RTRI Develops High-Performance Wireless Measurement System "IMPACTUS" Used in Impact and Vibration Tests

The Railway Technical Research Institute (RTRI) developed "IMPACTUS," a high-performance measurement system to support the estimation of natural frequencies of bridge piers. These frequencies are used as soundness evaluation indexes for one of the bridge substructure inspections.

The adoption of the dual tuning fork type crystal oscillator chip enabled the new system to reduce noise more significantly and to estimate natural frequencies more easily than with conventional systems. Moreover, the IMPACTUS sensor is smaller and lighter than conventional sensors, which provides superior portability and workability.

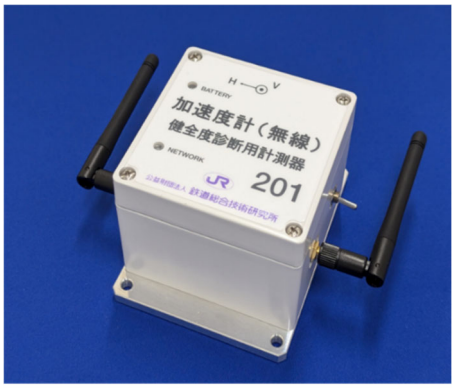


Figure 1 IMPACTUS Sensor
Size:115×90×66 mm
(dimensions exclude protruding parts)
Weight: Approx. 0.9 kg

1. Background of Development

The maintenance of bridge substructures primarily relies on visual inspections. However, the supporting ground of bridge piers is underground and cannot be directly observed. To resolve this inconvenience, "impact and vibration tests" (Figure 2) are widely conducted. In this type of test, impact is applied to the head of the bridge pier using a weight. From the resulting vibrations, the natural frequency of the bridge pier is estimated and the soundness of the bridge pier is assessed.

RTRI has been developing a series of vibration measurement systems, the "IMPACT" series, for impact and vibration tests. The results of frequency analyses of the recorded vibration waveforms sometimes showed phase variations depending on the shape of the piers, making it difficult to correctly estimate the natural frequencies. To improve the accuracy of the systems, we developed a new measurement system using a high-performance sensor, "IMPACTUS."

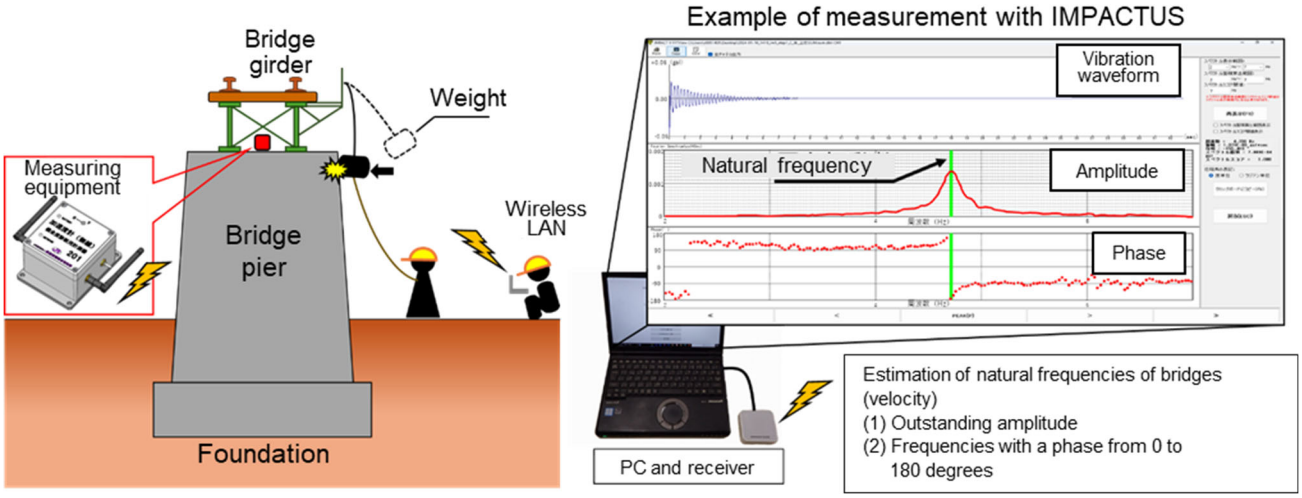


Figure 2 Schematic Diagram of Impact and Vibration Tests

2. Overview and Benefits of IMPACTUS

The sensor newly applied to the “IMPACTUS” system uses a crystal oscillator chip to reduce energy loss during vibration and frequency fluctuations caused by temperature changes, thereby improving the accuracy and reproducibility of measured values more significantly than the conventional piezoelectric accelerometers. Furthermore, high sensitivity and low-noise performance have been achieved by directly converting the measured vibrations to digital signals (Figure 3). In addition, the newly applied accelerometer can measure vibrations of up to 460 Hz, making it applicable to retaining walls with higher natural frequencies than bridge piers.

- This measurement system consists of a sensor (Figure 1) and an program for measurement and analysis (running on a laptop PC). The program has implemented the process in which data points measured by the sensor can be increased to over 16,384 (twice the previous amount), which enabled the system to display more detailed waveforms than did the conventional systems (Figure 4).
- The integration function, which was previously integrated in the sensor, has been implemented in the program in laptop, which reduced the size of the sensor, 46% smaller in volume and 60% lighter in weight than the conventional sensors, and improved portability and workability.

