



SPR RESEARCH PROGRAM SECOND-STAGE PROBLEM STATEMENT FY 2010

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I. PROBLEM NUMBER

ST-10-09

II. PROBLEM TITLE

Performance of Near-Surface Mounted CFRP for Shear Strengthening of Reinforced Concrete Bridge Girders

III. RESEARCH PROBLEM STATEMENT

ODOT is actively engaged in bridge rehabilitation and strengthening throughout the state. One area of focus has been in shear strengthening of reinforced concrete deck girder bridges. Methods that have been deployed include internal and external supplemental steel stirrups, surface-bonded carbon fiber reinforced polymers (CFRP), and post-tensioning. The CFRP method is popular because of the relative ease of installation and low impact on appearance. However, CFRP requires careful surface preparation to assure proper bond. Furthermore, recent research showed that exposure to freeze-thaw conditions when moisture is present can result in the moisture freezing behind the CFRP, thereby reducing the strength of the bond between the CFRP and the concrete.

A new strengthening method called near-surface-mount carbon fiber reinforced polymers (NSM-CFRP) has emerged that may avoid the problems of conventional CFRP. This relatively new technology involves cutting a shallow groove in the concrete, placing a strip or rod of CFRP material in the groove, and filling the groove with an epoxy adhesive to bond the CFRP to the concrete. The installation requires substantially less labor and uses significantly less adhesive materials than conventional CFRP methods. Because the adhesive is applied within the groove, bonding between the CFRP and concrete improves. In addition, the NSM-CFRP is below the concrete surface, which should eliminate the freeze-thaw problem observed for some conventional CFRP installations. A test conducted at Oregon State University (OSU) on a single large girder with NSM-CFRP showed good results. However, NSM-CFRP for strengthening is a new technique with little available test data especially for long-term durability under environmental exposure and fatigue conditions.

Experimental results are needed to quantify the structural performance of members strengthened with NSM-CFRP. If the results show that NSM-CFRP provides performance and cost benefits over CFRP, then design methods and installation details will be required for engineers to specify NSM-CFRP for strengthening projects.

IV. RESEARCH OBJECTIVES

The objectives of the research are:

- To quantify the structural performance under operating conditions of reinforced concrete girders strengthened for shear with NSM-CFRP.
- To develop design and detailing recommendations for shear strengthening reinforced concrete girders with NSM-CFRP.

V. WORK TASKS, COST ESTIMATE AND DURATION

Task I: Literature Review

Estimated cost: \$20,000

A literature review will be performed to collect information related to behavior of NSM-CFRP materials and retrofit applications to reinforced concrete beams.

Task II: Bond Performance

Estimated cost: \$50,000

Subassembly specimens representing an isolated portion of a girder will be used to assess how well NSM-CFRP strips remain anchored in their grooves. The subassemblies will be exposed to the stress conditions representative of actual girders and to freeze-thaw, varying levels of moisture, and high cycle fatigue.

Task III Shear Performance

Estimated cost: \$250,000

Large-scale specimens representative of lightly shear reinforced girders typical of those in the ODOT inventory will be strengthened with NSM-CFRP. The specimens will be strengthened following manufacturer guidance and available but unproven design codes. Ten full-size girder specimens are proposed:

- T specimens with different NSM-CFRP quantity and no exposure (2 specimens)
- Inverted T (IT) specimens with different NSM-CFRP quantity and no exposure (2 specimens)
- T and IT specimens with freeze-thaw exposure (1 of each = 2 specimens)
- T and IT specimens with moisture exposure (1 of each = 2 specimens)
- T and IT specimens with high-cycle fatigue exposure (1 of each = 2 specimens)

Specimens will be instrumented to measure overall member response as well as local component stresses and deformations. Cracking and any debonding of materials will be documented during exposure and strength tests. For high-cycle fatigue tests, baseline tests will be performed at intervals of 100,000 cycles to assess changes in behavior. In particular, NSM-CFRP stresses at diagonal crack locations will be measured and compared with design values. Experimental findings will be used in Task IV.

Task IV: Analysis and Design Methods

Estimated cost: \$60,000

Available design methods and analytical models will be compared with experimental findings. The ability of the current techniques to predict the available specimen strength will be evaluated. Where appropriate, modifications to existing approaches or new methods will be developed to better design NSM-CFRP for shear strengthening reinforced concrete girders, including the effects of high-cycle fatigue and environmental durability. Recommendations will be made for detailing, and design examples will be provided for the recommended approach.

Task V: Reporting

Estimated cost: \$20,000

A report detailing Tasks I – IV will be delivered to ODOT within twenty-two months after the project start-date. The report will include the experimental results, the evaluation of available analysis and design methods, and recommendations for design and detailing of NSM-CFRP for shear strengthening girders. Example calculations using the recommended methods and comparisons with existing practice will be included. A workshop will be conducted for ODOT personnel to describe the findings and the recommended guidelines.

Cost

OSU:	\$400,000
ODOT support:	\$10,000
Total:	\$410,000

Duration: 2 years

VI. IMPLEMENTATION

Meetings and presentations will be held with ODOT personnel to present research findings in-progress as well as summary findings. Background information and findings will be described in reports, papers, and peer-reviewed journals. Design examples will be provided for the methods developed. Web-based access to in-progress test data and images, analytical methods, and summary findings will be available on-line where appropriate.

VII. POTENTIAL BENEFITS

The research will reduce project costs and improve bridge strengthening project outcomes by enabling effective and durable design alternatives using NSM-CFRP materials. Findings may also be extended to flexural strengthening needs.

VIII. SUBMITTED BY

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