Wikipage publicly available at https://unr-wrf-fire.readthedocs.io/en/latest/index.html [January 2023].
4. Stakeholder Listening Workshop for Wildfire Technology Needs, University of Nevada, Reno, January 2022: About 20 local stakeholders and problem-owners engaged in a one-day workshop to discuss the research and technology development needs in wildfire management.

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Education

University of California, Berkeley, CA

2014 Ph.D., Civil and Environmental Engineering
Major: Structural Engineering, Materials and Mechanics (SEMM)
Minors: Computational Mechanics, Statistics
2014 Certificate, Engineering and Business for Sustainability
2010 M.S., Civil and Environmental Engineering

Ain Shams University, Cairo, Egypt

2008 B.S., Civil Engineering, Concentration: Structural Engineering (5-year degree)
Faculty Highest Honors (Recipient of 2008 Top National Engineering Student Award)

Appointments

Co-Director, Accelerated Bridge Construction University Transportation Center	2019 - current
Associate Professor, University of Nevada, Reno, NV (*tenured)*	2021 - current
Assistant Professor, University of Nevada, Reno, NV (*tenure-track)*	2015 - 2021
Postdoctoral Researcher, University of California, Berkeley, CA	01-06 / 2015
Graduate Student Researcher and Instructor, UC Berkeley, CA	2009 - 2014
Teaching Assistant, Ain Shams University, Cairo, Egypt	2008 - 2009
Structural Engineer, Arabia for Design and Engineering Consultants, Egypt	2007 - 2009
Surveying Engineer (part-time), Surveying Works Consulting Inc., Egypt	2004 - 2007

Research Experience

- PI/Co-PI on 14 research projects in past 6 years (about 3.5 million USD in funding) sponsored by federal and state agencies (e.g. USDOT, DOE, NSF, Caltrans, ACI) in areas of advanced construction materials, novel testing and monitoring techniques, computational technologies, and data analytics.

Certifications

- Professional Engineer (PE), California (License # C-82279)
- Professional Civil Engineer, Egyptian Engineers Syndicate (License # 35-02901)

Selected Relevant Publications

1. Aboukifa, M., M.A. Moustafa, M.S. Saiidi, (2021). “Seismic Response of Precast Bridge Columns with Composite Non-Proprietary UHPC Filled Ducts ABC Connections”, Composite Structures, 114376
2. Abokifa, M., M.A. Moustafa, (2021). “Mechanical Characterization and Material Variability Effects of Emerging Non-Proprietary UHPC Mixes for Accelerated Bridge Construction Field Joints”, Construction and Building Materials, 308, 125064
3. Naeimi, N., M.A. Moustafa, (2021). “Compressive Behavior and Stress-Strain Relationships of Confined and Unconfined UHPC”, Construction and Building Materials, 272, 121844
4. Abokifa, M., M.A. Moustafa, A. Itani, (2021). “Comparative Behavior of Precast Bridge Deck Panels with UHPC and Polymer Concrete Transverse Field Joints”, Engineering Structures, 247, 113195
5. Ghaffary, A., M.A. Moustafa, (2020). “Synthesis of Repair Materials and Methods for Reinforced Concrete and Prestressed Bridge Girders”, Materials, 13 (18), 4079
6. Aboukifa, M., M.A. Moustafa, A. Itani. (2020). “Comparative Structural Response of UHPC and Normal Strength Concrete Columns under Combined Axial and Lateral Cyclic Loading”, ACI Special Publication, 341, p. 71-96
7. Naeimi, N., M.A. Moustafa, (2020). “Numerical Modeling and Design Sensitivity of Structural and Seismic Behavior of UHPC Bridge Piers”, Engineering Structures, 219, 110792
8. Shoushtari, E., M.S. Saiidi, A. Itani, M.A. Moustafa, (2019). “Design, Construction, and Shake Table Testing of a Steel Girder Bridge System with ABC Connections”, ASCE Journal of Bridge Engineering, 24 (9), 04019088

9. Abbasi, M., and M. A. Moustafa, (2019). “Time-Dependent Seismic Fragilities of Older and Newly Designed Multi-Frame Reinforced Concrete Box-Girder Bridges in California”, Earthquake Spectra, 35 (1). 233-266
10. Dhakal, S., and M. A. Moustafa, (2019). “MC-BAM: Moment-Curvature Analysis for Beams with Advanced Materials”, SoftwareX, Volume 9, pp. 175-182.

