Evaluation of the Structural Soundness of Bridge Pier Foundations Under Flood Conditions

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Under flood conditions, a river can scour a bridge pier foundation, reducing its stability and even toppling it (see Fig. 1) and causing a train accident. Such an accident could be prevented through the development of a system to assess the soundness of a pier foundation during high water levels. This paper discusses changes in the nature of vibrations as the river level rises. The vibration values were extrapolated from micromotions measured with a vibration sensor mounted on the upper surface of the pier. Bearing in mind the fact that the degree of soundness of a pier foundation can be correlated with the characteristic frequencies of that pier, we developed a system to assess easily and in real time the soundness of a pier foundation during high water levels.

We mounted the vibration sensor on a bridge pier that stands on a spread foundation, and measured micromotions at five-minute intervals at both low water and high water. We then compared the Fourier spectra of the micromotions observed at both low water and high water (see Fig. 2). The response spectra during high water clearly indicated predominant peaks at around 7.5 and 11.5 Hz. On the other hand, at low water such a predominant spectral response was not observed. The shape of the spectra during high water closely resembles the Fourier spectra previously obtained during impact vibration (forced vibration) tests conducted at low water, and of these, the 11.5 Hz value was remarkably close to the pier's initial vibration frequency value of 11.3 Hz. From this we determined that, during high water, we could assign one predominant vibration frequency on the Fourier spectra of micromotions as a characteristic frequency for that specific pier. Fig. 3 shows the relationship between changes in water depth around the pier and changes in the pier's characteristic frequencies obtained from micromotions at various water levels. As the figure indicates, the deeper the water, the more the characteristic frequencies tend to converge toward the characteristic frequency values obtained previously during impact vibration tests.

Fig. 1 Destructive effect of scouring under a railway bridge (Japan)

Thus, by comparing characteristic frequencies obtained from impact vibration tests with the Fourier spectra of vibrations represented by micromotions, we determined that it may be possible to identify the characteristic frequencies of the pier at high water.

When in flood, a river may scour the riverbed around a pier, resulting in a shallower penetration depth for the pier. As a general rule, if a pier's penetration depth is sufficient, the pier will have enough resistance to withstand forces that would otherwise topple it, and the foundation will remain stable, keeping the pier sound. However, a reduction in penetration depth will diminish the soundness of the pier foundation. As the penetration depth declines, the pier's characteristic frequencies will tend to exhibit a corresponding decline. Focusing on the fact that characteristic frequencies change in this way, we developed a system that uses characteristic frequency values to determine the degree of soundness of pier foundations, then provides this quantitative data to be used as one factor for deciding whether or not to suspend train operations on the bridge. Fig. 4 illustrates the system process, and Fig. 5 shows the system configuration. The system is currently being tested in real-time assessments of the stability of bridge piers, with a view to improving system reliability and obtaining more data. System development has been subsidized by the Ministry of Land, Infrastructure and Transport.

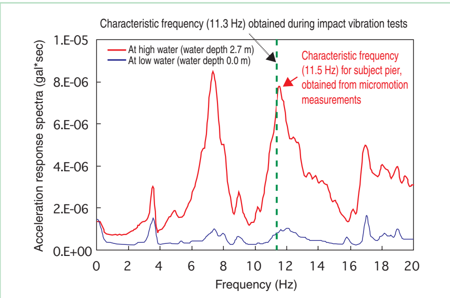

Fig. 2 Comparison of Fourier spectra of micromotions observed at low water and high water

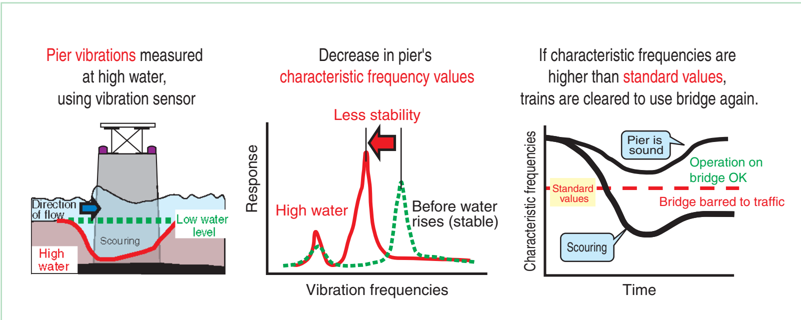

Fig. 4 Assessment of the soundness of a bridge pier foundation

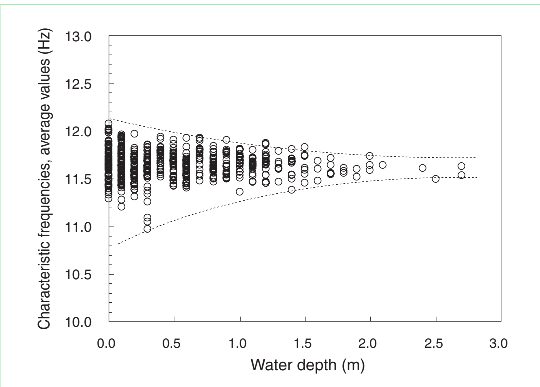

Fig. 3 Relationship between changes in water depth around pier and changes in pier's characteristic frequencies

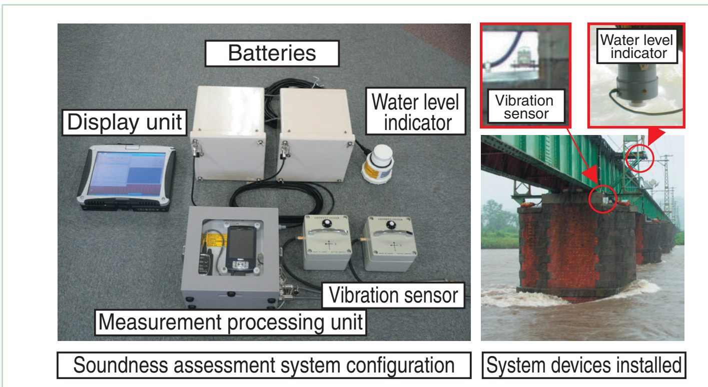

Fig. 5 Soundness assessment system configuration, and installation of system devices