USE OF FIBER-REINFORCED POLYMER COMPOSITES FOR BRIDGE REPAIRS IN MONTANA

by

Kirsten Matteson, PhD
Assistant Professor

and

Michael Berry, PhD
Associate Professor

Civil Engineering Department
College of Engineering
Montana State University – Bozeman

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Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

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PROBLEM STATEMENT

New methodologies are needed for repairing and strengthening the aging and failing transportation infrastructure. The use of fiber-reinforced polymer (FRP) composites for repair has gained popularity over the last decade as these methods are affordable, effective, and easy to implement. FRPs in general offer several key advantages over conventional building materials. Specifically, they have high strength to weight ratios, have increased durability and corrosion resistance, and are generally "greener" than conventional materials in terms of embodied energy [1, 2]. FRPs are composed of either thermoset or thermoplastic resins reinforced with (usually) glass or carbon fibers, GFRP and CFRP, respectively. FRPs can be used for strengthening in several forms, such as near-surface mounted (NSM) bars and externally applied wrapping. The use of FRPs as a repair method for bridges has been investigated by several state departments of transportation (DOTs) in recent years. For example, FRPs have been used to restore the original flexural strength of damaged reinforced concrete bridge girders, strengthen simple span reinforced concrete slab bridges, and seismically retrofit bridge columns. It should also be noted that MDT has used externally bonded FRPs in the past with mixed results. For example, MDT successfully used externally bonded FRPs to strengthen existing timber piles but had limited success strengthening concrete columns due to bonding issues.

Previous research conducted at Montana State University (MSU) has focused on using externally bonded FRP to strengthen reinforced concrete beams and evaluate their performance at cold temperatures. The results from this work were promising, indicating that externally bonded FRPs are suitable for repairs in cold environments, thus supporting the rationale for their use in repair/strengthening projects in the state. The focus of the proposed project is on investigating the various FRP repair/strengthening techniques, determining the methods most suitable for use on Montana bridges, filling any research gaps that may impede their use in Montana's unique climate, and helping implement and monitor the chosen application and methodology on a bridge project in the state. This proposed research is a necessary step to fully understand and capitalize on the benefits of using FRP for repairing/strengthening, and to subsequently increase the performance, and durability of Montana bridges.

BACKGROUND SUMMARY

While FRP has been used to strengthen bridges in the U.S. over the past three decades, this methodology is fairly new, with the application methods, specifications, and design criteria still evolving. Several state DOTs have investigated the use of FRPs to strengthen and repair/replace structural elements on bridges in recent years and documented their own design criteria and specifications to meet their unique requirements. As examples, FRPs have been used to restore the original flexural strength of damaged reinforced concrete bridge girders [3, 4], strengthen simple span reinforced concrete slab bridges [5], and seismically retrofit bridge columns [6] across several states in the country. Additionally, externally-bonded FRPs have been used by MDT with mixed results.

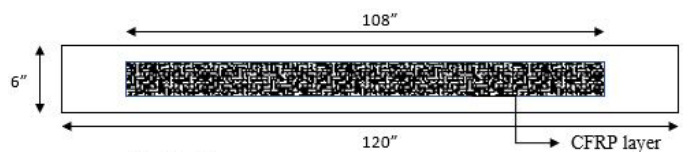
Chajes et al. [7] and Frankhauser et al. [8] both completed extensive literature reviews on this topic. A summary of their findings for FRP strengthening and/or repairing applications by state DOTs in the U.S. is provided in Table 1.

Table 1: State DOT Strengthening/Repairing Applications in the US. Information collected from Chajes et al. [7] and Frankhauser et al. [8].

