

MPC-437

January 1, 2013- December 31, 2013

Project Title:

Fiber Reinforced Concrete for Structure Component

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Research Needs:

Deterioration of concrete is one of the major causes for poor performance and shortened life expectancy of road way infrastructures nationwide. Transportation departments are challenged to extend the service life of PCC (Portland cement concrete) structural components such as columns, bridge decks, and abutments in light of budget constraints. Because traditional concrete material has very poor resistance to tensile stress, reinforced structures often experience cracking and spalling, leading to accelerated corrosion of imbedded reinforcement, failure under severe loading, and lack of durability. One technology that may generate promising solution to this longevity problem is applying fiber reinforced concrete (FRC) material to these dynamically loaded structural components. Originated in the 1950's, concrete material reinforced with steel (SFRC), glass (GFRC), and synthetic fibers such as polypropylene fibers has been used in many structural engineering applications for several decades. It has a solid reputation for superior resistance to crack development and abrasion. Studies also indicated improvement on strength, ductility, resistance to dynamic loading, and resistance to freeze-thaw effects. Because of these improved properties, FRC has been used in many forms including bridge deck, repair, and building beam column connections. Currently, there is a wide variety of FRC products available for engineering applications, the applicability and cost-effectiveness of different products has not been evaluated systematically for SDDOT in the past. There are many variables in the adoption of FRC products. Micro-synthetic or larger (macro) fibers are manufactured from polypropylene, polyethylene, polyester, nylon and other synthetic materials such as carbon, aramid and other acrylics. Depending on fiber type and application, dosage rates may range from 0.03 to 0.2% by volume of concrete (0.5 to 3.0 lb/y³). Engineers find it challenging to interpret performance claims by manufacturers based on unstandardized testing procedures and what seem to be high fiber dosage recommendations.

The sheer volume of relevant FRC literature, research and case studies is overwhelming, spanning a period of more than 45 years. Moreover, it has been nearly 20 years since SDDOT has delved into the topic. Many of the fiber materials used in SDDOT projects have been phased out or discontinued, and many more new products have been developed. What little guidance that is available on the proper specification and use of FRC comes from the American Concrete Institute (ACI) and is generic in nature. Research is needed to investigate recent product development, evaluate fiber products currently on the market, and generate guidance for use, testing, and potential application of FRC. For lack of guidance,

SDDOT may be sacrificing improved durability and performance as implementation lags technological developments in the area of fiber reinforced concrete structural components.

By the 1960s, steel, glass fiber reinforced concrete and synthetic fibers such as polypropylene fibers were being used in concrete in response to shortcomings of conventional concrete such as brittle failure under excessive loading, excessive cracking, and issues with durability. For more than 25 years, FHWA and AASHTO have supported research to demonstrate the benefits of fiber reinforced concrete in bridge construction and repair. Many projects have been funded through FHWA's Innovative Bridge Research and Construction and Innovative Bridge Research and Deployment programs. An extensive number of independent, ongoing research projects speak to the potential of fiber reinforcement to improve the durability and physical properties of concrete. In recent years, researchers continue to identify new materials in the family of FRC with potential to further improve structural performance. For example, high-performance fiber-reinforced cementitious composites (HPFRCCs) possess the unique ability to flex without fracturing and achieve strength hardening similar to steel material. Though new advanced materials such as HPFRCC have been tested extensively in the lab and employed in limited engineering applications, cost effectiveness for routine highway projects and long term performance is not well established.

Current material standard for fiber reinforced concrete material is ASTM C1116/C1116M-06, which does not address cost effectiveness of the material in bridge applications. The most commonly conducted test for FRC material is a two-point loading beam flexural test that focuses on flexural behavior. It is expected that the application of FRC in South Dakota bridge projects will utilize FRC in form of panel/slab or small patch for repairs. Thus it is unlikely these components will experience loading condition similar to a standard testing beam. As the resistance to crack development and fatigue in a plate form and the resistance to abrasion is more relevant to the expected application of FRC on bridges, a more representative testing procedure should be developed to address these properties directly. Testing of FRC plates has been done in other studies and revealed different aspects of material property than standard testing and can be referenced in this study. The standard testing procedure for abrasion (ASTM C944) can also be adopted to generate useful data related to FRC performance under repeated vehicle wear. The appropriate test procedures for the intended application of FRC will also need to be investigated in this study.

