Development of Concrete Spalling Inspection Device Incorporating Non-Contact Laser Measurement Technology

Norikazu Misaki (West Japan Railway Company)
Yoshinori Shimada (Institute for Laser Technology)
Oleg KOTYAEV (Institute for Laser Technology)
Masahiro Shinoda (Railway Technical Research Institute)
Shigeo Emoto (Unirock Corporation)

1. Background of development

The primary method for inspecting concrete is the hammering test. However, the hammering test requires inspectors to use vehicles with aerial inspection platforms in order to access the concrete surface. Because of the number of regions that must be inspected, the hammering test requires considerable time, which imposes a great burden on inspectors and is a constraining factor for railway tunnel lining inspections. Inspections are not possible during a railway's service hours. Moreover, arrangements must be made to transport to the site aerial-platform vehicles that can operate on railway tracks. Finally, electrical power for the railway service must be suspended during the inspections. To handle these conditions, we developed a concrete spalling inspection device that incorporates non-contact laser measurement technology. The device can detect problematic regions in the concrete before the concrete detaches. The device also minimizes the use of aerial platform vehicles and the suspension of electrical power. With this device, concrete structures can be inspected from a distance of a few meters.

2. Overview of the technology

2.1 Principle of non-contact laser measurement technology

The hammering test and the non-contact laser measurement technology both rely on the same principle for detecting defects: exciting the concrete surface to determine the surface vibration (Fig. 1). Figure 2 shows the technology's detection principle. The device irradiates the concrete surface with a high-power excitation laser, which converts solid materials (cement, etc.) on the surface to a gas that is then released into the air. The irradiation causes impact waves to propagate inside the concrete, exciting surface vibrations. The generated vibrations are measured by means of laser beam interference using a measurement laser capable of continuous oscillation. Because concrete surfaces are extremely rough, conventional laser interferometers produce lower measurement sensitivity. Our device, however, employs phase conjugation technology that uses dynamic holographic crystals. The laser beam is separated using a beam splitter into signal light and reference light. The signal light reflects off the concrete surface, carrying information about the surface geometry, and enters the dynamic holographic crystals, causing interference between the signal light and the reference light. This forms a hologram of the concrete surface geometry within the dynamic holographic crystals, which compensates for the roughness of the concrete surface. Free from influence of the concrete's surface roughness, the signal light and reference light then enter a detector, resulting in excellent detection sensitivity.