Other Selected Publications

1. Ngeljaratan, L., M.A. Moustafa, (2021). “Underexposed Vision-Based Sensors’ Image Enhancement for Feature Identification in Close-Range Photogrammetry and Structural Health Monitoring”, Applied Sciences, 11 (23), 11086
2. Abbasi, M., M.A. Moustafa, (2020). “Effectiveness and Implications of Seismic Retrofit Measures for Deck Unseating of Multi-Frame Bridges with Regular and Irregular Geometry”, ASCE Journal of Performance of Constructed Facilities, 34 (3), 04020037
3. Ngeljaratan, L., M.A. Moustafa, (2020). “Structural Health Monitoring and Seismic Response Assessment of Bridge Structures using Target-Tracking Digital Image Correlation”, Engineering Structures, 213, 110551
4. Hammad, A., M.A. Moustafa, (2020). “Numerical Analysis of Special Concentric Braced Frames under Short and Long Duration Earthquakes”, Bulletin of Earthquake Engineering (in-press)
5. Ghaffary, A., M.A. Moustafa, (2020). “Performance-Based Assessment and Structural Response of 20-Story SAC Building under Wind Hazards through Collapse”, ASCE Journal of Structural Engineering (in-press)
6. Bas, E.E., M.A. Moustafa. (2020). “Real-Time Hybrid Simulation with Deep Learning Computational Substructures: System Validation Using Linear Specimens”, Machine Learning and Knowledge Extraction, 2(4), p. 469-489
7. Bas, E.E., M.A. Moustafa. (2020). “Communication Development and Verification for Python-Based Machine Learning Models for Real-Time Hybrid Simulation”, Frontiers of Built Environment, doi: 10.3389/fbuil.2020.574965
8. Ngeljaratan, L., M.A. Moustafa, (2019). “System Identification of Large-Scale Bridge Models using Target-Tracking Digital Image Correlation”, Frontiers of the Built Environment, 5:85.
9. Wen, B., M.A. Moustafa, and D. Junwua, (2019). “Seismic fragilities of high-voltage electrical substation disconnect switches” Earthquake Spectra, November 2019, Vol. 35, No. 4, pp. 1559-1582.
10. Hammad, A., M.A. Moustafa, (2019). “Shake Table Tests of Special Concentric Braced Frames Under Short and Long Duration Earthquakes”, Engineering Structures, 200, 109695

Selected Synergistic Activities

1. Voting member of several national code committees that include: ACI 341- Earthquake Resistant Concrete bridges; ACI 239-Ultra High Performance Concrete; ACI 239-0C – Structural Design of UHPC; and Chair of ACI Subcommittee 341-0D on Performance-based design of Earthquake Resistant Concrete Bridges and member of ASCE/SEI subcommittee on Structures Retrofit under Dynamic Effects.
2. Organized and chaired several conference sessions and served as a member of the program committee for Seismological Society of America 2016 annual meeting conference (Reno, NV). Organized and chaired sessions include: Effects of earthquake durations on the built environment (SSA, Reno, NV 2016), Hybrid simulation techniques (6AESE, Urbana, IL 2015), Advanced in bridges modeling and nonlinear time history analysis (11NCEE, Los Angeles, CA 2018), and computational modeling of advanced materials and novel structural systems for hazard mitigation (EMI International conference, Shanghai, China, 2018).
3. Developed new computational tool for moment-curvature analysis of beams with advanced materials such as UHPC and the open-source software has open access through SoftwareX. I also contributed to development of hybrid simulation middleware (OpenFesco) by implementing a new geometric transformation and experimental setup. The development also included a novel inexpensive hybrid simulation communication scheme that utilizes available laboratory data acquisition systems along with Ethernet connections. Moreover, I recently extended hybrid simulation capabilities to the University of Nevada, Reno Earthquake Engineering Laboratory.

