SPR RESEARCH PROGRAM SECOND-STAGE PROBLEM STATEMENT FY 2009

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I. PROBLEM NUMBER

ST-09-09

II. PROBLEM TITLE

Alternative Strengthening Techniques for RCDG Bent Caps

III. RESEARCH PROBLEM STATEMENT

Diagonal cracks have been identified in both the main girders and bent caps of RC bridges across Oregon. Bent caps are members that support the main girders and are oriented transverse to the direction of traffic. Typical 1950's vintage bent caps are deep beams that support four to five main girders and are in turn supported on two relatively slender columns. Bridges containing these bent caps are nearing the end of their originally intended design lives but additional life may be available if effective strengthening/repair techniques can be implemented. Bent caps are non-redundant structural members and member failure can lead to collapse of the bridge.

Experimental tests of two full-size repaired bent caps at Oregon State University were recently completed. The bent caps were repaired using 1) external longitudinal post-tensioning and 2) externally bonded carbon fiber reinforced polymer (CFRP) stirrups, both of which are used for strengthening ODOT bridges. The test results showed that these repair methods for bent caps did not provide the anticipated performance. For one technique, the measured strength was approximately 20% of expected. The unique behavior of bent caps, members having short spans relative to the depth of the section, produce non-uniform strains and a single dominant diagonal crack at failure that requires special consideration for different repair alternatives.

As a result of the significant differences in behavior between bent caps and main girders, as well as recent test results with less than anticipated strength increases, additional research is needed to enable ODOT engineers to more effectively design and evaluate different repair techniques for diagonally cracked RC bent caps. Research is needed to characterize the different repair methods and to enable better design and analysis tools for strengthening bent caps. Repair techniques to be addressed include supplemental bonded internal stirrups (commonly used by ODOT), external post-tensioning (including epoxy injected cracks and non-injected cracks), near-surface mount CFRP, and additional externally bonded CFRP with anchorage concepts to delay/prevent debonding failures.

IV. RESEARCH OBJECTIVES

The proposed research will develop analysis, design, and detailing recommendations for different repair/strengthening techniques for bent caps in RC bridges. Research will enable validation of repair techniques to effectively extend the service life of bent caps and provide ODOT engineers with effective design alternatives.

V. WORK TASKS, COST ESTIMATE AND DURATION

Task I - Literature Review and ODOT Inventory Assessment

A literature review will be performed to collect information related to behavior of deep beams with different repair techniques. Much of the literature has been collected and synthesized and will accelerate this step. The proposed research will also collect and categorize the current repair techniques that have already been implemented by ODOT for RC slab-girder bridge bent caps. The design philosophy and alternative materials will be identified. A database will be developed and subsequent experimental results will compare expected performance with measured strength for elements in this inventory.

Task II - Laboratory Tests and Assessment of Alternative Repair Methods for Bent Caps
The proposed research will provide experimental data on the behavior and capacity of RC deep beams strengthened with alternative repair schemes. Final details will be developed based on the database collection in Task I. Ten full-size tests are proposed. Parameters to be included in the study are:

- Control specimen
- Effect of fully debonded stirrups on unrepaired strength
- Near-surface mount CFRP material
- 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

Experimental specimens will be constructed with reinforcing details and concrete sections typical of older RC bent caps. The specimens will be 16 in. by 68 in. deep and will include indirect loading. Specimens to be repaired will be strengthened after inducing diagonal cracking in the member. Service level performance will be measured before and after repair installation. Only one of the post-tensioned specimens will be uncracked before applying the post-tensioning to consider the viability of the technique as a preventive measure. Specimens will be instrumented to measure overall and local member responses.

Experimental findings will be used to develop design and analysis recommendations that will enable ODOT engineers to design and detail effective retrofits for RC bent caps.

Budget and Duration
Task I: 2 months, $25,000.
Task II: 20 months, $425,000.

Total: 24 months, $450,000.

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 developed and available on-line where appropriate.

VII. POTENTIAL BENEFITS
ODOT will be better able to make decisions regarding the most effective repair/strengthening technique for RC bridges with cracked bent caps. This will maximize the effective use of limited funds to maintain the safety and economy of bridges in the ODOT inventory.

VIII. SUBMITTED BY
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