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Soundness evaluation of adhesive anchors using magnetostrictive vibration
磁歪振動を用いた接着系アンカーの健全性評価

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1. Introduction

In recent years, the aging of social infrastructure such as tunnels, roads and bridges that were built in the period of high economic growth has become a problem. There has been growing interest particularly for testing the soundness of adhesive anchors. Bolts are connected to a concrete wall using holes filled with adhesive materials. Since anchor bolts have been inspected by skilled workers manually through, for example, hammering test and visual inspection, it is difficult to improve the inspection efficiency. Several sensing methods have been proposed to solve this difficulty [1, 2].

We propose a non-contact evaluation method of adhesive anchors using magnetostrictive vibration and acoustic detection. In this report, the relationship between the amount of filling adhesive and the resonance characteristics of the longitudinal vibrations of bolts is discussed.

2. Sample and excitation of vibration

Figure 1 shows the structure of a concrete sample used in experiments. An M12 steel bolt was fixed with epoxy resin in a hole of 14 mm in diameter and 70 mm in depth. Four samples were prepared, and the amounts of filling epoxy resin were 0, 3.55, 5.13, and 6.70 g. A coil of 300 turns was used to excite magnetstrictive vibration in the bolts. The coil diameter and length were 17 mm and 20 mm.

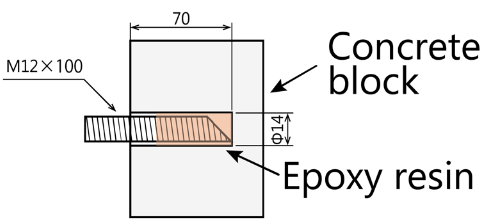

Fig. 1 Structure of concrete sample

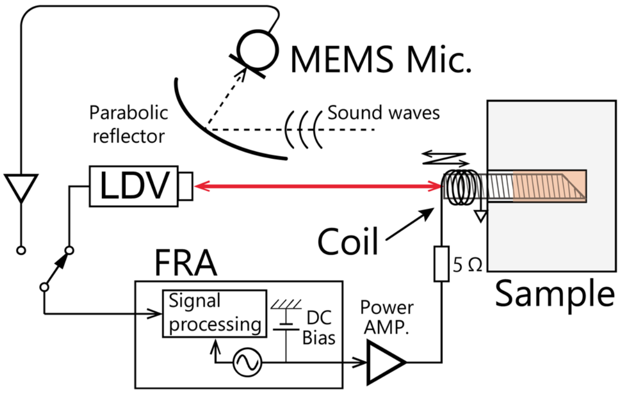

Fig. 2 Scheme of experimental system for measuring frequency characteristics of longitudinal vibration of bolts

Figure 2 shows a scheme of the experimental system for measuring the frequency characteristics of the longitudinal vibrations of the bolts. First, the vibration velocities were measured using a laser Doppler velocimeter (LDV, Graphtec Co., AT0023). By using a frequency response analyzer (FRA, NF Co., FRA5097), the frequency of magnetostrictive vibration was swept from 20 kHz to 60 kHz. The alternating current and the bias direct current were 700 mAp-p and 600 mA at 20 kHz. In addition, the sound wave radiated from the sample was measured using a MEMS microphone (Knowles Acoustics SPM0404UD5, 10~65 kHz) with a parabolic reflector (Diameter, 500 mm). Output signals from the LDV and the microphone were processed with the FRA.

3. Results and discussion

3.1. Frequency characteristics

The frequency characteristics for the different amounts of filling epoxy resin are shown in **Fig. 3**. For the results other than 0 g, moving average of 404 Hz was used for noise reduction. Sound velocity of the longitudinal wave in a steel thin rod is 5120 m/s [3)], and thus, the first and second resonances under free-free condition should appear

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at approximately 25.6 kHz and 51.2 kHz, respectively, for the bolt of 100 mm in length. These resonance peaks were observed roughly at the expected frequencies. **Figure 4** shows the resonance frequencies plotted as functions of the amount of adhesive at the first and second resonances, and **Fig. 5** shows the quality factor of the resonances. These results indicate that larger filling amounts basically lead to higher resonance frequencies and smaller quality factors for each resonance. These characteristics can be utilized to inspect the soundness of the adhesive anchors.