POSITION: Professor Emeritus, Department of Civil & Environmental Engineering, University of Nevada, Reno
Email: saiidi@unr.edu
Distinguished Research Faculty, University of California, Los Angeles, UCLA; Email: saiidi@ucla.edu
Senior Principal, Infrastructure Innovation, LLC; Email: infrastructure.innovation@gmail.com

RESEARCH AREAS:
Earthquake Engineering of Bridges and Buildings, Experimental Studies of Bridges and Components, Analysis and Design of Reinforced Concrete Structures, Novel Materials in Earthquake-Resistant Structures; Earthquake-Resistant Connections for Accelerated Bridge Construction

EDUCATION:
M.S. in Civil Engineering (Five-year program), Tehran University, 1973
M.S. in Civil Engineering (Structures), University of Illinois, Urbana-Champaign, 1977
Ph.D. in Civil Engineering (Structures), University of Illinois, Urbana-Champaign, 1979

EXPERIENCE:
Senior Principal, Infrastructure Innovation, 8/07- Present
Professor, Civil Engineering Department, University of Nevada Reno, 7/88 –6/2020; Emeritus since 7/2020
UNR Foundation Professorship since 1997
Distinguished Research Faculty and Adjunct Professor, University of California, Los Angeles, UCLA, 7/2019- Present
Director, Office of Undergraduate Research, University of Nevada, Reno, 8/03-7/09
Chairman, Civil Engineering Department, University of Nevada, Reno, Nevada, 7/86 - 6/94
Associate Professor, Civil Engineering Department, University of Nevada, Reno, Nevada, 7/83 - 6/88
Assistant Professor, Civil Engineering Department, University of Nevada, Reno, Nevada, 8/79 - 6/83

SYNERGISTIC ACTIVITIES:
Collaborated with Washington State Department of Transportation in securing FHWA-IBRD funds to implement SMA/ECC in a bridge in Downtown Seattle, Washington
Founding Chair of ACI Committee 341 - Earthquake-Resistant Concrete Bridges, 1991-1997. Chair of Subcommittee on Bridge Pier Walls (1997-2002)
Director, NSF Grantees Workshop, Hazard Mitigation Programs, Lake Tahoe, Nevada, 1995; NSF US/Central Europe Workshop on Civil Infrastructure Systems for the next Century, Cracow, Poland, October 1996; NSF US-Turkey Workshop on Bridge Seismic Retrofit and Design, September 2004; FHWA/NSF Workshop on Long-Term Bridge Performance, Las Vegas, Nevada, January 2007; NSF Workshop on Bridges of the Future- Widespread Implementation of Innovation, Las Vegas, Nevada, June 2011.
Chaired the Civil Engineering Department for eight years and helped build a dynamic department with worldwide reputation in bridge engineering research.
Developed proposal and received a $2M NSF-NEES-SG grant to lead a major research effort on novel materials in bridges with participation from other universities [Cal-Berkeley, Florida Int., Georgia Tech, Illinois (Chicago), Kansas, Stanford, and Cal-San Diego]. Research on novel materials led to interviews by the Wall Street Journal, USA Today, The Economist, Engineering News Record, National Public Radio, Popular Mechanics, Science Daily, the Discovery Channel, etc.
Served as Subject Matter Expert on Domestic AASHTO Scan 11-02 on accelerated bridge construction under multi-hazard loading.
Served as the Director of Undergraduate Research (UR) Office at the University of Nevada and built sustaining infrastructure to promote and support UR in various fields including arts, science, engineering, humanities, medicine, and business. Secured funding as an area leader from NSF-EPSCoR approximately $3.0M to promote and expand UR in Nevada universities.