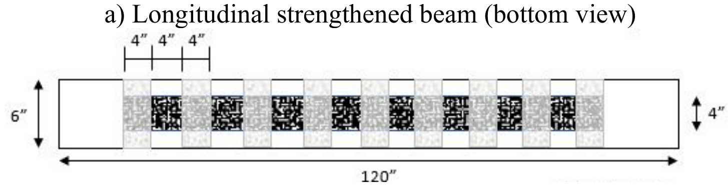
DOT	FRP usage in strengthening/repair	General comments
Florida DOT	Near-surface mounted (NSM) repairs using CFRP Externally bonded FRP	Many concrete structures in coastal environment that suffer the effects of corrosion Has published updated and comprehensive guidelines for using FRP composites
Kansas DOT	Column strengthening with FRP wrap Concrete beam strengthening	Has been using FRP materials in bridge applications since 1995 Currently investigating the use of GFRP reinforcing for new construction
Maine DOT	CFRP transverse post tensioning	Recently performed a series of projects using FRP composites as both strengthening systems and structural components of bridges Published specific design and construction guidelines for FRP piles, structural FRP tubes, and FRP-based strengthening
Michigan DOT	Beam shear strengthening Column wraps	Supported to develop corrosion-free prestressing (P/S) tendons and guidelines for the design and use of externally bonded FRP strengthening systems for Michigan bridges
Missouri DOT	Carbon FRP laminates Bonded FRP laminates	---
Nebraska Department of Roads	FRP pier cap protection/strengthening FRP girder strengthening	Currently developing an FRP-reinforced approach slab/paving section standard
Oregon DOT	Deck strengthening with NSM CFRP rods Girder flexure and shear strengthening with CFRP strips Pier cap flexure and shear strengthening with CFRP	Performed several projects using externally bonded strengthening wraps and near-surface mounted FRP rebar Studied the performance of the FRP composite decks and bolted connections between the composite decks and the steel girders
Washington State DOT	Superstructure strengthening of Alaskan Way Viaduct bridges after Nisqually Earthquake (2005) and US-2 bridges; Phase 1 (2006) and Phase 2 (2008)	Performed a project involving dowel bars made of glass fiber reinforced polymers Published recommendations on the installation and performance of the GFRP dowel bars
California DOT	---	Developed LRFD guidelines for FRP strengthening systems for RC structures
Texas DOT	External wrapping with FRP	Conducted several projects involving the long-term performance and durability of the FRP strengthening systems Developed specific design guidelines for FRP structural systems
Kentucky Transportation Cabinet	Retrofit of the Louisa-Fort Gay Bridge Using CFRP laminates External wrapping with CFRP	Has been conducted FRP-related projects since 1996 and implemented over 20 projects involving externally bonded FRP composites for strengthening and retrofitting of in-service bridges
Virginia DOT	GFRP bars FRP composite girders	Investigated the design and performance of bridge components made of FRP composites (FRP girders and FRP decks under service conditions) and performance of GFRP bars used in bridge structures
New York State DOT	Bonded FRP composite plates FRP laminates	Conducted a series of projects on the use of FRP composites Developed design and long-term performance guidelines specifically for FRP decks and strengthening wraps

A literature review on the use of FRP in bridge repairs was also conducted by the MDT librarian as a result of the Stage 1 submission. Key findings from this review include: 1) FRP materials have been successfully implemented in repair/strengthening applications by several state DOTs, 2) the long-term performance of FRP wrapping is somewhat limited and has been (and continues to be) evaluated by several state DOTs, and 3) research is lacking concerning the material's short- and long-term performance in cold environments. The lack of information on the long-term performance/durability of these methods is particularly concerning for Montana bridges due to their exposure to extreme temperature ranges and cycles.

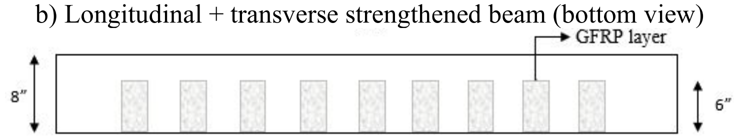
Preliminary research on the use of externally-bonded FRPs has been conducted at MSU over the last two years to supplement the work proposed herein. Overall, this research investigated how the behavior of reinforced concrete beams were affected by multiple FRP strengthening techniques and cold temperatures. The research included testing 3 beam designs at two temperatures (room temperature ~70ºF and -25ºF), for a total of 6 beams. The 3 beam designs consisted of three different FRP reinforcement schemes: a control beam with no FRP reinforcing, a longitudinal-strengthened beam with CFRP wrap secured on the bottom of the beam, and a longitudinal and transverse strengthened beam with CFRP secured longitudinally along the bottom with transverse GFRP wrapping. The strengthened beam profiles are shown in Figure 1 and example beams being tested in room temperature and -25ºF are shown in Figure 2.



a) Longitudinal strengthened beam (bottom view)



