SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2010

ODOT Research Unit
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I. PROBLEM NUMBER

ST-10-11

II. PROBLEM TITLE

Effects of Bond-Fatigue on and Alternative Strengthening Techniques for Reinforced Concrete Bent Caps

III. RESEARCH PROBLEM STATEMENT

Many of Oregon's reinforced concrete bridges built in the 1950's were designed to permit higher shear stress in the concrete than permitted by current AASHTO standards. Compounding this problem are increased traffic volume and truck load magnitudes. Consequently, in many of ODOT's older bridges, the deep transverse beams called bent caps that support the main girders have insufficient load ratings, and in some cases the bent caps have cracked. Bridges containing these bent caps are nearing the end of their intended design lives, but additional life may be available if effective strengthening/repair techniques can be implemented.

A research program was recently completed at Oregon State University to predict the existing strength and to conduct an initial assessment of some repair techniques for cracked bent caps. A single fatigued bent cap specimen showed reduced strength because the bond between the steel shear reinforcement and the concrete had deteriorated (bond fatigue). The findings showed that more heavily reinforced members were more susceptible to bond-fatigue. These findings were in contrast to previous work on girders (slender beams) that showed more lightly reinforced members were more susceptible to bond-fatigue. Additional research is needed to quantify the effects of bond-fatigue on deep beams to accurately predict available strength of existing members that have been subjected to repeated service loads for decades.

Previous limited research on repair techniques for bent caps showed that the strength gain was not as much as anticipated. The unique behavior of bent caps and other deep beams produces a complex stress state in the member that requires special consideration for different repair alternatives. These repair alternatives include internal shear reinforcement, external post-tensioning, near surface mount carbon fiber reinforced polymers (NSM-CFRP), and externally bonded CFRP with improved anchorage. Additional research is needed to assess these repair methods for bent caps and to enable better analysis and design tools for shear strengthening bent caps.

IV. RESEARCH OBJECTIVES

The objectives of the research are:

- Quantify the potentially deleterious effects of bond fatigue on bents caps.
- Develop analysis, design, and detailing recommendations for different repair/strengthening techniques for bent caps.

V. WORK TASKS, COST ESTIMATE AND DURATION

Task I: Literature Review and ODOT Inventory Assessment *Estimated cost: $20,000*

A literature review will be performed to collect information related to behavior of deep beams with different repair techniques. A database of ODOT bent caps already strengthened will be developed to ensure that the subsequent experimental specimens reflect the inventory conditions.

Task II: Laboratory Tests *Estimated cost: $350,000*

The results of Task I will be used to develop the details of laboratory testing in Task II. It is anticipated that ten large-size specimens representing deep beams will tested to collect performance data. Characteristics of the specimens will be:

- Control specimen
- Fully debonded stirrups

- NSM-CFRP
- Surface bonded CFRP without supplemental anchorage
- Surface bonded CFRP with supplemental anchorage
- Post-tensioning with epoxy injection of cracks
- Post-tensioning without epoxy injection of cracks
- Post-tensioning of uncracked specimen
- Supplemental internal epoxy-bonded steel reinforcing
- Additional specimen alternative based on outcomes

Task III: Analysis and Design Methods *Estimated cost: $60,000*

Available design methods and analytical models will be compared with the experimental findings. The ability of the current techniques to predict the measured specimen strength will be evaluated. Where appropriate, modifications to existing approaches or new methods will be developed to better predict strengths and to design repairs for shear strengthening bent caps, including those subjected to high-cycle fatigue effects. Recommendations will be made for detailing the repairs, and design examples will be provided for the recommended approaches.

Task IV: Reporting *Estimated cost: $20,000*

A report detailing Tasks I – III 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 alternative repair techniques for shear strengthening bent caps. 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:	$450,000
ODOT support:	$15,000
Total:	$465,000

Duration: 2 years

VI. IMPLEMENTATION

Meetings and workshops 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

Research will ensure that the capacity of existing bent caps is adequately characterized including the effects of bond-fatigue; that repair techniques for diagonally cracked RCDG bent caps are experimentally validated to effectively extend the service life of these bridge members; that the repaired member performance can be reasonably predicted; and that ODOT engineers can make effective and economical selection of strengthening alternatives. These will help ensure continued safe operation of bridges while minimizing unnecessary replacement, posting, or strengthening and facilitate economic movement of freight. Without this research, the capacity and therefore reliability of large in-service deep beams subjected to high-cycle bond fatigue is uncertain and expensive bridge repairs could be put into service that do not provide the strength anticipated by the designers.

VIII. SUBMITTED BY

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