Development of Strong Motion Monitoring System

(Study period: FY2017 to FY2019)
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1. Introduction

NILIM has been observing seismic behavior since 1958 for the purpose of rationalizing / upgrading seismic design standards and analyzing seismic behavior for civil engineering structures. Conventionally, about three spots per structure have been observed for the reason of cost, etc. In addition, the validity of seismic design method has been comprehensively verified in light of the state of damage in the event of an earthquake based on the analysis of seismic behavior of structures with the observation record obtained. However, assuming development of new structure forms, etc., it would be necessary to grasp accurately the damping characteristic of each component, etc. and the relationship with the behavior of the whole structure. Accordingly, multiple spots need to be observed for each structure.

In recent years, in response to the development of small and inexpensive measuring devices, such as MEMS (Micro Electro Mechanical Systems) accelerometer, and advancement of wireless communication technology, it is expected to be able to observe a single structure at multiple spots and at low cost. For such new technologies, however, verification in terms of practical use was insufficient, such as communication technology for use in the outdoors and securing of power supply. Although the seismic behavior of structures is widely observed, there are not so many cases where MEMS accelerometer or wireless communication technology is used outdoors. Hence, NILIM has verified the applicability of such new technologies and constructing a system ("Strong Motion Monitoring System") that is able to observe easily the behavior of the whole system of structure by observing multiple spots of a single structure using new technologies.

2. Outline of the observation system

Fig. 1 shows the outline of Strong Motion Monitoring System. The record of observation with the accelerometer installed on the bridge is collected into the on-site receiver in wireless communication as real-time continuous record, and transmitted from the receiver to the server of the monitoring system. In the server, the behavior of bridge, etc. is calculated with the obtained record, and the results of calculation can be confirmed by accessing the server from the office PC.

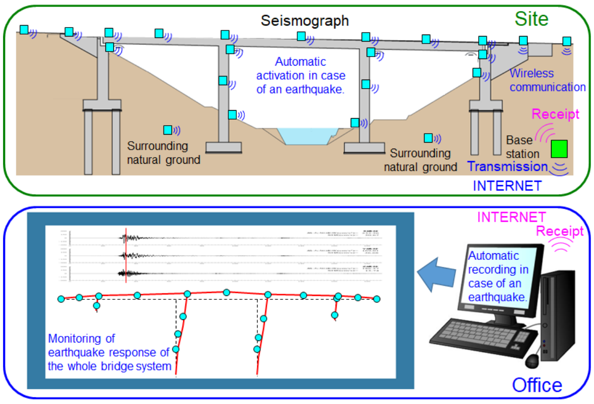

Fig.1 Outline of the Strong Motion Monitoring System

In order to verify the usefulness of the Strong Motion Monitoring System, NILIM installed an MEMS accelerometer on a trial basis on an elevated bridge in Ibaraki-ken.

Since the Strong Motion Monitoring System established in this study can collect observation record in wireless communication, it is not necessary to design or install cables, etc. Further, the sensor is smaller and can be installed with a magnet or adhesive using the inspection passage, which will make installation work easier. Each accelerometer that constitutes the Strong Motion Monitoring System is powered by a battery, and it is easy to secure electricity in the outdoors.

3. Performance verification

The following was confirmed as the result of installing an MEMS accelerometer on the bridge and conducting verification based on the record obtained through wireless communication for which FM communication module is used, from which long-distance communication with power saving is expected.

- As a result of installing multiple accelerometers on the bridge and comparing the observed earthquake records, the records obtained from the main girder lower flange, bridge pier / bridge seat, and the footing top face had different characteristics respectively, and the complex behavior of each part of the bridge in case of an earthquake was confirmed.

- The MEMS accelerometer showed a shape of spectrum that is almost the same as the record of the seismograph (servo seismograph) that has been conventionally used for observation (Fig. 2), so that it was confirmed that observation with MEMS accelerometer is equivalent to the conventional