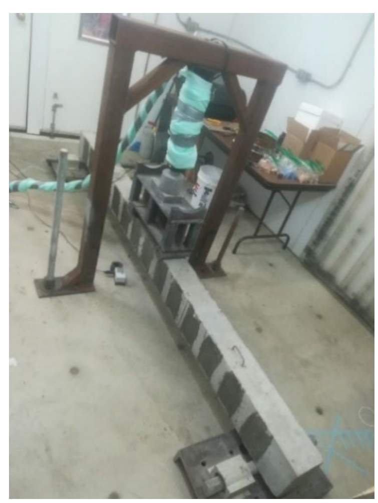
b) Longitudinal + transverse strengthened beam (bottom view)



c) Longitudinal + transverse strengthened beam (side view)

Figure 1: Profiles of strengthened beams. All dimensions shown in inches.

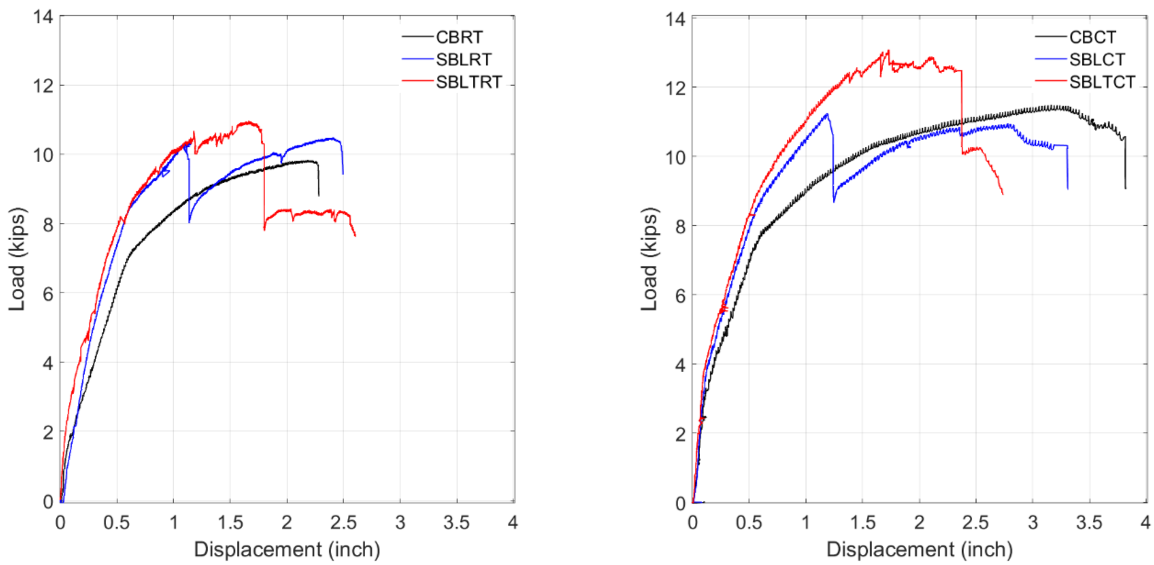
a) In room temperature.



b) In cold room.

Figure 2: Test setup of example beams.

Load vs. mid-span displacement for all beam types are shown in Figure 14, for both (a) room and (b) cold temperature testing conditions. The main conclusions drawn from the study include the following: 1) FRP strengthening increased beam capacities, 2) beams showed higher load carrying capacities in cold temperatures vs. the room temperature counterparts for all beam types, 3) FRP delamination was delayed in cold temperatures (occurred at higher displacements), and 4) FRP transverse wrapping helped delay longitudinal delamination in both temperatures. Additionally, there were several non-quantified lessons learned while gaining experience working with the materials that will be useful for the proposed research. These lessons included shelf life/storage, pot life, and batching of the epoxy resin and storage and handling requirements for the FRP. Overall, the results from this work were promising, indicating that externally bonded FRPs are suitable for repairs in cold environments, although the long-term performance was not evaluated.



a) Room temperature. b) Cold temperature.

Figure 3: Load vs. mid-span displacement results for all beam types. Acronyms: CBRT = control beam room temperature, SBLRT = strengthened beam longitudinal reinforcement room temperature, SBLTRT = strengthened beam longitudinal + transverse room temperature, and similar for cold temperature.

Additionally, as part of the preliminary research and to supplement the research proposed herein, a thorough literature review was conducted to investigate and learn from existing research to determine the appropriate use of this material in Montana, taking into consideration extreme temperatures and short construction seasons, challenges unique to our state. This literature review supported the use of this material in Montana and will be revisited as part of the proposed project.