HONORS, AWARDS, RECOGNITION, AND PROFESSIONAL ACTIVITIES:
Fellow, ASCE; Fellow, ACI
Member ACI Committees 318-D, 341, and 352
Member, ACI, ASCE, EERI, Phi Kappa Phi, NEES Consortium, CUREE
Registered Professional Engineer in the State of Nevada and California
Reviewer of the National Science Foundation Research Proposals

Reviewer of ASCE, ACI, EERI, PCI, Journal of Engineering Structures, Journal of Structural Engineering and Mechanics, Earthquake Engineering and Structural Dynamics, TRB Records, etc., Member of Review Panels for NCHRP and NSF Proposals

Who's Who in Frontiers of Science and Technology, 2nd Edition

Distinguished Leadership Award for Outstanding Contributions to Civil Engineering, 2nd Edition

UNR-Foundation Professorship Award, 1997

UNR Outstanding Researcher of the Year Award, 2000

Outstanding Civil and Environmental Engineering Alumni Award, University of Illinois at Urbana-Champaign, 2003

Regents Researcher Award, University and Community College System of Nevada, 2003

Lemelson Award for Innovative Research, College of Engineering, University of Nevada, Reno, 2004

Advisor of the Year Award, Associated Students at the University of Nevada, Reno, 2004

Distinguished Alumni Award, College of Engineering, Tehran University, 2004.

College of Engineering Excellence in Research Award, University of Nevada, Reno, May 2014.

Established Innovator Award, Office of Vice President for Research and Innovation, University of Nevada, Reno, May 2016**.**

National Academy of Engineering of Mexico, Member, 2017

SELECT RECENT JOURNAL PUBLICATIONS:

Romero, A., M. Moustafa, M. Saiidi, and H. Ebrahimian, "Shake Table Testing of Out-Of-Plane Response of Repaired Bridge Subassembly with Simplified ABC-Inspired Cast-In-Place Joints," Journal of Engineering Structures, Vol. 285, June 2023, 116064.

Raza, S., R. Widmann, J. Michels, M. Saiidi, M. Motavalli, and M. Shahverdi, "Self-Centering Technique for Existing Concrete Bridge Columns Using Prestressed Iron-based Shape Memory Alloy Reinforcement," Journal of Engineering Structures, Vol. 294, November 2023, 116799.

Piras, S., A. Palermo, and M. Saiidi, "State-of-the-Art of Posttensioned Rocking Bridge Substructure Systems," Journal of Bridge Engineering, ASCE, Vol. 27, No. 3, March 2022.

Benjumea, J., M. Saiidi, and A. Itani, "Biaxial Seismic Performance of a Two-Span Concrete Bridge Model with Six ABC Connections," Journal of Bridge Engineering, ASCE, Vol. 126, No. 8, August 2021

Benjumea, J., M. Saiidi, and A. Itani, "Large-Scale Bi-Axial Shake Table Studies of a Precast Bridge Model," Journal of Structural Engineering, ASCE, Vol. 147, No. 5, July 2021.

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COLLABORATORS IN THE PAST 5 YEARS:

Dr. H. Ebrahimian, Dr. Muhamad Mustafa, University of Nevada, Reno; Dr. Y. Bozorgnia, Dr. Y. Jiang, Dr. E.T. Ertugrul, University of California, Los Angeles, Dr. K. Kawashima, Tokyo Institute of Technology, Japan; Dr. M. Tazarv, South Dakota State University; Dr. A. Mirmiran and Dr. A. Azizinamini, Florida International University, Dr. B. Phares, Iowa State University; Lee Marsh, Berger-ABAM, WA, Tom Murphy, Modjeski & Masters, PA, Quincy Engineering, CA, Bora Gencturk, University of Southern California.