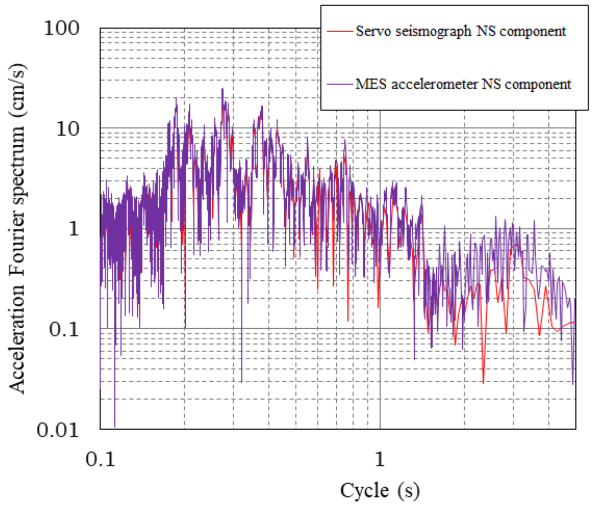

Fig. 2 Comparison of servo seismograph and MEMS accelerometer

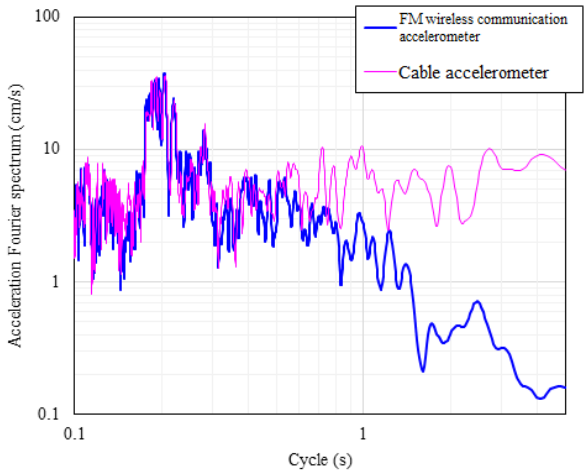

Fig. 3 Comparison of observation records by wireless communication and cable communication

observation.

- The observation record by FM wireless com munication included some inaccurate data in a longer cycle due to data compression in transmission, but the characteristics necessary for observation of the seismic behavior of bridge, including peak value, were the same (Fig. 3). The peak value was almost equivalent even in a longer cycle after improvement of the data compression.
- We confirmed that observation record can be transmitted even when at least 100 m away by changing the communication module of FM wireless communication to Sub-GHz zone. In addition, the distance of wireless communication was shortened by adding the function of transmitting and receiving observation record in wireless transmission to each accelerometer and relaying transmission using them, without transmitting observation record from each accelerometer to the receiver. As the result, stability of communication improved.

Fig. 4 shows the configuration diagram of the Strong Motion Monitoring System built in this study. Fig. 5

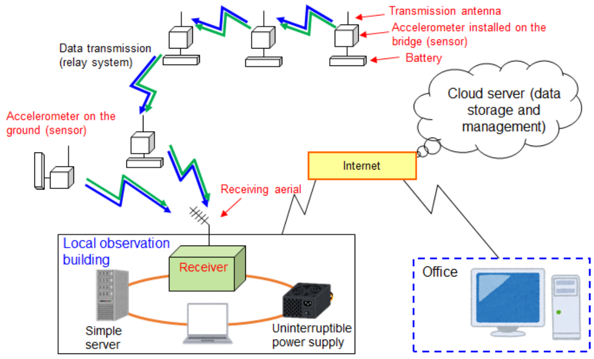

Fig. 4 Strong Motion Monitoring System Configuration Diagram

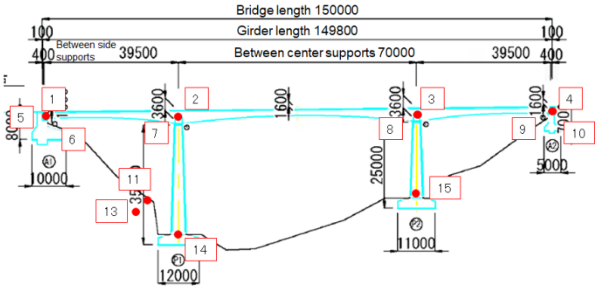

Fig. 5 Example of Strong Motion Monitoring System installation

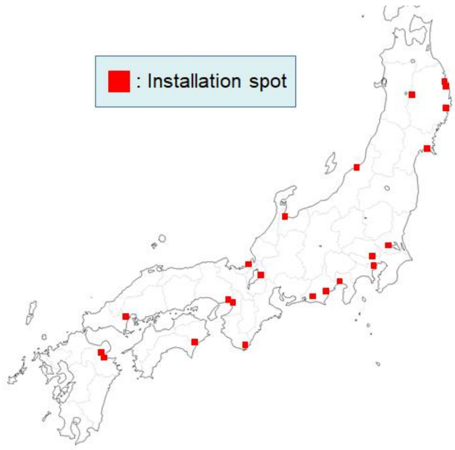

Fig. 6 Installation points (Tohoku to Kyushu Regions)

shows an example of installation of the Strong Motion Monitoring System. In fiscal 2019, Strong Motion Monitoring Systems were installed on some bridges in area from the Tohoku to Kyushu Regions as shown in Fig. 6.

4. Future schedule

We intend to analyze of the seismic behavior record of various types of bridges in the country to be obtained from the Strong Motion Monitoring System and verify the seismic behavior of bridges. In addition to Strong Motion Monitoring, we are also going to verify the "immediate damage detection function," which detects the state of damage from observation results in the event of a strong earthquake or damage.