BENEFITS AND BUSINESS CASE

The aging and deteriorating transportation infrastructure requires proven, cost-effective, and efficient repair/strengthening methods, especially when replacement is not feasible due to economic and technical constraints. FRP repair methods are well suited to address this need. These methods have been successfully used by various DOTs across the country; however, research is needed to determine the most appropriate methods for Montana, and to ensure the successful implementation of these methods including the development of appropriate specifications for their use. This research will lead to more confidence in using FRP in bridge repairs (and possibly strengthening) in the state, and will allow the state to capitalize on the inherent benefits of this material and related repair methods.

Compared to most traditional repair methods, FRP requires less installation time and the effect of traffic loading on the strength of the FRP bonding has been found to be minimal [7, 8]. Therefore, it can reduce the time for traffic closure and improve the bridge's overall performance. The research performed herein could lead to improved quality of repairs, increased life cycles of Montana bridges, reduced traffic closures during repairs, and ultimately time and money savings for MDT.

Overall, Montana's aging transportation infrastructure requires proven, robust, and cost-effective repair and strengthening methods. FRP may be the ideal material to satisfy these needs and the proposed research on the use of FRP in strengthening and repair applications is a necessary step to ensure the desired performance of this method in field applications in the state. If the method is proven to be viable, Montana could take advantage of the time effectiveness of the strengthening method and ultimately improve the performance and durability of their bridges. Similar to the ultra-high performance concrete research, the currently proposed project will provide the underlying benefit of simply adding another tool in the MDT Bridge Bureau's toolbox when considering methods and materials for Montana bridge repairs and strengthening.

OBJECTIVES

The primary objective of the proposed research is to investigate and help implement the use of FRPs to enhance the performance of Montana bridges. Specific objectives of the proposed research include to: (1) conduct an updated and thorough literature review to investigate the feasibility of using FRPs in various bridge applications in Montana, (2) identify the most promising applications of this technology for use in the state, (3) fill any minor research gaps that may affect/limit the successful application in Montana's unique climate, (4) assist in implementing the application(s) of this material in a bridge demonstration project in the state, and (5) monitor the performance of this bridge after the demonstration project. FRP composites could provide a viable solution to Montana's aging infrastructure's repair/strengthening needs. This research will provide the necessary step to capitalizing on the inherent benefits of these composites.

RESEARCH PLAN

The research proposed herein will focus on identifying the most promising applications of FRP technology for use in the state, filling in any minor research gaps, and eventually implementing this technology in a bridge project in Montana. Specifically, this research will include the following tasks.

Task 0 – Project Management

The Principal Investigator for this project will manage the project with respect to contractual compliance, budget and schedule, administrative tasks, and communications with the Technical Panel (TP) at MDT. Dr. Kirsten Matteson of the Civil Engineering Department at Montana State University will serve as the Principal Investigator. She will be the primary contact and assume the majority of the project management responsibilities. Management will generally be achieved through regular communication between the Principal Investigator, co-PI Dr. Michael Berry, the MDT project manager and TP, and other research team members.

Task 1 – Literature Review and Identification of Pursued Application

As this research moves ahead, it is essential to be aware and take advantage of any work completed to date by other investigators/organizations. A comprehensive literature review will be conducted to evaluate the state-of-the-practice for and recent advances in FRP, and in particular, this review will focus on the use of FRP in actual bridge strengthening and repair projects. Material properties, specifications, and application methods documented by other researchers and state agencies will also be investigated. In general, the topics will include standard practices of other states that have successfully implemented FRP for strengthening and repair, including required equipment for different techniques (NSM, external-wrapping, etc.), timber vs. concrete repairs, surface preparation, typical application methods, debonding mitigation, performance in extreme environments, etc.

Additionally, FRP applications that MDT has already pursued will be investigated as part of the literature review and the levels of success of each will be discussed and documented. The research team will coordinate with MDT bridge engineers and repair teams to identify the biggest needs and determine the most likely candidates for the use of this technology. This information will be used to inform the decision on which application will be pursued during Tasks 2-4 of the research and the ultimate timeline to implementation.