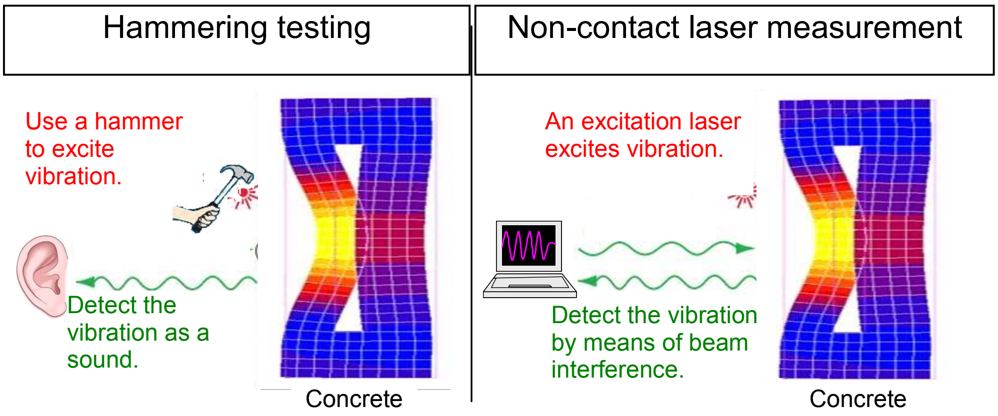

Fig.1. Comparison of hammering test and non-contact laser measurement

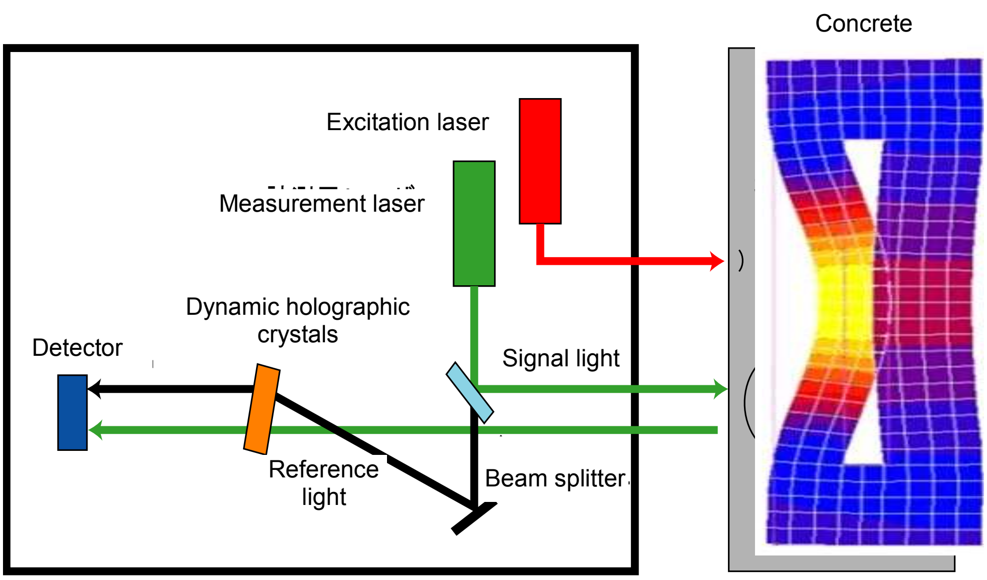

Fig. 2 Principle of non-contact laser measurement technology

2.3 Verification test using test device in a Sanyo bullet train tunnel

A verification test using the test device was conducted at night in a Shinkansen bullet train tunnel. Because the vibration measurements were hampered by noise and vibration from maintenance vehicles and power generators, a vibration isolation bench was employed and sound protection measures implemented. Figure 6 is an example of the testing results. The spectrum results show good agreement between the proposed technology and the hammering method (surface excitation test).

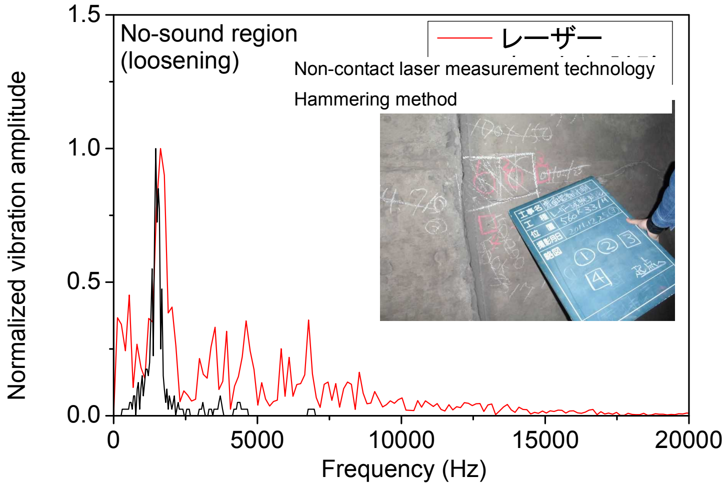

Fig.-6 Verification test results in bullet train tunnel using improved version of test device

2.4 Development of practical device

The results of the verification test show that ambient vibration and noise in the bullet train tunnel were reduced, allowing the device and its technology to successfully take measurements. For practical applications, the device should travel along the inspection passage provided in the center of a bullet train tunnel. Therefore, a smaller device having the same functions as the larger test device was developed (Fig. 7). The smaller device significantly reduces the time and labor required for inspection work.

Fig. 7. Device in operation in tunnel's central passage