GRADUATE STUDENTS, POST-DOCTORAL FELLOWS, AND VISITING PROFESSORS IN THE PAST 5 YEARS:

E. Zengin, Research Associate, H. Huanpeng, PhD, M. Cetinkaya, PhD, M. Vahedi, PhD, A. Vosooghi, PhD, Post-doc, Z. Haber, PhD, Post-doc; A. Zaghi, PhD; C. Cruz, PhD, S. Ardakani, PhD, F. Kavianipour, PhD, A. Larkin, MSCE, A. Mehrsoroush, PhD, Post-doc, A. Saini, PhD, M. Tazarv, PhD, Post-doc, A. Akl, PhD, Z. Hua, PhD, B. Nakashoji, MSCE, B. Abdollahi, PhD, M. Mehraein, PhD, K. Shrestha, Post-doc, S. Varela, PhD, J. Jones, MSCE, PhD; G. Shrestha, PhD, A. Mohebbi, PhD, J. Benjumea, PhD, E. Shoushtari, PhD, J. Ge, Visiting Assoc. Professor, E. Jordan, MSCE, C. Liu, Visiting Researcher. Dr. J. Jia, Visiting Professor, has sponsored and supervised research for 62 MS students, 36 PhD students, and 23 post-doctoral/research fellows.

Standard Budget Itemization for Department Research Projects

Project Title: **Use of Fiber-Reinforced Polymer (FRP) Bars in Seismic Design of Building Structures**
Project Duration: **07/01/2024 – 12/31/2026**

Name and Position	Hourly Salary	Total Salary/Wage	Fringe Benefit	Total Year 1
Dr. Hamed Ebrahimian, PI	$88.76	$8,000	$200	$8,200
Dr. Mohamed Mustafa, Co-PI	$104.55	$5,000	$125	$5,125
Senior Researcher (TBD)	$ -0-	$ -0-	$ -0-	$ -0-
Graduate Assistant	$30.62	$29,400	$4,439	$33,839
Year 1 Totals		**$42,400**	**$4,764**	**$47,164**
Name and Position	**Hourly Salary**	**Total Salary/Wage**	**Fringe Benefit**	**Total Year 2**
Dr. Hamed Ebrahimian, PI	$88.76	$8,000	$200	$8,200
Dr. Mohamed Mustafa, Co-PI	$104.55	$5,000	$125	$5,125
Senior Researcher (TBD)	$41.78	$25,200	$2,470	$27,670
Graduate Assistant	$30.62	$29,400	$4,439	$33,839
Year 2 Totals		**$67,600**	**$7,234**	**$74,834**
Name and Position	**Hourly Salary**	**Total Salary/Wage**	**Fringe Benefit**	**Total Year 3**
Dr. Hamed Ebrahimian, PI	$88.76	$8,000	$200	$8,200
Dr. Mohamed Mustafa, Co-PI	$104.55	$5,000	$125	$5,125
Senior Researcher (TBD)	$41.78	$25,200	$2,470	$27,670
Graduate Assistant	$30.62	$29,400	$4,439	$33,839
Year 3 Totals		**$67,600**	**$7,234**	**$74,834**
	Year 1	**Year 2**	**Year 3**	
A. Personnel and Fringe	$47,164	$74,834	$74,834	
B. Travel			$2,200	
C. Operating Costs (Materials & Supplies)	$3,000	$1,500	$1,000	
D. Final Report Preparation & Submission				
E. Equipment				
F. Other Costs				
F.1. Contractor	$ -0-	$46,000	$30,000	
F.2. Lab Fees	$1,000	$48,500	$27,500	
G. Subcontract (1st $25,000)	$14,000	$11,000	$-0-	
H. Subtotal of Direct Costs	$65,164	$181,834	$135,534	
I. Total Indirect Cost (10%)	$6,516	$18,183	$13,553	
J. Student Tuition and Fees	$4,158	$4,368	$4,590	
K. Subcontract (w/o Indirect Cost)	$ -0-	$3,000	$14,000	
L. TOTAL PROJECT COST PER YEAR	$75,838	$207,385	$167,677	
TOTAL PROJECT COST	**$450,900**			

