Displacement measurement of concrete bridges by the sampling moiré method

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Abstract. Measuring accurate deformation distribution of large-scale structures inexpensively and efficiently is a crucial challenge of structural health monitoring. In this study, the sampling moiré method was applied to the displacement measurement of a concrete bridge for the high-speed railway in Japan. Results of the dynamic deflection obtained from the sampling moiré method were in good agreement with those from a conventional laser Doppler vibrometer. Furthermore, the time-series of displacement were successfully measured when the outbound or inbound trains passed at the speed of 320 km/h through the bridge.

Introduction

Monitoring structural health conditions enable early detection of problems and prevent the catastrophe of aging infrastructures [1]. Measuring the dynamic displacement of in-service structures is, therefore, important for their safety assessment. Unfortunately, the conventional practice based on periodic human visual inspection is inadequate for constant monitoring of structural conditions. Traditional techniques using contact ring-type displacement sensors take a lot of work in installation.

In the research community of experimental mechanics, some researchers are actively exploring new technologies that can advance the state-of-the-practice in structural health monitoring (SHM). For example, the digital image correlation (DIC) technique [2] where random patterns are used as targets was applied to measure the deflection of a bridge in a static test [3].

A sampling moiré method is another imaging technique to measure the displacement rapidly and accurately by utilizing repeated patterns [4, 5]. The displacement is obtained from calculating the phase difference of the moiré fringe before and after deformation based on a discrete Fourier transform (DFT) algorithm. In this study, the sampling moiré method was applied to displacement measurement of a concrete bridge for Shinkansen to address the challenge of accurate deflection measurement of large-scale structures [6].

Field experiment

To demonstrate the effectiveness of the sampling moiré method, a field experiment for measuring the displacement of a concrete bridge in Japan was carried out. Figure 1 shows the target concrete bridge and the span length of the bridge is 30 m with a width of 12 m. To measure the displacement by the sampling moiré method, we used retroreflective Moiré markers with a 50 mm grating pitch as the measurement targets.

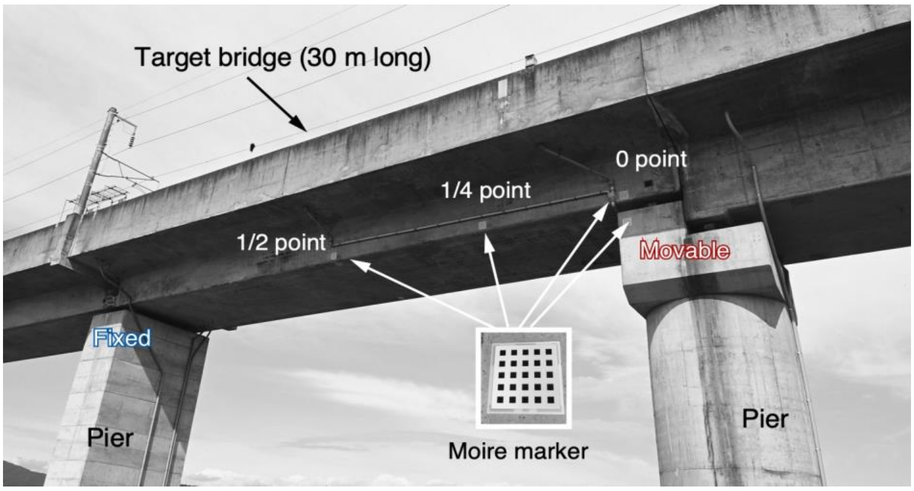
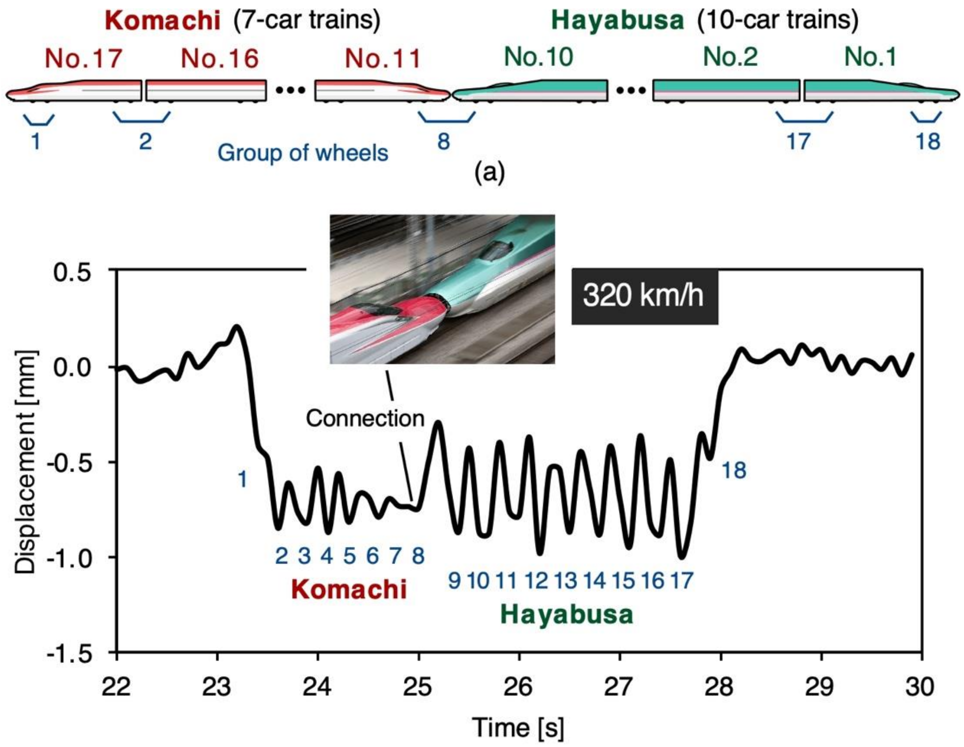


Fig. 1 The overall view of the target concrete bridge. The grating pitch of the moiré marker was 50 mm in field experiment measurement.



(b)

Fig. 2 Experimental results of deflection measurement by the sampling moiré method: (a) The locations of 18 groups of wheels in the configurations of the 7-car train of the Komachi Series E6 connected to 10-car of the Hayabusa Series E5; (b) Deflection measurements in the *y*-direction by the sampling moiré method for a bullet train with 17 cars moving with 320 km/h.

Figure 2(a) illustrates the car arrangements of the 17-cars train bound for Morioka in which 7 cars of the Komachi Series E6 are connected with 10-cars of the Hayabusa Series E5. Figure 2(b) shows the deflection measurements in the *y*-direction from the sampling moiré method when the bullet train with 17 cars passed at a speed of 320 km/h at night. The downward displacement peaks about 1 mm correspond to the passage of 8 wheels located at both sides of the car coupling. As shown in Fig. 2(b), the configuration of car coupling between the tail end car of the Komachi and the head car of the Hayabusa is different from that of other car couplings. This different car coupling configuration causes the different displacement behaviour observed around 25 seconds. The time intervals between displacement peak when the Komachi passed is shorter than that of the Hayabusa because the length of Komachi's car is 23.1 or 20.5m that is shorter than that of the Hayabusa of 26.5 or 25.0m.

Conclusion

The sampling moiré method was applied to the displacement measurement of a concrete bridge for the bullet trains in Japan. The utilization of the retroreflective moiré markers enabled to measure the two-dimensional in-plane displacement at multiple locations easily using digital images recorded from a distance of more than 20 m regardless of daytime and night time. We confirmed that this method by using a single digital camera was advantageous to investigate the dynamic displacement behaviour of large-scale structures with easy setup and low cost for a wide field of view.

References

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