TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT
Q1/2023

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 $	Obligations to date $	Contracted to date $	Completed to date $	Completed to date %	Contracted this quarter $	Completed this quarter $
200,000	170,000	120,000	13,580	11.3%	N/A	N/A

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.):

In this quarter, experimental studies were carried out on Cu-Al-Mn and Fe-Mn-Si alloys. More than fifty experiments were performed on these two materials, and a large amount of useful test data was obtained and analyzed. Progress meetings with WSDOT were held approximately every two monthly, during which the latest research status and plans were presented.

Specifically, ten Cu-Al-Mn and twenty Fe-Mn-Si alloy samples were prepared and tested under the designed conditions. Monotonic and incremental cyclic loading were performed on Cu-Al-Mn alloy at low temperature -40℃, room temperature 20℃ and high temperature 50℃. Key mechanical properties for bridge applications were extracted and analyzed. For Fe-Mn-Si alloy, monotonic and incremental cyclic loading similar to that for Cu-Al-Mn alloy was used; in addition, actuation tests simulating the post-tensioning applications of self-centering bridge columns were also performed on Fe-Mn-Si alloy.

Currently, low cycle fatigue testing of Fe-Mn-Si alloy is in progress and it is expected to be completed within two weeks.

Anticipated work next quarter:

Low-cycle fatigue actuation tests on Fe-Mn-Si alloy will be completed and the experimental data will be extracted and analyzed. Machining of Ni-Ti-Co and Ni-Ti alloy into designed geometry will be completed. (Since Ni-Ti-Co and Ni-Ti alloy are very difficult to machine, special machine operation, such as water jet cutting, electrical discharge machining and low speed turning, are needed. These operations are currently ongoing). After that, monotonic, and incremental cyclic tests on Ni-Ti-Co and Ni-Ti alloys will be conducted at low temperature -40℃, room temperature 20℃ and high temperature 50℃. The mechanical properties important for bridge applications will be extracted and analyzed.

Significant Results:

Based on the tests performed so far, the main findings concerning Cu-Al-Mn and Fe-Mn-Si alloys are described as follows. For Cu-Al-Mn alloy, the maximum recovery strain and fracture strain are about 7% and 10% respectively at different temperatures. The yield strength of Cu-Al-Mn increases linearly with the increasing of ambient temperature, at around 2 MPa/℃. The maximum recovery strain and temperature dependence of Cu-Al-Mn are all superior to conventional Ni-Ti alloys (according to existing literature), indicating the potential of applying Cu-Al-Mn alloy in bridges. For Fe-Mn-Si alloy, the yield strength decreases with increasing ambient temperature. From -40℃ to 50℃ , the yield strength decreases from 532 MPa to 472 MPa. In addition, excellent deformability and ductility were observed within a wide range of temperature, the fracture strain exceeds 50% in all test scenarios from -40℃ to 50℃. The high deformability and low temperature dependence of Fe-Mn-Si alloy suggest their advantages for bridge applications.

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).

None.

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 has been committed to complete Phase 2.