Magnetic flux leakage (MFL) method for nondestructive testing of pre-stressed steel reinforcement strands

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Abstract

Deterioration of the prestressed reinforcing steel is one of the most dangerous faults in prestressed concrete girders which can lead to girder strength reduction and, ultimately, bridge collapse. The fact that the reinforcing tendons as usual are hidden under the concrete cover complicates their evaluation. This paper investigates the application of MFL non-destructive testing method for the appraisal of reinforcing steel. Magnetic and measuring systems and their design principles are discussed. Laboratory testing results for equipment prototype are also given.

1. Introduction

As part of concrete bridge construction, prestressed girders are a subject of influence of both natural and human factors like precipitation, temperature fluctuations, gritting salt etc. Due to the concrete's gradual deterioration, the prestressed reinforcing steel comes into contact with aggressive substances that manifests in corrosion. Evaluation of prestressed steel is a complicated problem and magnetic nondestructive technology is one of the possible solutions. There are a few ways to realize magnetic NDT - Induced Magnetic Field (IMF) (1) and Magnetic Flux Leakage (MFL) in Residual (2,3) or Applied (3) Fields (RF or AF). All of these realizations have similar obstacles. One of the obstructing factors is the presence of non-tensioned reinforcement. Reinforcement grids and stirrups are made with ferromagnetic still and produce high influence disturbances on magnetic instrument signal.

2. Principle of double measuring system

Periodical transverse non-tensioned bars or stirrups are parts of girders' construction and usually lie under the surface of concrete, closer to it than prestressed reinforcement tendons (Figure 1). Such location leads to their strong influence on the magnetic field sensors which are usually placed near the surface.

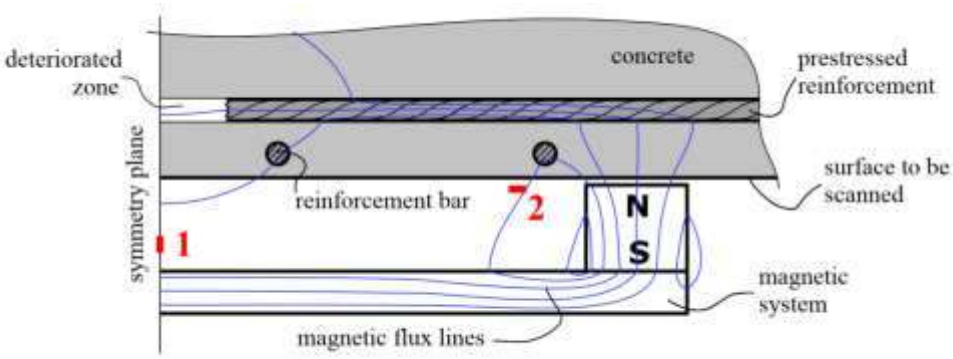

Figure 1. Schematic of magnetic NDT instrument and prestressed girder under during testing.

In this case, the signal trace will be periodical and the magnitude of peaks may exceed the signal caused by critical loss of reinforced tendons cross section. The interpretation of such traces is a very complicated task, with the result being unreliable (1). One way to increase reliability is by using two or more sets of data which are obtained with a different method or its realizations. The idea is to get a set of data sensitive to conditions of both prestressed and non-stressed reinforcements, and another set of data sensitive to the condition of non-stressed reinforcement only. Successive data processing allows to emphasize the target signal for evaluation of prestressed tendons only.

In (3), it is suggested to analyse MFL in AF and MFL in RF data sets simultaneously. This approach requires at least two scanning cycles, but up to 13 are recommended. Data set alignment quality for simultaneous processing depends on factors such as distance measurement accuracy, surface roughness and the ability to precisely repeat the scanning path. All impact the reliability of interpretation data.

