TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT
Q2/2023

Lead Agency:
Washington State Department of Transportation (WSDOT)

INSTRUCTIONS:
Lead Agency contacts should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # ***TPF-5(491)***	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 1 – December 31)

TPF Title (follow link to TPF webpage)**:**

Super-Elastic Copper-Based and Iron-Based Shape Memory Alloys and Engineered Cementitious Composites for Extreme Events Resiliency

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Lead Agency Project ID: UCB 1874	**Other Project ID (i.e., contract #):** T-1874	**Project Start Date:** 2022-12-01
Original Project Start Date: 2022-12-01	**Original Project End Date:** Phase 1 - 2023-11-30 Phase 2 – 2025-11-30	**If Extension has been requested, updated project End Date:** N/A

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Commitments to date $ (3yrs)	Obligations to date $	% Obligated	Contracted to date $	Expended to date $	Expended to date as % of $ contracted	Completed this quarter $
220,000	170,000	77.27%	120,000	67,289	56.07%	53,709

Project Description:

The objective of this research project is to:

1. evaluate and test several innovative columns which have self-centering feature to provide minimum residual displacement after earthquake.
2. improve column serviceability after earthquake by decreasing damage and spalling of concrete within column plastic hinge region; and
3. provide cost comparison among columns having different engineered materials; and
4. develop self-centering column design specifications. Particularly, in this proposed research, the low-cycle fatigue characteristics, corrosion resistance, machinability and coupling mechanisms with traditional steel rebar, and cost of CAM and Fe-SMA super-elastic alloy (SEA) bars will be studied.

Direct comparisons will be made with Nickel-Titanium (NiTi) SEAs (and traditional steel reinforcing bars as applicable) to illustrate the advantages/disadvantages of each material. If successfully demonstrated for their suitable characteristics, the CAM and Fe-SMA SEA bars could replace their NiTi counterparts at a significantly lower (up to ten times) cost and accelerate their applications in bridges. Therefore, the outcomes of this project are directly relevant to state departments of transportation and bridge and structural engineers and designers. This proposed project will build on the success of previously implemented WSDOT's application of shape memory alloy/engineered cementitious composite (SMA/ECC) in the columns of the SR-99 on-ramp bridge in downtown Seattle while making a direct impact on advancing and securing the national transportation network.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Low cycle fatigue testing of Fe-Mn-Si alloy that started in the previous quarter were completed. Additionally, the machining of both NiTi and NiTiCo was completed. Preliminary monotonic and cyclic testing of the NiTi and NiTiCo bars was performed to understand the basic properties of these shape memory alloys. It was found that additional heat treatment was required on these bars to achieve superelastic properties. The necessary heat treatment was performed and the super-elasticity was achieved. Simultaneously with the testing activities, moment-curvature analysis of typical columns with conventional reinforcement and shape memory alloy reinforcement in the plastic hinge started.

Anticipated work next quarter:

In the upcoming quarter, the remaining tests on the NiTi and NiTiCo bars will be completed. Specifically, we need to perform monotonic and cyclic tests at different temperatures as well as low-cycle fatigue testing. Additionally, the work on moment-curvature analysis will continue and preparation of the draft final report for the first phase of the project will start.

Significant Results:

For Fe-Mn-Si alloys, it was found that the initial prestrain has a large influence on the residual prestress when the bars are subjected to different levels of cyclic strain amplitude. Given the high ductility of the bars, we found that the bars can be prestrained to large strains in the order of 20%. This allows the bars to maintain a higher prestress force even at large lateral drift ratios in bridge columns. It was found that the bars could retain about 50% of the actuation stress or prestress at 1% strain amplitude if they are prestrained to 25% strain for actuation. The same bars showed 30% remaining prestress if they were prestrained to 15% and no prestress if they were prestrained to less than 5%. It was also found that the temperature did not affect remaining prestress as a function of the strain amplitude. Under low-cycle fatigue

testing, the Fe-Mn-Si alloys showed very high cycle counts achieving no degradation of maximum or minimum stresses when the bars were cycled 500 times up to 0.5% or 1% strains.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

On successful completion of Phase 1 (proof of Concept) we will be ready to start with Phase 2 which involves large-scale model testing, cost analyses, and the development of design specifications. Ideally, we want to run this back-to-back with Phase 1. However, we can only do this if we have sufficient funds to cover the budget needed for Phase 2 ($280k) already obligated and available. At this point we will only have $100k of remaining commitments of which only $50k is obligated and available to contract. It seems difficult to break Phase 2 up into smaller chunks that can run sequentially, have meaningful interim deliverables, and still stay on schedule and budget. At the end of Phase 1 (Nov 2023) we need a total of another $180k in commitments and obligations in order to proceed to Phase 2.

Potential Implementation:

We will have a better idea on the implementation trajectory of the findings on completion of Phase 1 (proof of concept) of this study which will lead to Phase 2, within the scope of this pooled fund, if successful and if adequate funding is committed and obligated to conduct Phase 2. The results of Phase 1 look very promising so far!