Specific topics that were identified during the first TP scope meeting, that will be investigated during Task 1, and that could ultimately be chosen as pursued applications are summarized as follows:

- Repairing deteriorating sub-structures
- Strengthening super structure to increase load ratings
- How to deal with hard to reach "vertical" applications
- Learning what other states are doing with NSM strengthening bars
- Seismic retrofitting

Information gathered for Task 1 will be helpful in guiding the future directions of this research. This literature will be revisited throughout the research and will be updated before submittal of the final report. A Task 1 report will be submitted by the end of the month following the completion of this task.

Intermediate Technical Panel Meeting

The MSU research team will meet with the MDT TP upon completion of the first task to present their findings, and to discuss the focus and direction of the implementation portion of this research. This will serve as a decision point of the project for determining the application(s) that will be pursued. The overall goal of this meeting will be to gather input from the TP required to guide key aspects of the remaining research for successful implementation. Once the pursued application is chosen, it will be ideal for an appropriate bridge project to be selected soon after, such that the details of Task 3 can be planned.

Task 2 – Close Minor Research Gaps

This task will focus on closing any minor research gaps in order to ensure the successful use of the chosen FRP material(s) and application(s) in the proposed field demonstration implementation project. The researchers will use the findings of Task 1 to identify existing knowledge gaps and perform necessary testing to close those gaps.

Specifically, the researchers foresee Task 2 investigating the following possible topics:

- Material availability and sourcing
- Surface preparation techniques
- Application procedures
- Bond behavior/debonding issues

Experimental testing will most likely be performed to evaluate the chosen material(s) and application(s) in cold temperatures and potentially under freeze-thaw cycles. Strength testing (e.g. flexural, tensile, shear, dependent on application) may also be performed.

As one specific example, if timber girder repair with FRP wet layup is the chosen application, the bond strengths between the FRP and timber surface would need to be investigated. The expected climate per the timing and location of the chosen implementation project would need to be considered and multiple timber surface preparation techniques and FRP material choices may be investigated. As another example, the TP may deem strengthening concrete girders using NSM bars in combination with external wrapping to be a priority in order to increase load ratings on posted bridges. In this case, techniques for cutting existing concrete, cleaning surfaces, installing the bars, and following-up with external wrapping will be investigated. Additionally, some larger scale testing could be performed on strengthened concrete beams. A Task 2 report will be submitted by the end of the month following the completion of this task.

Task 3 – Implementation

This project will culminate in an implementation project in which the chosen FRP repair/strengthening technique will be used on an actual bridge project in Montana. The research team will assist in developing the specifications for the chosen FRP method, which will include at a minimum, appropriate material properties, surface preparation requirements, and application/curing processes. Specifically, this task will involve: (1) assisting MDT in the development of specifications and procedures (or modification of existing ones if needed) to be used on the proposed bridge project, (2) assisting the contractor during trial FRP applications and mockup construction, (3) assisting contractor during bridge repair/strengthening and performing any related quality control testing, and (4) installing any required monitoring equipment. A Task 3 report will be submitted by the end of the month following the completion of this task.

Task 4 – Monitoring Bridge Performance

The research team will monitor the performance of the bridge routinely between its completion and the completion of the proposed research project. This monitoring will include inspecting the bridge and documenting any potential signs of damage (e.g., cracks, debonding, delamination, etc.). The work completed for Task 4 will be included in the final report. Additionally, the final report will include all necessary information required for MDT Bridge Inspectors to perform future inspections following (as appropriate) methods and procedures used in Task 4, to continue consistent monitoring of the FRP repaired/strengthened element(s). The report will detail an overview of potential future issues of which to be aware.

Task 5 – Analysis of Results and Reporting

The results from this work will be thoroughly analyzed in this task. A comprehensive final report that includes all data, analyses, and recommendations will be written in conformance with MDT's standard research report format to thoroughly document the findings of this project. A draft report will be sent to MDT to be distributed to the Technical Panel for review and comment. The results of the project will also be disseminated, as appropriate, to the professional community through presentations at various conferences and/or through journal papers. A four-page "Project Summary Report" will be written and submitted to MDT near the end of the project to summarize the background, methodology, results and recommendations of this research. Details on the timing of additional reporting requirements are shown below in Table 2 in the Schedule section of this proposal.

In addition to the final report, three intermediate task reports will be written to summarize work associated with the following major activities.

