Improved Maintenance Management for Aging Infrastructure

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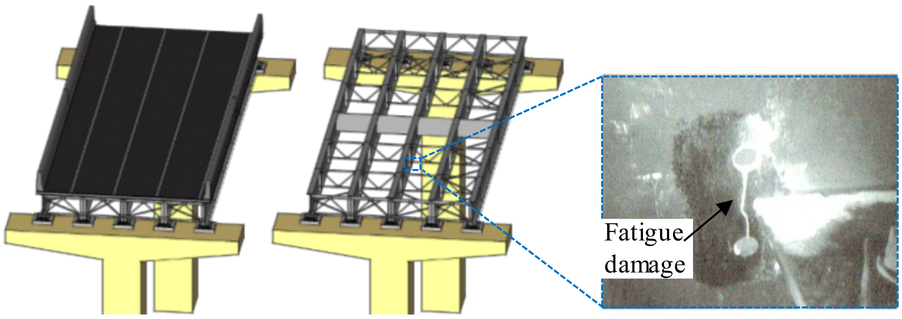
1. Background and Purpose

Transport infrastructure in Japan such as bridges and tunnels is crucial for both business and society. It is therefore important to maintain such infrastructure in a state where it can be used safely. However, many bridges in our country have started to exceed their useful lifespan of 50 years, and problems such as fatigue and corrosion damage have begun to occur. In particular, fatigue damage (Fig. 1) in steel bridges is difficult to detect visually, and there is a danger of brittle fracture occurring, so that sophisticated maintenance management is required.

In the present study, we aim to develop a maintenance management scheme for fatigue damage in steel bridges, and construct a bridge monitoring system using sensors based on microelectromechanical systems (MEMS).



(b) Steel bridge with RC slab (b) Steel bridge without RC slab (c) Example of fatigue damage

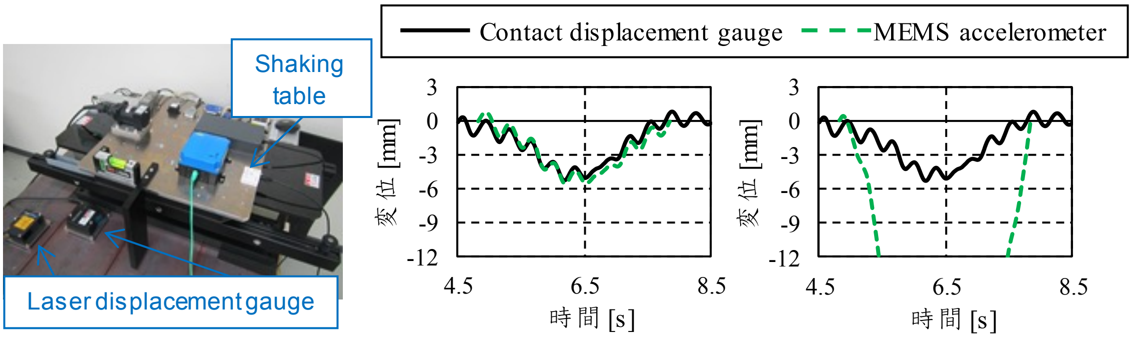
Figure 1. Example of fatigue damage in steel bridge

2. Methods

Field measurements were carried out using MEMS sensors on actual in-service bridges, and a bridge monitoring system was developed and evaluated. The first step was to select a MEMS sensor suitable for measuring the response of a bridge to moving vehicles. We then constructed an algorithm for calculating the displacement and rotation of the bridge from the measured acceleration and angular velocity data. The displacement provides information such as the vehicle weight, type, movement speed and travelling lane. This allows potential damage to the bridge to be assessed. Based on the calculated displacement and rotation, it is possible to ascertain the deformation of the bridge in the presence of a moving vehicle, and to identify the mechanism by which fatigue damage occurs. This is important when planning appropriate repair methods. We also consider approaches such as low power wide area (LPWA) wireless technology.