University of Nevada, Reno
Research & Innovation

Sponsored Projects

Budget Setup, Memo Account, Increase/Decrease in Sponsor Support

ENGINEERING

Revised 1/05/2024

PREPARED BY **Brett Shirey**
PRINCIPAL INVESTIGATOR Hamed Ebrahimian
PROJECT TITLE Use of Fiber-Reinforced Polymer (FRP) Bars in Seismic…

AWD #
GR#
INFOED# **2400442**

PROJECT BUDGET

	Fringe Rates	Y1 8-12/2024	Y2 2025	Y3 2026	Y4 1-7/2027	Year 5	Cumulative
LOA - All	9.80%		25200.00	25200.00			50400.00
Total LOA Salaries		**0.00**	**25200.00**	**25200.00**	**0.00**	**0.00**	**50400.00**
Professional Faculty (Acad./Admin)	31.60%						0.00
Overload (w/o retirement)	2.50%	6500.00	13000.00	13000.00	6500.00		39000.00
Postdoctoral	31.60%						0.00
Total Professional Salaries		**6500.00**	**13000.00**	**13000.00**	**6500.00**	**0.00**	**39000.00**
Graduate Assistants	15.10%	12250.00	29400.00	29400.00	17150.00		88200.00
Classified Personnel	41.60%						0.00
Hourly Wages	2.50%						0.00
Total Other Salaries		**12250.00**	**29400.00**	**29400.00**	**17150.00**	**0.00**	**88200.00**
Total Salaries		**18750.00**	**67600.00**	**67600.00**	**23650.00**	**0.00**	**177600.00**
Fringe Benefits-Manual Entry		2012.00	7234.00	7234.00	2752.00	0.00	19232.00
Total Salaries & Fringe		**20762.00**	**74834.00**	**74834.00**	**26402.00**	**0.00**	**196832.00**
Travel				2200.00			2200.00
Materials & Supplies		3000.00	1500.00	1000.00			5500.00
Services		1000.00	94500.00	57500.00			153000.00
Rentals-Off Site Facilities							0.00
Participant Support							0.00
Subawards first $25,000		7000.00	14000.00	4000.00			25000.00
Subawards over $25,000				10000.00	7000.00		17000.00
Total Subawards		**7000.00**	**14000.00**	**14000.00**	**7000.00**	**0.00**	**42000.00**
Tuition & Fees		2028.00	4260.00	4476.00	2352.00		13116.00
Fellowships & Scholarships							0.00
Capital Equipment							0.00
Other Fixed Assets							0.00
Total Direct Costs		**33790.00**	**189094.00**	**154010.00**	**35754.00**	**0.00**	**412648.00**
Modified Total Direct Costs		31762.00	184834.00	139534.00	26402.00	0.00	382532.00
F&A Rate		**10.0%**	**10.0%**	**10.0%**	**10.0%**	**47.0%**	
F&A Costs		**3176.00**	**18483.00**	**13953.00**	**2640.00**	**0.00**	**38252.00**
Total		**36966.00**	**207577.00**	**167963.00**	**38394.00**	**0.00**	**450900.00**

This budget and level of effort is consistent with the approved budget as agreed to by the sponsor.

Signatures:

☐

Principal Investigator

Grants & Contracts Officer

BUDGET JUSTIFICATION

The University of Nevada, Reno is on an 8-month academic and 4-month summer calendar schedule.

<u>A. Personnel:</u> $177,600

Principal Investigator. $24,000. The commitment of PI (Hamed Ebrahimian) is for 0.56 summer months each year. Based on a salary of $120,009 (assuming a 11% COLA in Year 1, $108,116 currently), the project salary is $8,000 each year. Total PI salary requested for the project: **$24,000** ($8,000/year x 3 years).

Co-Principal Investigator. $15,000. The commitment of Co-PI (Mohamed Moustafa) is for 0.30 summer months each year. Based on a salary of $141,356 (assuming a 11% COLA in Year 1, $127,348 currently), the project salary is $5,000 each year. Total Co-PI salary requested for the project: **$15,000** ($5,000/year x 3 years).

