AUTOMATED MFL SYSTEM FOR CORROSION DETECTION

Quarterly Progress Report
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Submitted to:
ABC-UTC
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1. Background

The proposed project is aimed at using the methodology that is developed under other projects and supported by other agencies and automates the process for accelerated field application. The scope of the work and budget is kept at minimum budget since the majority of the related work and research have been completed under other projects.

2. Problem Statement

Bridge owners are facing a challenging problem of inspecting steel elements embedded in the concrete. Examples include steel strands in the grouted ducts (plastic or metal ducts) within segmental concrete bridges, prestressing steel in the prestressed concrete girders and post-tensioning tendons in the adjacent concrete box girders. Within the next two decades, it is expected that the condition of embedded steel elements within concrete bridges to pose serious safety problems. The use of prestressed concrete girders in the US dates to about the early 50's. Discussion with State bridge engineers indicates that there is a tremendous interest in developing a methodology that can inspect the condition of embedded steel elements within concrete bridges in ways that is quick, economical and user-friendly for field application.

Over the last 20 years, PI, Dr. Azizinamini has been working on the development of Magnetic Flux Leakage (MFL) method for inspection of steel strands embedded in concrete bridges, such as segmental concrete or post-tensioned bridges. At the same time, Professor Hillimeir, of the Technical University of Berlin, over the last 30 years has been carrying out similar research in Germany. In 2016, an agreement was made between Dr. Azizinamini and Dr. Hiilimier to join forces and develop a version of the MFL method suitable for US application for inspecting steel elements in concrete bridges. Both were successful to obtain a project from FDOT to conduct a joint research, with Dr. Azizinamini as PI and Dr. Hillimier as Co-PI. Since 2016, Dr. Azizinamini has visited Berlin several times, while Dr. Hillimier visiting FIU to exchange research results.

The MFL method is not new and has been used by many in the past. However, one major problem has prevented the effective use of MFL. Namely, the presence of other mild steels over and under the ducts or post-tensioning rods or prestressing strands, mask the signals coming out of embedded steel elements of interest. The research team led by Dr. Azizinamini was finally able to solve this challenge and presently the method is fully capable of identifying the areas where corrosion activities are present.

3. Research Approach and objectives

The main objective of this limited project is to automate the technology that is developed to inspect the health of steel elements within concrete bridges.

4. Prior Example Results

This section provides a very brief summary of one test that demonstrates the manual application MFL method.

Figure 1 shows four segments of a segmental concrete bridge that were saw cut and brought to FIU Labs for the development of the MFL method.

Figure 1: Segments of segemental concree bridge at FIU.

Surprisingly few ducts within these segments were not grouted, which provided an opportunity for researchers to place steel strands with known damages and check the capabilities of the method.

Figure 2 shows the location of the main strands, the location of secondary strands and the location of rebars with the location of the defect. The strands were magnetized from the bottom side initially with a depth of 7" of the magnet from the bottom surface of the segment and then the strands were again magnetized by keeping the depth of the magnet 3" from the bottom surface of the segment. **Figure 3** shows the MFL system which includes a permanent magnet, magnetic sensors, linear encoder, data acquisition system, and power supply.

