SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2017

ODOT Research Unit
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I. PROBLEM NUMBER AND TITLE

FY 17-051 A Comparative Study of Materials for Concrete Patch Repair

II. RESEARCH PROBLEM STATEMENT

Patch repair is a commonly used method for rectifying localized deterioration and damage in reinforced concrete members. Our existing infrastructure continues to age and funds for repair and new construction are increasingly tightened. It is essential for ODOT to specify constructible and durable repair materials that are also cost effective. Of particular concern is the long-term performance of patch repair materials, particularly those exposed to deicing chemicals. In Oregon, $MgCl_2$, with a corrosion inhibitor, is the main deicing chemical used. A current ODOT research project, led by the authors of this proposal, is investigating the impact of $MgCl_2$ on the current inventory of ODOT bridge deck concrete. As also shown in this ongoing project, little is known about the performance of repair materials subject to the $MgCl_2$-based deicers with or without corrosion inhibitors. While the deleterious role of magnesium on the hydrated phases of concrete is well documented [1], there is no reliable literature on the performance of the interface between the repaired zone and the substrate in the presence of magnesium-based deicers nor on the repair material itself. Experience in other jurisdictions where deicing salts are heavily used shows us that patches fail, regardless of the repair material used, with accelerated rates of corrosion at the borders of the repaired zone where the concrete contains chlorides. This type of failure, referred to as “halo” or “ring-anode” failure is a result of electrochemical incompatibility between the repaired zone and the substrate [2, 3]. Embedded sacrificial anodes (e.g. zinc anodes) are recommended to minimize this halo effect, but their effectiveness depends on the repair material properties (e.g. electrical resistivity), its compatibility with the substrate, and the type of the deicing chemical used.

III. RESEARCH OBJECTIVES

The objectives of this project are to: **(1)** develop quantifiable information to compare the performance between different repair materials in field and laboratory investigations; **(2)** refine criteria to identify other acceptable sources for repair materials for the qualified products list (QPL); and **(3)** improve current specifications and guidance to ensure successful application and performance of repair materials. <u>It should be noted that ASTM (or equivalent) tests that the repair material vendors provide to demonstrate the effectiveness of their products do not cover ODOT’s unique circumstances with respect to structures, environmental/exposure conditions, and the type of deicing chemical used. Our investigation will address performance issues above and beyond those provided by the product vendors.</u>

IV. WORK TASKS, COST ESTIMATE AND DURATION

Task 1: Review current concrete repair practices and materials of ODOT and other DOT’s having similar durability issues (e.g. corrosion, freeze/thaw, other) with particular emphasis to physical, chemical and electrochemical incompatibility issues between the repaired zone and the substrate. We will also investigate resources related to the use of $MgCl_2$ + corrosion inhibitor-based deicers with a focus on long-term impacts to repair material concrete. The objective is to short list the best options that are currently used based on performance and best practices and document this in a state-of-the-practice report.

Task 2: Identify field sites where concrete patch repair has been done using the material (s) currently on ODOT’s approved material list. The research team will work with ODOT to select the most relevant locations to give a range of exposure conditions, repair type and repair material as well as age of the repair. The field sites will be monitored periodically throughout the project using both non-destructive and destructive evaluation techniques to determine the current performance of the repair materials. The concrete surrounding the patches is also of great interest due to the aforementioned halo effect caused by electrochemical incompatibility between the patch and the substrate. <u>Additionally, the research team will include the small-scale slabs already at OSU’s exposure site (part of SPR 780) that have been repaired using one of the ODOT approved repair materials. These slabs (and repair materials) have been subject to wet/dry cycling with the commercially available $MgCl_2$ deicing chemical</u>

(and under control conditions) for approximately the past 1.5 years. This represents a highly controlled and well-known source of information and samples for this project. It also represents a significant economic benefit given that the samples have been cast as part of SPR780 and they have long-term exposure already well underway.

Task 3: The research team will work with ODOT to select and procure different repair materials for laboratory investigations. Materials currently on the approved materials list as well as additional materials based on discussions with ODOT and the outcomes of Task 1 will be selected.

Task 4: Laboratory investigations will be done to characterize and evaluate each repair product. These will include: working time, strength gain versus ambient temperature, durability factors such as, abrasion, impact, shrinkage, permeability (water and chlorides), electrical conductivity for sacrificial anode compatibility and performance factors such as cracking, bond and life cycle cost analysis. Our investigation will address performance issues above and beyond those provided by the product vendors.

Task 5: From Tasks 1-4 modifications to ODOT's current specifications will be proposed. The research team will develop a best practices guide that includes guidance for selection of new/alternative repair materials for the QPL.

Total Duration: 30 months Budget: $275,000 (OSU portion)

V. IMPLEMENTATION

The project will involve comparative, experimental and analytical studies to accomplish the tasks identified above. Main implementation outcomes of the study will be **1)** best practices guide **2)** selection criteria for new/alternative repair materials **3)** identification of currently available materials that satisfy the performance criteria established by this project. The research team will work with ODOT to revise, publish and distribute the best practices guide and to provide selection criteria for new/alternative repair materials. Also, the current list of accepted materials for repair may be augmented based on the findings of this research project for currently available materials

VI. POTENTIAL BENEFITS

As result of current and foreseeable economic challenges and reduction in State and Federal funds for new infrastructure, it is critical to extend the service life of existing transportation assets in Oregon. Repair of reinforced concrete structures, constitutes a large part of the efforts to achieve this goal. This research will allow ODOT to pre-emptively reduce the number of repair failures by developing effective and reliable repair procedures for reinforced concrete elements that are exposed to its de-icing chemical. The proposed research will provide ODOT the tools to 1) identify repair materials with advantageous characteristics for repair of ODOT structures 2) modify existing best practices documents to ensure long-term performance of repairs with these materials and 3) develop selection criteria for new/alternative repair materials. As the main benefit of this research ODOT will be able to extend the lifespan of existing infrastructure in an economically viable way. The use of existing slabs that are part of an ongoing ODOT project (SPR 780) will bring additional value to the proposed project and will allow us to conduct our research on realistically deteriorated specimens that reflect conditions of ODOT's bridge inventory.

VI. LIST OF REFERENCES *(optional)*

[1] Cody, R.D., Spry, P.G. (1997). The role of magnesium in concrete deterioration. Iowa DOT HR-355.

[2] Soleimani, S., Ghods, P., Isgor, O.B., Zhang, J. (2010). Modeling the kinetics of corrosion in concrete patch repairs and identification of governing parameters. Cement and Concrete Composites, 32(5): 360-368.

[2] Emberson, N.K., Mays, G.C. (1990). Significance of properties mismatch in the patch repair of structural concrete, Part 1: properties of repair systems, Magazine of Concrete Research, 42: 147-160.

VII. SUBMITTED BY

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