- Task 1 Report—Literature Review and Identification of Pursued Application
- Task 2 Report—Close Minor Research Gaps
- Task 3 Report—Implementation

Quarterly progress reports will be submitted to provide updates on the administrative aspects of the project, such as progress regarding the deliverables, schedule, and budget. It should also be noted that the literature review will be updated during the preparation of the final report to include any work that may have been completed after the completion of Task 1.

INTELLECTUAL PROPERTY

There are no expected intellectual property issues with the proposed research project.

MDT AND TECHNICAL PANEL INVOLVEMENT

The PI and co-PI recognize the importance of ongoing communication between the research team and MDT and will ensure regular communication occurs between the involved parties. This includes prompt responses to emails from MDT's Research Programs staff and TP throughout the project. In keeping with standard requirements, MDT will review and comment on all products, including but not limited to task reports, quarterly progress reports, the final report, and the project summary report. Depending on which bridge project is selected for Task 3, MDT may also be asked to assist with traffic control and other tasks surrounding implementation.

OTHER COLLABORATORS, PARTNERS, AND STAKEHOLDERS

FHWA will also be interested in the proposed research project and will have a representative on the Technical Panel.

PRODUCTS

The products to be delivered during this project include the following items.

- Kick-off meeting and subsequent notes.
- 11 quarterly progress reports.
- 3-task reports (Tasks 1-3).
- Draft final report and executive summary describing the research methodology, findings, conclusions, and recommendations, followed by a final report addressing comments and suggestions from the Technical Panel.
- Final presentation and webinar.
- Draft project summary report.
- Implementation report, meeting, and material specifications.
- Performance measures report.
- Project Poster.

RISKS

Previous research has clearly established the benefits and effectiveness of using FRP for bridge repair/strengthening, and several states have demonstrated their applications in actual bridge projects, some of which have resulted in specifications/guidelines. While these applications have been successful, research is still needed to identify the most appropriate methods for use in Montana and its unique infrastructure and demanding climate. The research team is well suited to complete the proposed research, as it has the necessary expertise, equipment, instrumentation, laboratory space (including cold labs), and experience with implementation projects. The proposed research has a high likelihood for success and is low risk.

One potential risk involves the dependency on an appropriate project to be identified for the implementation portion of the project. Depending on overall project availability and construction schedules, this could cause a delay to the project. However, during initial discussions between the researchers and MDT, the technical panel has been optimistic about identifying an appropriate bridge to be used for Tasks 3 and 4.

IMPLEMENTATION

Upon completion of this project, MDT will have a new technology available to repair and/or strengthen deteriorating bridges with FRP composites. This project will demonstrate the feasibility of using the specific application in an actual bridge project, and will result in material specifications necessary for MDT/contractors to successfully use this technology in the future. Additionally, the Implementation Section of the Final Report and the Implementation Report will outline additional existing research gaps and potential barriers of implementation for some of the applications that do not get chosen for the current project. These applications will include those deemed of most importance to the TP during the Intermediate TP Meeting. Overall, this project will demonstrate the benefits of using FRP in the chosen application, and MDT will have a refined and proven technique for repairing/strengthening existing bridges.

SCHEDULE

The estimated project schedule is depicted in Table 2. The total proposed duration of the project is 36 months, with an estimated start date of January 1, 2023, and an estimated completion date of December 31, 2025. In addition to the project deliverables shown in Table 1, quarterly progress reports (QPRs) will be submitted at the ends of Quarters 1-11.

It is important to note that the dates for Task Reports 2 and 3 may be shifted (if so, most likely to sooner dates), depending on the discussion at the Intermediate Technical Panel Meeting and the scheduling of the implementation portion of the project. The duration of Task 2 will of course depend heavily on the chosen pursued application(s). The timing of the implementation project and bridge monitoring will depend on the duration of Task 2, the identification of a bridge project for implementation, and ultimately the construction schedule. The research team will be in constant communication with the TP concerning any changes to the proposed project schedule shown in Table 2.

