JUNE 2008

LTRC

RESEARCH
PROJECT CAPSULE

07—3ST

TECHNOLOGY TRANSFER PROGRAM

REPAIRING/STRENGTHENING OF BRIDGES WITH POST-TENSIONED FRP STRANDS AND PERFORMANCE EVALUATION

PROBLEM

According to TRIP (The Road Information Program, 2002), in the state of Louisiana, 4,591 bridges, or 34% of the total 13,426 bridges, are classified as substandard; Louisiana was ranked 10th in the nation, with the highest deficient bridge rate. A large number of existing bridges on both on-system (interstate and state routes) and off-system (parish routes) in Louisiana are weight restricted. There is an urgent need to repair and upgrade this state's bridge system. Applications of new materials, such as fiber reinforced polymers (FRP), to bridges are new explorations in the process of dealing with the state's infrastructure problems. FRP has been used since the 1940s in the aerospace and defense industries. However, only in recent times has it won the attention of civil engineers as an alternative to more conventional structural materials. This proposed study deals with externally post-tensioned strands to strengthen/repair a load-posted concrete and/or steel bridge. The long term performance of the bridge will then be monitored during its service. Taking advantages of FRP materials will potentially provide a new approach to enhancing the transportation infrastructure in Louisiana.

OBJECTIVES

The proposed project is to take advantage of some new developments in bridge engineering to apply FRP post-tensioning strands on a selected structure. The use of externally post-tensioned FRP strands to repair/strengthen bridges and fiber optic sensor (FOS) systems is envisioned in this study. The ultimate objective is to take advantage of promising FRP materials to develop a more durable, lower maintenance intensive bridge system to save the limited budget for other urgent needs of the transportation infrastructure system.

METHODOLOGY

In an attempt to achieve the research objective previously stated, work is classified into six parts. The first part is to collect information for FRP post-tensioned bridges; the second part is to design the FRP repairing/strengthening scheme following design codes/guidelines; the third part is to conduct finite element analysis in order to verify the design and provide a comparison basis for field measurements; the fourth part is to verify instrumentation in a laboratory environment; the fifth part is field installation and testing, and the sixth part is to develop a long-term monitoring strategy. The entire research plan is divided into the following tasks.

Task 1—LADOTD Inventory Survey

The objective is to obtain a general idea of how many bridges might be candidates for superstructure (more specifically girders) strengthening using the FRP post-tensioning techniques. Practice of some lead states will also be reviewed. Information will be presented to PRC as described in Task 3.

JUST THE FACTS

Start Date:
October 1, 2007

Duration:
30 months

End Date:
April 1, 2010

Funding:
Federal

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SPECIAL POINTS OF INTEREST:

- Problem Addressed
- Objectives of Research
- Methodology Used
- Implementation Potential

Application of P-T force on one end of a bridge

A sample FRP rod used for post-tensioning

Task 2—Literature Review
The research team will examine and review the current technology and state-of-the-art practice regarding the application of FRP strands in bridges, especially post-tensioned FRP strands. Information will be gathered from journals, research reports, and other avenues.

Task 3—Interim Report
An interim report summarizing findings from Tasks 1 and 2 will be submitted within six months of the initiation of this project. The PRC will decide in which direction to go for the remaining tasks of the study.

Task 4—Design of Bridge Repairing/Strengthening with FRP Post-Tensioning Strands
The repairing/strengthening of the selected bridge (either steel or concrete) will be designed following available guidelines, such as those developed by the ACI 440 committee. The information regarding the post-tensioned FRP strands, i.e., number of strands, locations, post-tensioning forces, etc., will be determined based on the requirements of both strength and serviceability.

Task 5—Numerical Modeling of Bridge with FRP Post-tensioning Strands
A numerical prediction procedure will first be developed, and the results will then be used to verify the design. The predicted results will also be compared with future field test results under given loads. In addition, the predicted results will be used to guide the future instrumentation and monitoring study.

Task 6—Design of Monitoring Systems
Bridges are by nature very large in size. Instrumenting and monitoring an entire bridge is very expensive. Therefore, optimizing the instrumentation is very important. The numerical results from Task 4 will provide important information, such as stress distribution, of the FRP post-tensioned bridge system. The information will be used to guide the design of the instrumentation and monitoring system for the selected bridge. The information collected from monitoring/testing will, in turn, be used to calibrate the calculation model in an effort to improve the future prediction, which reflects the interactive nature of prediction and monitoring.

In the preliminary plan, the following instrumentation and monitoring systems will be designed to thoroughly evaluate the bridge performance.

Instrumentation for Strains—Traditional strain gages will be installed at critical places across the bridge section(s), as will be suggested by the numerical predictions. Possible placements of strain gages may be the bottom of beams at the critical section and the FRP strands. The number of gages will be decided once the bridge system and product are selected. The sensors will also serve the purpose of cross-checking the fiber optic sensor readings.

Instrumentation for Accelerations—Accelerometers will be installed along the bridge span. The bridge acceleration under ambient vibration or truck-induced vibration will be processed to predict the modal information. Dynamic approaches, such as using natural frequency, natural mode, or flexibility matrix for damage detection and model calibration, have been used by many researchers for the past few decades. The change of modal information will indicate the change of structural properties between the current conditions and future deteriorated conditions. The collected modal information will provide a baseline for future bridge performance assessment.

Embedded Sensors for Long-term Performance—The fiber optic sensor system is a good candidate for long-term performance evaluation. The sensor can either be embedded in the FRP strands or surface mounted to the structure and can be used over the bridge's service life. If possible, the research team will work with the manufacturer to embed the optic sensors in the FRP strands for a long-term performance monitoring of the deck.

Task 7—Installation and Field Testing
The research team will participate in the field installation process and will install different gages as discussed earlier. The bridges will be field tested under given loads, perhaps before and after the repairing/strengthening. Short-term performance will be assessed using instrumentation, as discussed above. Measured strains and accelerations will provide useful information for the structural behavior and will be helpful for the calibration of the finite element models. Measured information will also provide baseline information regarding the bridge system for long-term performance monitoring and evaluation.

Task 8—Guideline for Long-Term Monitoring of Deck with FRP Prestressing Strands
Strain gages will be installed on the bottom surface of the bridge girders and on FRP strands. With time, the change in strain can give a rough estimation of the change in the stiffness of the FRP post-tensioned bridge, and thus the degradation of the bridge. A guideline and/or strategy for long-term monitoring of the specific bridge will be developed for the LADOTD engineers for future long-term monitoring.

Task 9—Final Report
The final report will document the results of the entire research effort, including, but not limited to, evaluation of previous methods, methodology used in the present study, experimental and analytical findings, conclusions, and recommendations. Appropriate items listed under "deliverable" will be included in the final report.

IMPLEMENTATION POTENTIAL

The project is a direct implementation of research results by using FRP post-tensioned strands to repair/strengthen bridges in Louisiana, which will develop needed expertise and application procedures. The research results may be presented to the state structural and bridge engineers and also at the Louisiana ASCE meeting, Louisiana Transportation Conference, TRB conferences, and in journals. Dissemination of the research results will aid in the implementation of future FRP post-tensioned bridges, and feedback from practical engineers will help judge the progress of implementation. It has direct implication for meeting LADOTD performance measures to improve the condition and safety of Louisiana's deficient bridges.

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