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PROJECT OVERVIEW REPORT

1. UTC Identifying Number
   DTRT12-G-UTC16
2. Center Identifying Number
   CAIT-UTC-036
3. Project Title
   Guidelines for Embedment Length of Carbon Fiber Reinforced Polymer (CFRP) Strips in Near Surface Mount (NSM) Retrofitted Concrete Structures
4. Principal Investigator & Contact Information
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7. Project Description
   The NSM-CFRP method for retrofitting is becoming an effective way of strengthening reinforced concrete structures compared to the conventional external bonded retrofitting (EBR) technique. This can be attributed to increased stiffness and strength resulting from the significantly more effective bonding in the NSM method. In this method grooves are cut on the concrete surface, epoxy is filled in and then CFRP reinforcement is inserted in the slits. The commonly used CFRP reinforcements for strengthening in the NSM method are round and square/rectangular bars. Recent studies have shown narrow rectangular CFRP strips to be highly effective and more economical than round or rectangular bars in resisting static, fatigue and impact loads. However, research highlights the need to provide larger development length for these strips than what is recommended by ACI 440.2R-08 [1] to avoid premature failure. There is also clear lack in the literature for the recommended embedment length of CFRP strips in concrete owing to limited experimental data. It is also noteworthy that the development length formula for rectangular reinforcements given in ACI 440.2R-08 is only applicable to normal strength concrete (i.e. up to 5000 psi) and it does not distinguish between flexural and compression strengthening. However, in-situ concrete strengths are often found to be well above this limit and CFRP strips are known to perform differently in tension and compression. As a result, the use of same formulation for both cases cannot be justified. Finally, although rectangular in nature, CFRP strips should be treated differently than conventional square/rectangular reinforcements due to higher

stress concentrations at the edges. All these factors provide impetus for this research project.

8. Implementation of Research Outcomes (or why not implemented)
   This research intends to address the limitations of current development length formula for rectangular NSM reinforcements in ACI 440.2R-08 and extend it to CFRP strips as well. To overcome the issue of premature debonding failure resulting from high stress concentrations at the edge of strips, in practice, there are several cases where NSM reinforcement is embedded into the supports. Although this seems to fix the problem it can significantly drive up installation cost and in some cases support conditions prohibit this solution completely. On the other hand, if one were to strictly follow the current design guidelines, they are at serious risk of producing deficient structures from incorrect provisioning of development length for CFRP strips. To strive balance, the multi-faceted problem has to be looked at rigorously with laboratory testing and proper analyses that accounts for debonding due to knife edge effect at the ends of strips.
   To achieve the aforementioned objectives, a thorough literature study will be done to identify critical relationships such as beam span to depth ratio, length of CFRP to beam ratio, concrete strength, etc., for all the test specimens that performed well and poorly. From the lessons learned and to test new criteria we will then focus our efforts on experiments where we test several small size, mid-size and few large size beams and/or slabs. Parameters will include concrete strength, CFRP strip size (thickness) and length, strengthening in tension and compression. We will also develop theoretical models to capture experimental bond behavior.
   In order to ensure the project produces practical solutions, we will closely collaborate with state bridge engineers and practitioners.
9. Impacts/Benefits of Implementation (actual, not anticipated)
   To Be Determined
10. Dates and Budget
    Start date: 01/01/2014
    End date: 12/31/2014
    UTC (CAIT) Dollars: $50,000
    Cost Sharing: $50,000
    Total Dollars: $100,000
11. Keywords
    NSM-CFRP, near surface mount, carbon fiber reinforced plastic, carbon fiber reinforced polymer, development length, concrete strengthening, retrofit
12. Web Links (Reports and Project Website)
    http://cait.rutgers.edu/cait/research/guidelines-embedment-length-carbon-fiber-reinforced-polymer-cfrp-strips-near-surface-m