Table 2: Project Time Schedule

Activities	Dates	Project Quarters 1-12											
		1 Jan 1 - Mar 31, 2023	2 Apr 1 - Jun 30, 2023	3 Jul 1 - Sep 30, 2023	4 Oct 1 - Dec 31, 2023	5 Jan 1 - Mar 31, 2024	6 Apr 1 - Jun 30, 2024	7 Jul 1 - Sep 30, 2024	8 Oct 1 - Dec 31, 2024	9 Jan 1 - Mar 31, 2025	10 Apr 1 - Jun 30, 2025	11 Jul 1 - Sep 30, 2025	12 Oct 1 - Dec 31, 2025
Kick-off Meeting	1/23/2023	X											
Task 0 - Project Management		X	X	X	X	X	X	X	X	X	X	X	X
Task 1 - Literature Review and Identification of Pursued Application		X	X							X	X	X	X
Task 1 Report	6/23/2023		X										
Intermediate Technical Panel Meeting	7/10/2023			X									
Task 2 - Close Minor Research Gaps				X	X	X	X	X					
Task 2 Report	8/30/2024							X					
Task 3 - Implementation							X	X	X	X			
Task 3 Report	3/28/2025									X			
Task 4 - Monitoring Bridge Performance										X	X	X	X
Task 5 - Analysis of Results and Reporting			X				X	X	X	X	X	X	X
Draft Final Report	8/29/2025											X	
Project Summary Report	10/10/2025												X
Performance Measures Report	10/10/2025												X
Project Poster	10/10/2025												X
Final Report	11/21/2025												X
Final Presentation and Webinar	12/12/2025												X
Implementation Meeting	12/12/2025												X
Implementation Report	12/19/2025												X

BUDGET

This proposal requests $260,055 in funding from MDT, as shown in the itemized budget presented in Table 3. The researchers have tentatively allocated a $1,500 budget for in-state travel expenses. The travel costs are difficult to itemize at this time, due to the unknown location/environment of the implementation portion of the proposed project. The researchers tentatively expect to make 2-3 trips somewhere in the state. The costs will include vehicle fuel and (most likely) no more than 2 overnight stays at a nearby hotel for 3 people. The pay rates and benefit rates of the investigators are provided in Table 4. Projected expenditures by task and deliverable are shown in Table 5. Projected expenditures by state fiscal year are shown in Table 6.

The budget below reflects total costs for MSU to complete its role in the proposed tasks. It does not include the total costs for the implementation project beyond MSU's role. The implementation project will follow MDT's standard letting and bidding processes and will include the costs of the implementation of the FRP technology, including mockup and construction costs. The MDT technical panel will be heavily involved in conversations beforehand to mitigate there being any completely unexpected deviations from this proposed project budget of $260,055.

Table 3: Project Budget

Item	Total
Salaries	$143,653
Benefits	$27,891
In-State Travel	$1,500
Expendable Supplies and Materials	$20,000
Student Tuition	$15,000
Total Direct Costs	$208,044
Overhead - 25%	$52,011
Total Project Cost	**$260,055**

Table 4: Key Personnel Pay Rate and Benefits

removed from publicly posted proposal

Table 5: Task, Meeting, and Deliverable Budget

Task	Budget
0 - Project Management	$13,542
1 - Literature Review and Identification of Pursued Application	$26,476
Deliverable: Task 1 Report	$2,302
2 - Close Minor Research Gaps	$70,556
Deliverable: Task 2 Report	$6,135
3 - Implementation	$61,348
Deliverable: Task 3 Report	$5,335
4 - Monitoring Bridge Performance	$38,724
5 - Analysis of Results and Reporting	$35,638
Total	**$260,055**

Table 6: State Fiscal Year (SFY) (7/1 – 6/30) Breakdown

	State Fiscal Year				
Item	2023	2024	2025	2026	Total Cost
Salaries	$23,942	$47,884	$47,884	$23,942	$143,653
Benefits	$4,648	$9,297	$9,297	$4,648	$27,891
In-State Travel	$250	$500	$500	$250	$1,500
Expendable Supplies and Materials	$3,333	$6,667	$6,667	$3,333	$20,000
Student Tuition	$2,500	$5,000	$5,000	$2,500	$15,000
Total Direct Costs	$34,674	$69,348	$69,348	$34,674	$208,044
Overhead - 25%	$8,669	$17,337	$17,337	$8,669	$52,011
Total Project Cost	**$43,343**	**$86,685**	**$86,685**	**$43,343**	**$260,055**

STAFFING

Dr. Kirsten Matteson will be the Principal Investigator (PI) and will be the primary manager and sole point of contact with the MDT project manager. The Principal Investigator will be responsible for ensuring that the objectives of the study are accomplished, executing the project tasks, and preparing the written reports. Dr. Michael Berry will be the Co-Principal Investigator and will assist Dr. Matteson in project management and research-related tasks. One graduate student will be employed to assist with all aspects of the proposed project and one undergraduate student will be employed for assistance in the laboratory. Regular meetings will be held between the PIs and students throughout the project.

