Key Points

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$35,000

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Tran-SET
Texas A&M University

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$70,000

Reduction of Structural Damage from the Thermal Expansion of Concrete Using Multifunctional Materials

Brief Project Description

Thermal expansion of concrete plays a significant role in durability of the transportation infrastructure and causes misalignment, cracking, and structural failure. This study aims to use high performance materials that address the issue of thermal expansion integrated into next generation designs, to enhance the longevity and safety of these structures. As a result, the objective of this study is to design and characterize the use of multifunctional materials that stabilize the changing structure due to thermal expansion. The characteristics of these materials will work in conjunction with the temperature dependence of concrete. This will require very specific properties from the materials, making trained shape memory alloys (SMA's) a likely candidate, to meet the characteristics required to address the problem statement.

Problem Statement

Control of thermal expansion is a critical goal of engineering design in a wide range of applications, particularly in cases where system components are small, are subject to large changes in temperatures, or require extreme dimensional stability over a wide range of temperatures. Thermal expansion causes thermal stresses in structures and structural failure can happen as a result of excessive thermal strains. In structures made of brittle materials (e.g., concrete), stresses induced by the thermal expansion would lead to the catastrophic structural failure.

Thermal expansion compensation often requires materials with either negative or (close to) zero thermal expansion. SMAS are one of the best candidates for this purpose. However, integrating such high performance materials into next generation designs is challenging since systems and materials that address the problem of thermal expansion must not significantly increase the overall complexity of the current infrastructure and must be scalable so that they may be implemented in a variety of structural configurations. Materials with passive actuation based on changes in temperature could be used to counter the damage caused by thermal expansion. Solutions that incorporate design optimization and adaptive, durable materials are of particular interest.

Objectives

The main objective of this study is to improve durability and extending the life of the transportation infrastructure using multifunctional materials. More specifically, the objective is to design and characterize the use of multifunctional materials that stabilize the changing structure due to thermal expansion.

Intended Implementation of Research

Workforce Development

The research team has previously given short courses on SMAs to engineers from numerous Texas companies (oil and gas focused). This course will be updated based on the study findings. Additionally, a series of live web-based seminars will be organized on topics related to the study to further demonstrate its impact.

Education

Training of graduate students will be coordinated with the recently awarded NSF-NRT-DESE program at TAMU on the design and discovery of smart materials. Each year, support for two undergraduates will be sought through the Summer Research Experience for Undergraduate Students Program and recently awarded NSF-REU site on multifunctional. Research findings will also be used to develop experimental learning modules for a graduate-level courses as well as an introductory level undergraduate materials science course.

Outreach

Outcomes will be promoted amongst K-12 students on various occasions to attract them to pursue a degree in one of the STEM disciplines, including: STEMFest to mentor Girl Scouts and the Women in Mathematics and Sciences (WIMS) community, “Kids Career Day” Camp, and “Summer Experience in Engineering” (SEE).

Anticipated Impacts/Benefits of Implementation

Study results will help design smarter civil infrastructures incorporating multifunctional materials into the old civil engineering material. Since the SMA proposed is relatively cheaper than other common SMAs, it is anticipated that the findings could be implemented in real infrastructures made of concrete, asphalt concrete, and other complex large infrastructures. Low-cost Fe-SMAs and other multifunctional materials can be considered as a replacement for components made of steel (e.g., in reinforced or plain jointed concrete pavements) to control distresses resulting from thermal expansion during seasonal/daily temperature change. Through a combined approach of structural optimization, mechanics, and materials design, this research aims at simultaneously achieving advantageous mechanical properties and passive actuation behavior in a single material for concrete infrastructures. The study will define a viable path for technology transfer by establishing partnerships with commercial alloy manufacturers and cultivate awareness through workforce development and outreach activities.

Weblinks:

- Tran-SET's website (http://transet.lsu.edu/research-in-progress/)
- TRB's Research in Progress (RIP) database (https://rip.trb.org/View/1505441)