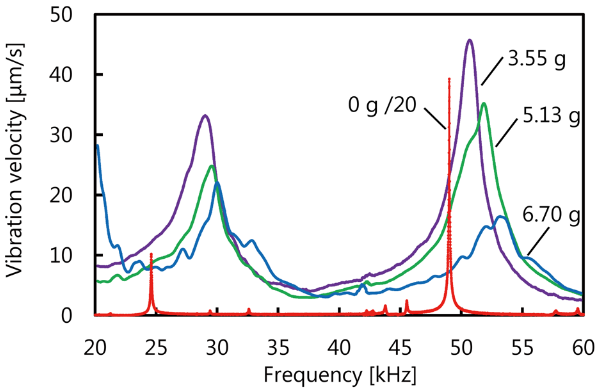

Fig. 3 Frequency characteristics of bolt vibrations measured by LDV

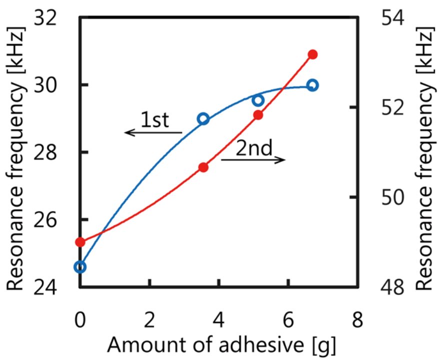

Fig. 4 Resonance frequency vs. amount of adhesive

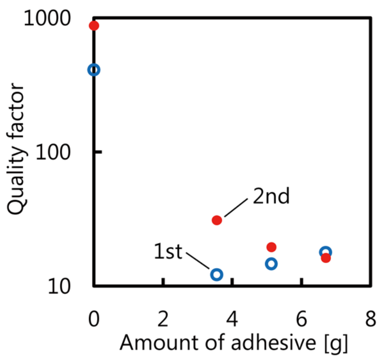

Fig. 5 Quality factor vs. amount of adhesive

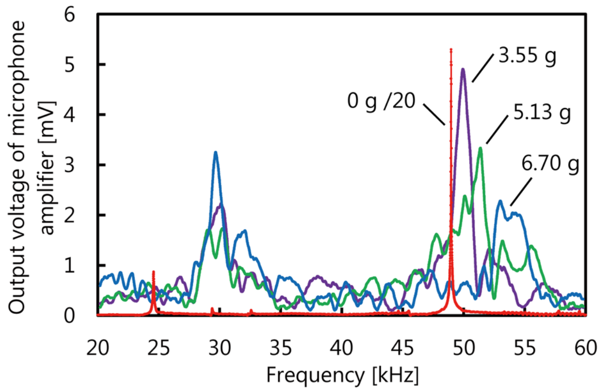

Fig. 6 Frequency characteristics of bolt vibration measured with a microphone

3.2 Characteristics of detected sound wave

The frequency characteristics of the radiated sound measured with the microphone are shown in **Fig. 6**. For the results other than 0 g, moving average of 404 Hz was used for noise reduction. Similar trends were obtained as compared with the results of the direct measurement of the vibrations. Precise evaluation of the resonance characteristics was, however, difficult because of the unstable spectra with many dips, which probably originate from the sound waves reflected from objects around the sample and the microphone. Some additional signal processing should be required to exploit the microphone data.

4. Conclusion

Evaluation methods of adhesive anchors using magnetostrictive vibrations were developed. We investigated the dependence of the adhesive volume on the resonance characteristics, which is potentially applicable to the soundness diagnosis of the adhesive anchors. In this experiment, the coil was located near the bolt since the excitation intensity of the magnetic field was extremely low. Higher-power excitation for remote measurements will be an important task to be conducted in future.

References

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