The research team is well qualified, experienced, and available to conduct this research, and, to the best of its ability, will deliver a quality finished product in a timely and efficient manner. The level of effort proposed for principal and professional members of the research team will not be changed without prior consent of the TP. The following subsections describe some of the qualifications and experience of the project personnel in addition to each person's role in this study.

11.1 Dr. Kirsten Matteson – Principal Investigator

Dr. Matteson is an Assistant Professor in the Civil Engineering Department at MSU, joining the Department in August of 2018. Her primary research interest involves investigating new materials and their possible structural applications, especially materials with potential for a positive global change. Her research experience includes investigating composite materials for structural elements and numerical modeling. Her modeling background is with both the finite element method and the discrete element method. She has performed extensive FEA simulations on composite materials, including plastic-aluminum composite I-beams and multi-layered ceramic capacitors. More recently she has focused her research efforts on ultra-high performance concrete applications. She was a Co-PI on MDT's Trail Creek Bridges project where UHPC was used in precast pile cap joints and shear keys between precast deck elements. She is also currently the PI on the Exploration of UHPC Applications for Montana Bridges project, which is now focused on bridge deck overlays. This project is on track and set to conclude July 31, 2023.

11.2 Dr. Michael Berry – Co-Principal Investigator

Dr. Berry is an Associate Professor in the Civil Engineering Department at MSU and has a research background in reinforced concrete structures and the behavior of these structures subjected to earthquake excitations. More recently his work has focused on concrete materials and their use in transportation applications and structural elements. Of note, he recently completed multiple phases of research to develop and implement non-proprietary UHPC in Montana, culminating in an implementation project in which the MT-UHPC was used in all field cast joints on two bridges over Trail Creek near Wisdom, MT. This project was awarded AASHTO's President's Transportation Award for Research. He currently serves on several ACI committees including: Committee 341A - Earthquake-Resistant Bridge Columns, Committee 555 - Recycled Materials in Concrete, and Committee 306 - Cold Weather Concrete.

11.3 Graduate and Undergraduate Students

This research effort will be supported by qualified graduate and undergraduate research assistants, who will work part-time on this project throughout its duration. A graduate student has been identified, Emtiaz Ahmed, a current Ph.D. student whose master's thesis was titled "Performance of FRP-Strengthened Reinforced Concrete Beams Subjected to Low Temperature", the preliminary research discussed previously in this proposal. Pertaining to the proposed research project, he will assist with performing the literature review, identifying the FRP application(s) that will be pursued, carrying out any required specimen preparation and laboratory testing, analyzing data, implementation and bridge monitoring, and helping to synthesize information for the final report. The undergraduate student will mainly provide assistance with the laboratory work, including specimen preparation and testing.

11.4 Research Team Hours and Availability

It is anticipated that the proposed work associated with this research project will take 4676 person hours. The number of hours committed to the project, the percent of time vs. total project hours, and the percent of time on an annual basis for each member of the research team are shown in Table 7. Key personnel assigned to accomplish the work associated with this project are generally available throughout the duration of this project. In the event that the level of effort proposed for the principal investigator requires significant modification, written consent will be sought from the Technical Panel to justify and approve this change.

Table 7: Summary of Person Hours by Task

Name or Support Classification	Role in Study	Task 0	Task 1	Task 2	Task 3	Task 4	Task 5	Total	Percent of Time vs. Total Project Hours	Percent of Time - Annual Basis
Kirsten Matteson	Principal Investigator	90	24	200	200	50	60	624	13%	10%
Michael Berry	Co-Principal Investigator	45	24	200	170	20	60	519	11%	8%
Graduate Student	Involved in Tasks 1-5	0	600	600	600	600	600	3000	64%	48%
Undergraduate Student	Involved in Tasks 1-5	0	100	100	100	100	100	500	11%	8%
Business Mgr.	Assisting with reporting and accounting	12	0	0	0	0	0	12	0%	0%
Admin Staff	Assisting with reporting and accounting	6	3	3	3	3	3	21	0%	0%
	TOTAL:	153	751	1103	1073	773	823	**4676**	N/A	N/A

FACILITIES

The required equipment is already available in the Civil Engineering Department at MSU.

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