3. Results

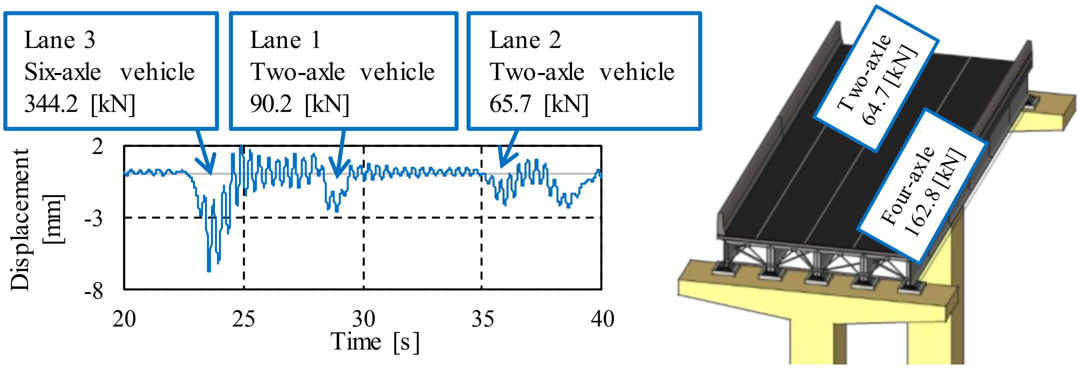
We previously evaluated a number of MEMS sensors to determine their suitability for measuring the response of a bridge to a moving vehicle (Fig. 2(a)), and verified the practicality of these sensors by on-site experiments (Fig. 2(b),(c)) [1]. Next, we propose a method for calculating the bridge displacement and rotation from the acceleration and angular velocity data obtained using such sensors [2,3]. As shown in Fig. 2(b), by using a suitable sensor, it was possible to accurately calculate the bridge displacement.



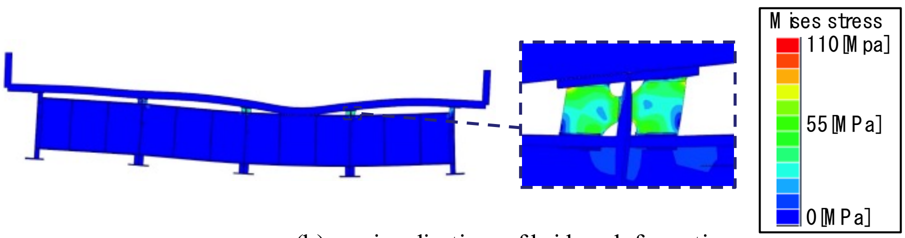
(a) Shaking table setup (b) Accelerometer A (c) Accelerometer E

Figure 2. (a) Shaking table setup and (b), (c) comparison of displacement response calculated displacement using two different sensors [1]

Based on the calculated displacement and rotation, a system for obtaining information on the traveling vehicle was developed (Fig. 3(a)), together with a method for visualizing the bridge deformation (Fig. 3(b)) [4-6]. The vehicle weight was estimated by an inverse analysis of the bridge displacement [7]. From the visualization results in Fig. 3(b), the high stress occurring in the web gap plate is due to a large deformation of the concrete slab.



(a) Estimated vehicle information



(b) visualization of bridge deformation

Figure 3. (a) Estimated vehicle information and (b) visualization of bridge deformation

4. Conclusion

We developed a system for monitoring the cause of fatigue damage in steel bridges based on the use of compact low-power MEMS sensors. It can estimate the weight and number of travelling vehicles, which are the main factors that leads to fatigue damage. By visualizing the bridge deformation under the influence of a moving vehicle, it is possible to identify the mechanism by which fatigue damage occurs and plan appropriate repair methods.

In future research, we plan to improve the accuracy of the vehicle information obtained using the MEMS sensors. In addition, we will consider the use of a low power wide area network to obtain sensor information.

Recently, the Japanese Government has revised the PFI/PPP action plan so that it should also be applied to maintenance, rehabilitation and renewal projects for existing infrastructure using new technology such as the Internet of Things. The present study is well timed to fit into this scheme. In addition to the technological developments described above, PPP/PFI related projects are also being developed. As an initial step in project development, issues of economically most advantageous tender in procuring PFI projects have already been investigated [8].

Representative Reference

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