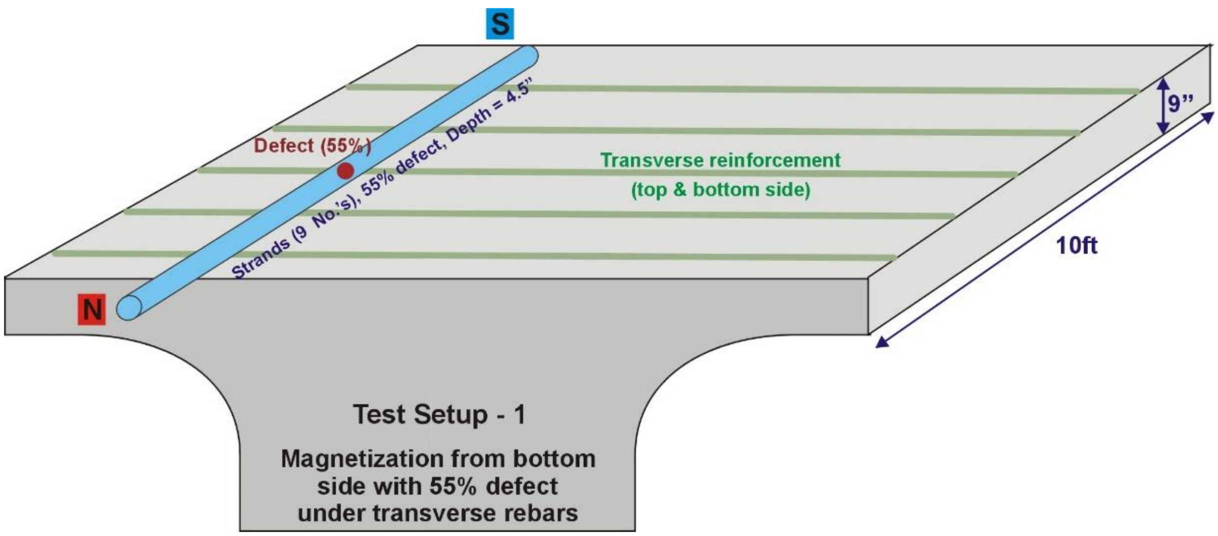

Figure 2: Location of defects in post-tensioning strands with transverse reinforcment.

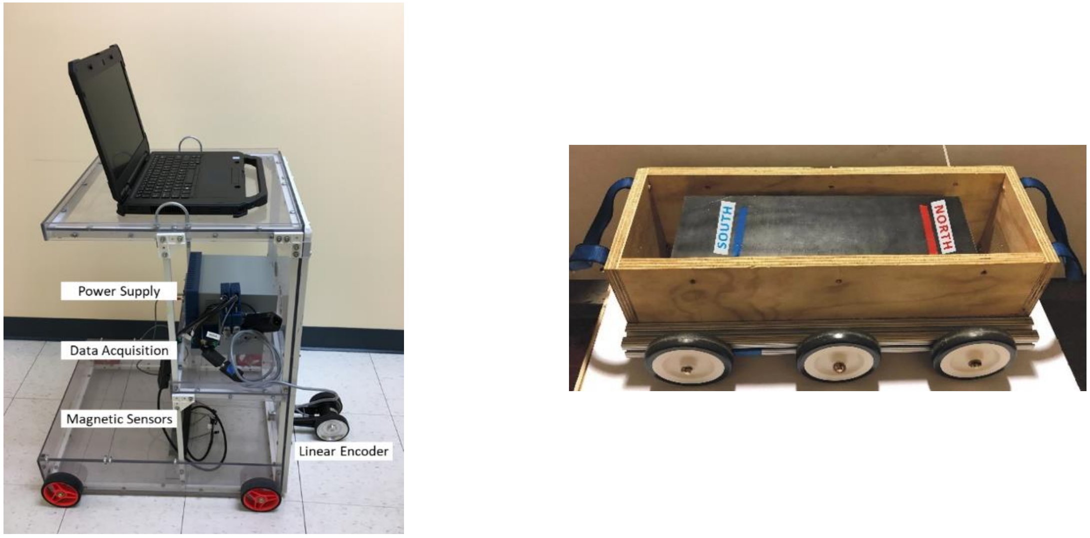

Figure 3: MFL measuring system (left), permanent magnet (right).

Results of MFL with signal of 55% defect under transverse reinforcement

The first test was performed by keeping the location of the defect in such a way that the transverse reinforcement is passing just above and below the defect. As the tendon contains nine strands and the defect was introduced in five strands which makes it 55%. The MFL signal is shown in **Figure 4**. The signal shows clearly the location of the defect and the transverse rebars present above and below the defect are not affecting the signal.

This methodology is effective when active corrosion is caused by 20% steel cross-sectional losses.