There has been some research conducted in SD on FRC for road overlay construction. In 1994 a SDDOT research project (SD1994-04, Evaluation of Non-Metallic Fiber Reinforced Concrete) was initiated to study the use of 3M's Polyolefin Fibers in several applications, including a bridge deck overlay for the structure at Exit 212 over I-90. The study indicated that the overlay performed favorably. Because of the fibers' ability to enhance the concrete's structural properties, the Department decided to include them in the deck overlay concrete for two severely deteriorated bridge decks at Exit 32 on I-90. Study SD1997-11 (Evaluation of Two Low-Slump Dense Non-Metallic Fiber Reinforced Concrete Deck Overlays at Exit 32 on I-90 in South Dakota) of the overlays, which were constructed in 1997, recommended that fiber concrete overlays be considered not only on badly deteriorated bridge decks, but on a case by case basis for all bridges. Since these research results were obtained more than a decade ago, it is of the interest of this study to look into similar applications with the newer fiber products available today.

Research Objectives:

- 1) Identify and describe prevailing and best practices for design and construction of fiber reinforced concrete structural components in South Dakota and nationally.
- 2) Assess potential application, performance, costs, benefits, drawbacks, and constructability of fiber reinforced concrete structural components.
- 3) Develop guidance for design, material selection, construction, testing, and application of fiber reinforced concrete structures in South Dakota.

Research Methods:

The project will start by conducting extensive literature search, survey of different state agencies, and interview with SDDOT. Although there are numerous FRC products available, it is expected that only a subset of them is suitable for structural applications in DOT related projects. The commonly used products will be identified and the most suitable applications in South Dakota will be examined.

Proper structural applications of FRC common in South Dakota DOT projects will be identified through interview with DOT engineers. The FRC material and potential structural components will be evaluated experimentally at SDSU's structures lab. The testing results together with literature review and interview findings will be combined to provide realistic assessment on performance, costs, benefits, drawbacks, and constructability of these structural applications.

A South Dakota specific guideline of using FRC in structural applications will be developed with consideration of the nature of work, availability, experience, and economic aspect of FRC application in South Dakota. This guideline will be concise but cover all of commonly available products in SD construction projects.

Expected Outcomes:

If successful, this research will provide practical but valuable guidance for cost-effective design, performance testing, and construction of FRC structural components. Guidance may be incorporated into the SDDOT Materials Manual.

Relevance to Strategic Goals:

The expected outcomes of this project are directly related to the following goals: State of Good Repair and Economic Competitiveness.

Educational Benefits:

This project will provide a valuable learning experience to both graduate and undergraduate students. A master's level graduate student will be hired to work on this project which will provide the material for a master's thesis. Undergraduate students will also be hired to work on this project. Results from the study can be incorporated into courses on structural concrete and concrete materials.

Work Plan:

- 1) 1) Meet with the project technical panel to review project scope and work plan.
- 2) Review and summarize existing literature pertaining to prevailing and best practices in structural applications of fiber reinforced concrete regionally and nationally—including design, materials selection, construction, and laboratory and field testing.
- 3) Interview SDDOT personnel to assess performance of previous FRC structural projects and describe current FRC specifications and practices in South Dakota.
- 4) Prepare a draft interview guide and a list of candidates for interviews of state transportation agencies with experience and expertise in structural applications of FRC.
- 5) Meet with the project's technical panel so present findings of tasks 2 & 3 and to secure approval of the draft interview guide and list of interview candidates.
- 6) Conduct and summarize interviews of officials from other state transportation agencies with experience and expertise in structural applications of FRC to assess agency specifications, practices, and experience with cost and performance.

- 7) Prepare a laboratory testing plan to verify material properties, determine optimal fiber dosage, and assess the performance of a select list of candidate fibers with high potential for success based on evidence of superior performance in structural applications.
- 8) Meet with the project's technical panel to review results of agency interviews and the proposed testing plan.
- 9) Develop concise but comprehensive guidance for design, materials selection, construction, and laboratory and field testing of FRC for structural applications.
- 10) Prepare a final report and executive summary of the research methodology, findings, conclusions, and recommendations.
- 11) Make an executive presentation to the SDDOT Research Review Board.

Project Duration: 18 months

Project Cost:

Total Project Costs: \$100,000

MPC Funds Requested: \$45,000

Matching Funds: \$55,000

Source of Matching Funds: SDDOT

TRB Keywords:

FRC; Fiber reinforced concrete; Bridge deck; Long term performance

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