Senior Researcher. $50,400. The commitment of Senior Researcher (TBD) is for 50% FTE in Years 2-3 at a salary of $25,200 each year. Total salary requested for the project: **$50,400** ($25,200/year x 2 years).

Graduate Assistant. $88,200. One graduate assistant will each commit approximately 20 hours per week for 12 months each year at a wage of $2,450 per month or $29,400 each year. Total wages for one graduate assistant: **$88,200** ($29,400/year x 3 years).

<u>Fringe:</u> $19,232

Fringe rates for the University of Nevada, Reno are based on approved DHHS rates. The rate for the PI and Co-PI as overload without retirement is 2.5% (**$975**). The rate for the senior researcher is 9.8% of requested salaries (**$4,939**). The rate for graduate assistants is 15.1% of requested wages (**$13,318**).

<u>B. Travel:</u> $2,200

Domestic. Travel is requested for the PI to attend the ACI conference and meetings with committee members related to the project to disseminate research findings and help adopt research outcomes. The cost for a typical 4-day trip (for example, Washington DC) is approximately $2,200/person: transportation/mileage ($915), lodging ($969 for 3 nights, $323/night), and per diem ($316 for 4 days, $79/day). Estimated one trip is **$2,200** for the project period. *Travel costs are based on current GSA rates.*

<u>C. Operating Costs:</u> $5,500

Costs include necessary lab supplies and consumable materials for the project duration. The estimated total is $3,000 in Year 1, $1,500 in Year 2, and $1,000 in Year 3, or **$5,500** ($3,000+$1,500+$1,000) for the project period. *Estimated costs are based on vendor and historical costs.*

<u>F. Other Costs:</u> $153,000

F.1. Contractor. $76,000. Costs include a contractor to build test specimens in Years 2-3 of the project. The estimated total for a contractor is $46,000 in Year 2 and $30,000 in Year 3 or **$76,000** ($46,000+$30,000) for the project period.

F.2. Laboratory Fees. $77,000. Costs include structural laboratory staff and equipment usage for testing specimens. The estimated total is $1,000 in Year 1, $48,500 in Year 2, and $27,500 in Year 3 or **$77,000** ($1,000+$48,500+$27,500) for the project period.

G. Subcontract: $25,000
A subcontract will be issued to Dr. Saiid Saiidi to assist with the project. The estimated total is $42,000. *Subcontracts above $25,000 are excluded from F&A.*

H. Subtotal of Direct Costs: $382,532

I. Indirect Costs: $38,252
The University of Nevada, Reno has an approved, federally negotiated facilities and administrative cost rate for on-campus research of 47.0% on Modified Total Direct Costs (MTDC), excluding equipment and tuition costs. However, due to the sponsor's indirect cost requirement, 10% has been implemented. MTDC base is $382,532.

J. Student Tuition and Fees: $13,116
Tuition is required on all assistantships at UNR. Considering an average course load of 12 credits per year (6 per semester), the estimated tuition rates are:

- Year 1: $338/credit x 6 credits= $2,028 + $355/credit x 6 credits= $2,130. Total= $4,158
- Year 2: $355/credit x 6 credits= $2,130 + $373/credit x 6 credits= $2,238. Total= $4,368
- Year 3: $373/credit x 6 credits= $2,238 + $392/credit x 6 credits= $2,352. Total= $4,590

Total tuition cost is **$13,116** ($4,158+$4,368+$4,590). *Tuition cost per credit is projected to increase at 5% annually. Tuition costs are excluded from the F&A base.*

K. Subcontract: $17,000
A subcontract will be issued to Dr. Saiid Saiidi to assist with the project. The estimated total is $42,000. *Subcontracts above $25,000 are excluded from F&A*

Total Funding Request: $450,900 *(Federal: $360,720; State Funds: $90,180)*