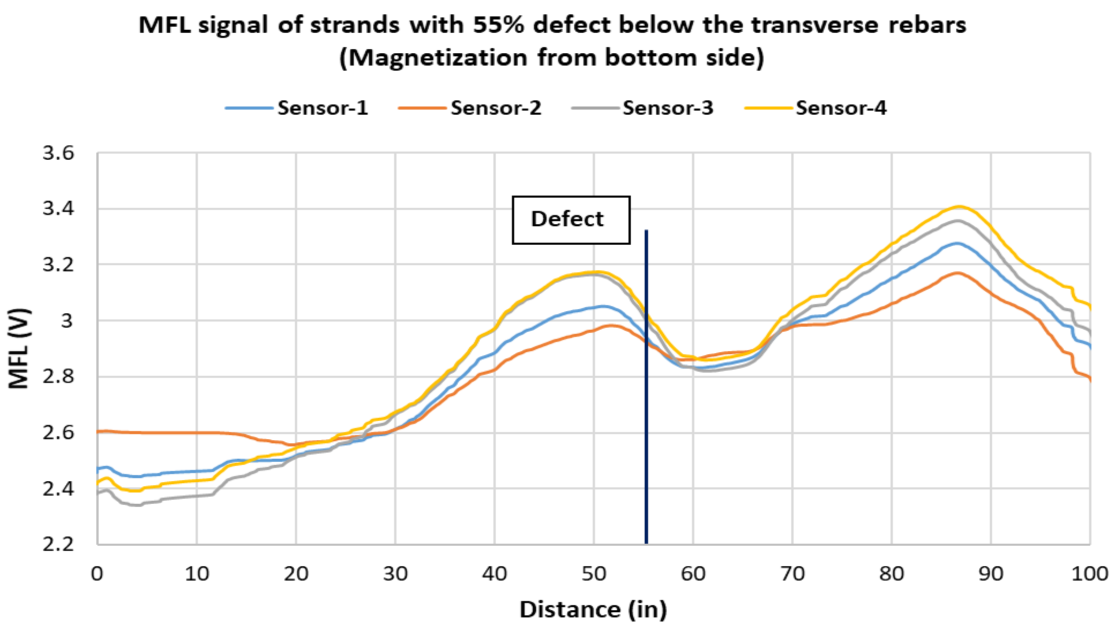

Figure 4: MFL results for 55% defect under transverse reinforcement.

5. Description of Research Project Tasks

The following is a description of tasks carried out to date.

Task 1- Development of an automated approach for MFL

The use of various small robots in conjunction with wireless data acquisition with robots controlled from a distance is the solution for automating the procedure. Under this task, the elements of the current MFL system will be modified to make use of wireless sensors in conjunction with the use of small robots.

> *Progress: A small robot as shown in Figure 5 has been utilized as first prototype and the MFL system with wireless data acquisition was mounted on it. A second robot with an integrated MFL system will be developed next.*

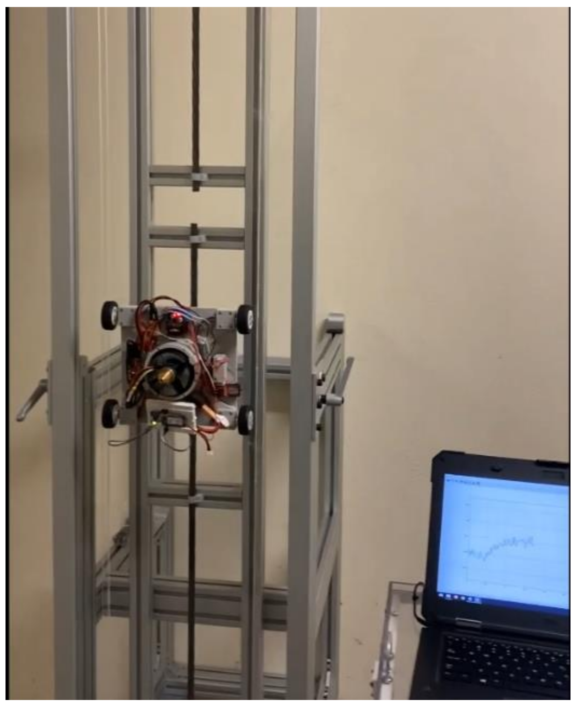

Figure 5: Prototype of automated MFL system

Task 2- Laboratory validation of the new automated system for MFL

In this task, laboratory validation of the efficacy of the automated system utilizing small robots and wireless data acquisition system. The laboratory test will be conducted on the bridge segments at FIU as shown in **Figure 1**.

> *Progress: Few laboratory tests have been performed using the prototype robot and results were satisfactory. Further testing will be performed as developed.*

Task 3– Field validation of the new automated system for MFL

In this task, field validation of the efficacy of the automated system utilizing small robots and wireless data acquisition system. The PI will work closely with FDOT to identify a bridge candidate for the deployment of the new system for field validation.

Progress: Not started.

Task 4- Final Report

A final report will summarize the findings of this proposed research.

Progress: Not started.

6. Expected Deliverables

The main deliverables will be a final report for the new proposed automated system for MFL

7. Schedule

Item	% Completed
Percentage of Completion of this project to Date	30%