Evaluation of Debonding Between Rebar and Concrete with Magnetic Force Induced Vibration Evaluation (M5) Method

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Abstract

This paper aims to present the effectiveness of the new nondestructive method dedicated to detection of the rebar-concrete debonding. The Magnetic Force-Induced Vibration Evaluation (M5) method is designed to detect changes caused by corrosion. The method's concept is to directly induce rebars' vibrations (not a whole structure), measure them, and analyze the frequency spectrum changes. The presented in the paper experiments show that the structure condition correlates with its response to electromagnetic excitation at different frequencies. In the purpose to avoid the damping of the mechanical wave by the concrete cover, a magnetic coupling was implemented. Such a solution allowed to increase the sensitivity and reproducibility of measurements significantly. The work presents the principle of operation of the M5 method as well as the results of the most critical tests.

1 Introduction

The degradation of reinforced concrete structures caused by corrosion is a significant problem all over the world. The existing NDT methods and systems allow to locate the reinforcing bars, determine their diameter, and assess the level of carbonation of concrete. The electromagnetic methods are beneficial in such applications. However, detecting the rebars' corrosion in the early phase of formation or identification of debonding remains an unresolved issue. The modal analysis is a promising tool for this purpose. [1]

2 Description of the M5 Method

The principle of operation of Magnetic Force Induced Vibration Evaluation (M5) is presented in Fig.1a. The block diagram of basic version of the M5 system is presented in Fig. 1b.

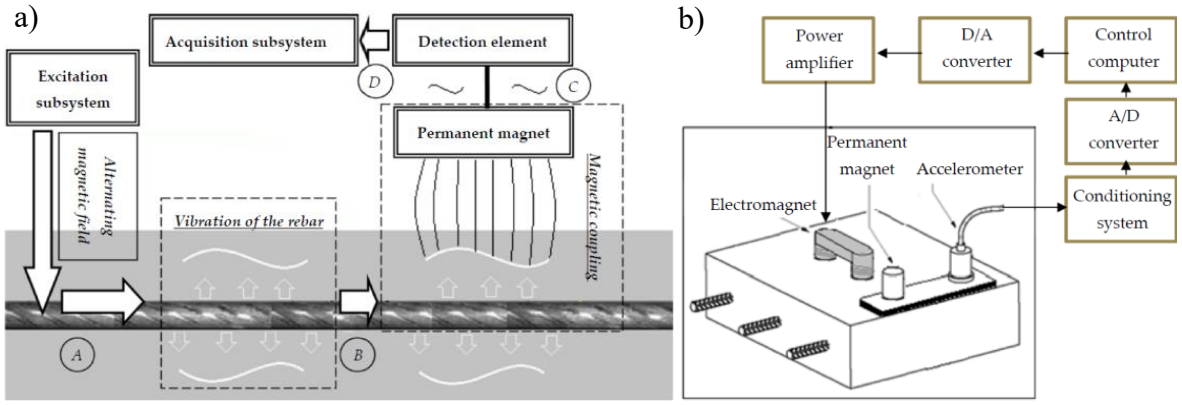
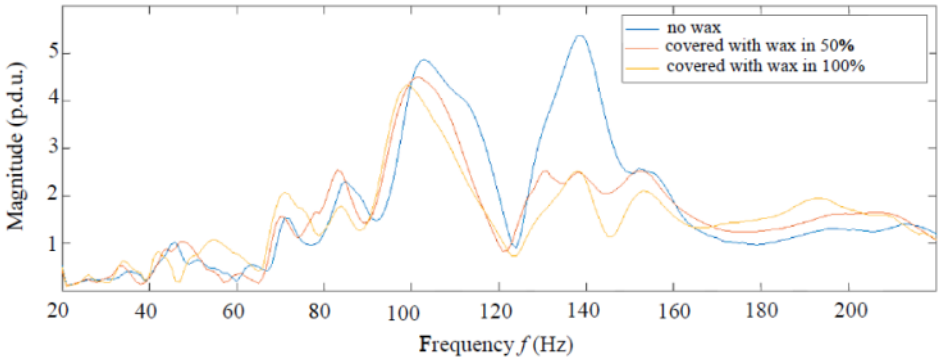


Figure 1: a) The principle of operation of the M5 system. A: vibrations of the rebar induced by an alternating magnetic field; B: vibrations of the rebar transferred to the magnet by magnetic coupling; C: vibrations of the magnet transferred to the sensing element by physical connection; D: analysis of the vibrations (e.g. modal analysis). b) The M5 system with vibrations induced by the electromagnet - block diagram.

3 Results

Three cuboidal concrete samples were used in the experiments. Every single sample contained one ribbed steel rebar. The class of the rebar was: B500 SP and diameter D = 20 mm. The rebar was placed symmetrically along the sample's length and not symmetrically along the height, giving two different concrete covers: h = 20 mm and 60 mm. In the case of 2 samples, the reinforcing bars were covered with wax: half for sample C01 and completely for sample C02. The bar in reference sample C00 remained unmodified. The wax insulation was supposed to simulate corrosion and loss of bond between the rebar and the concrete. The impact of structure debonding is presented in Fig. 2a, repeatability of the measurements in Fig. 2b.

a)



b)

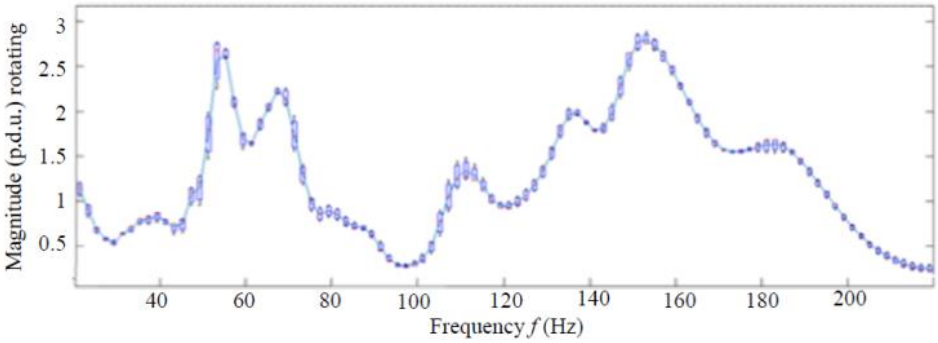


Figure 2: a) Frequency characteristics obtained for three different samples: C01 – the rebar fully covered with wax, C02 – the rebar covered with wax in 50% and C00 – the reference sample (rebar not covered with any coating), h = 20 mm; b) Evaluation of the repeatability of measurements. The sample C02; h = 60 mm with the rebar fully covered with wax was utilized.

The most significant differences between the characteristic frequency of the vibrations can be observed for frequencies between 120 and 160 Hz (Fig 2a). Theoretically, because of the system complexity and sensitivity to various factors, it can be predicted that the repeatability of the measurements can be a significant problem. However, experiments proved that this problem practically does not exist. The repeatability is a strong point of the M5 system (Fig 2b).

References

[1] Frankowski P.K., Chady T., Zieliński A., Magnetic Force Induced Vibration Evaluation (M5) Method for Frequency analysis of Rebar-Debonding in Reinforced Concrete, Measurement, Vol.182, 2021, DOI: 10.1016/j.measurement.2021.109655.

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