Disadvantages listed above can be bypassed by combining two measuring systems into one. A magnetic system with permanent magnets to magnetize longitudinal reinforcement tendons (Figure 1) is proposed. The configurations of magnetic poles and iron yoke are numerically optimized to produce both main and stable secondary fluxes on the working position. The main flux is coupled with both kinds of reinforcements, but mostly with longitudinal ones. On the other side, a secondary fluxis coupled with transverse stirrups. The primary magnetic sensor (usually a line of sensors) is placed at the symmetry plane of the magnetic system with a calculated gap (point 1 on Figure 1) for additional reduction of transverse stirrups influence. The primary magnetic sensor measures the leakage of main magnetic flux. The secondary magnetic sensor (also a line of sensors) is placed at the calculated distance to the pole at the concrete surface (point 2 on Figure 1) and measures the secondary magnetic flux or its perturbations, which are coupled with transverse reinforcement. The same sensor can be placed near another magnetic pole. This approach requires only one scanning cycle, alignment of data sets becomes more reliable and a complex data set becomes suitable for automated processing.

2. Laboratory testing results

The principle of presented double measuring system has been developed into a prototype. It consists of two poles with permanent magnets, a yoke, a double measuring system with three lines of Hall sensors, distance counter and a PC for the purpose of data logging. A wooden real size mockup of a prestressed concrete girder was built as a test sample for the prototype. The sample has three strands of steel wires encased in plastic tubes at the depth of 90mm from the surface to the axis and a few transverse steel rods at the depth of 25mm. Each strand consists of 32x6mm wires. Diameter of all transverse rods is 12mm.

Two events were modeled. The first was with 30% loss of strands cross section area at the length of 100 mm and the second with the absence of one of transverse rods. Results are shown as C-scans at Figure 1. 1a and 1b – main and secondary sensors signals for the first event. 1c and 1d – main and secondary sensors signals for the second event.

It can be seen, that the loss of strands cross sections appears greater on the main sensors (Figure 1a) whilst the absence of a transverse rod – on the secondary sensors signal.

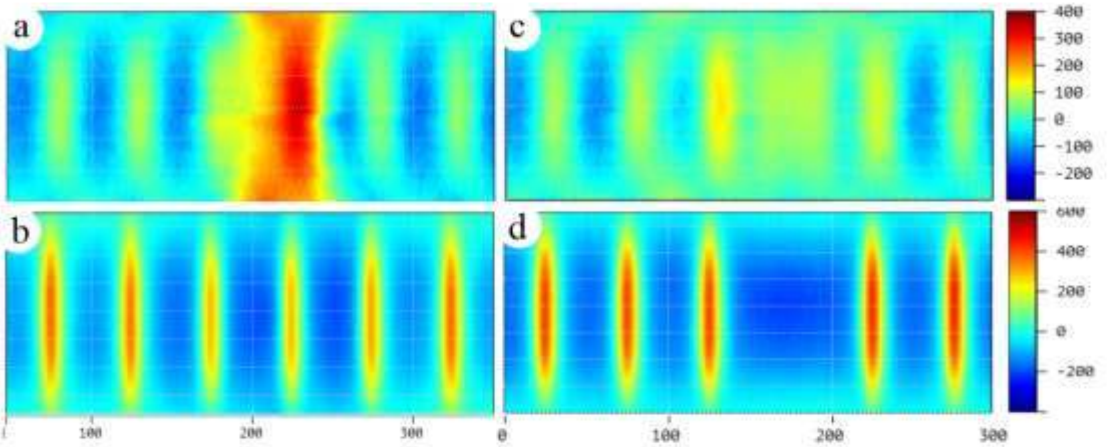

Figure 2. Experimental signals in C-scan mode.

3. Conclusions

The presence of non-tensioned reinforcement in concrete prestress girders obstructs wide application of magnetic methods for prestressed steel tendons evaluation. The discussed double magnetic measuring system simplifies in interpretation of data signals, improving their reliability and opens the way for the development of MFL nondestructive equipment for the evaluation of prestressed tendons.

References

1. Nims D. K. "Magnetic Sensor for Nondestructive Evaluation of Deteriorated Prestressing Strand – Phase II, Final Report." University of Toledo, August 2011.
2. Titus M. D. "Development of Induced Magnetic Field Procedure for Nondestructive Evaluation of Deteriorated Prestressing Strand." University of Toledo, May 2011.
3. Maierhofer C., Reinhardt H.-W., Dobmann G. "Non-destructive evaluation of reinforced concrete structures." Woodhead Publishing Limited, Vol.2, pp 215-243, July 2010.