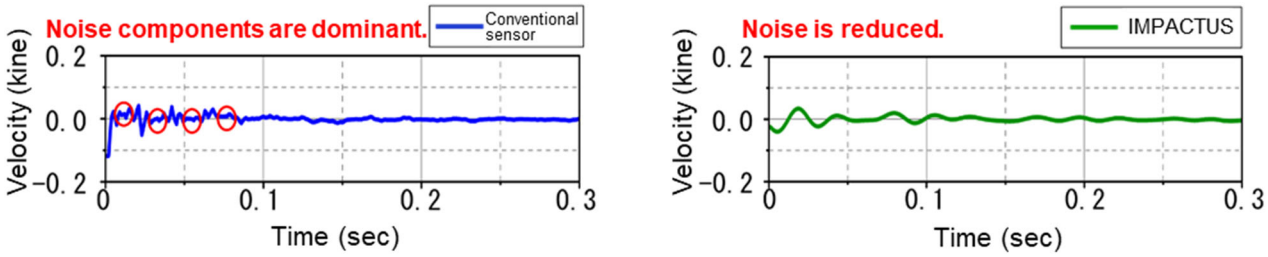
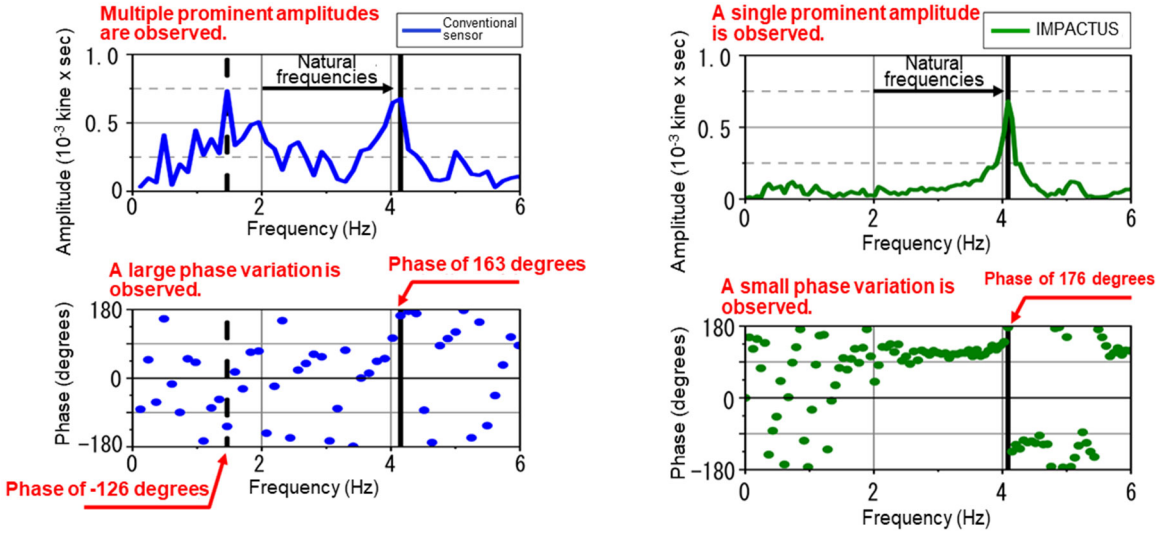


Figure 3 Noise Reduction in Vibration Waveform
(Measurement Results Obtained from Impact Tests on the Same Wall-Type Piers)



- Two prominent amplitudes and varying phases make it difficult to determine which is the natural frequency.

- The natural frequency can be easily determined because the prominent amplitude is at one location and the phase is close to 180 degrees.

Figure 4 Comparison of Frequency Analysis Results of Fig.3
(Measurement Results Obtained from Impact Tests on the Same Wall-Type Piers)

3. Miscellaneous

- IMPACTUS enabled high-resolution measurements, thanks to its improved sensor, making it possible to detect subtle changes in the vibration modes of bridge piers due to scouring. This advancement allows for the estimation of the run-off range of the ground supporting the bridge foundation due to scouring (x in Figure 5) with an accuracy of ±5.0% relative to the foundation width (Figure 5).

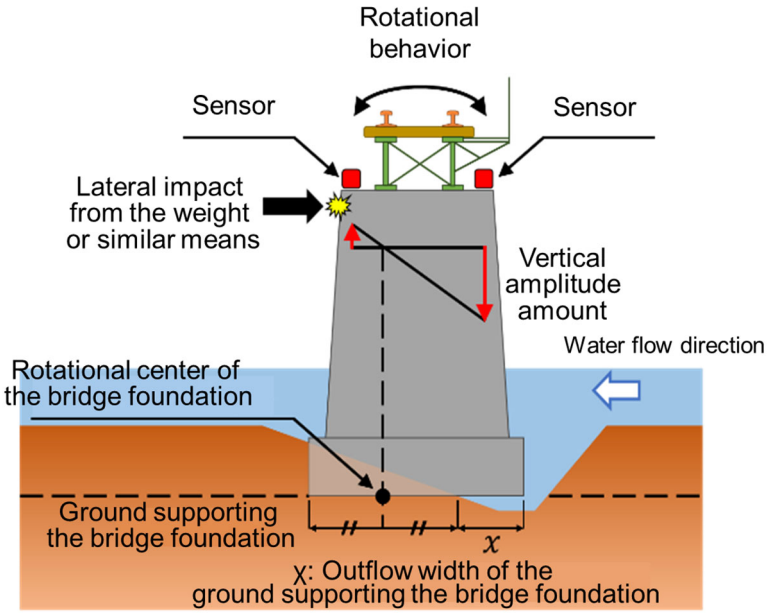


Figure 5 Overview Diagram of the Evaluation Method for the Run-off Range of the Ground Supporting Bridge Foundation

- A new function allows the measurement in two directions (vertical and horizontal) during constant microtremor measurement. The installation of additional software enables the calculation of natural frequencies on the basis of constant microtremor measurement results without conducting impact and vibration tests using an iron-ball weight (scheduled for release in July 2025).
- IMPACTUS has been available since June 2024.