Diagnostic Technology to Improve the Upkeep and Maintenance of Railway Tunnels

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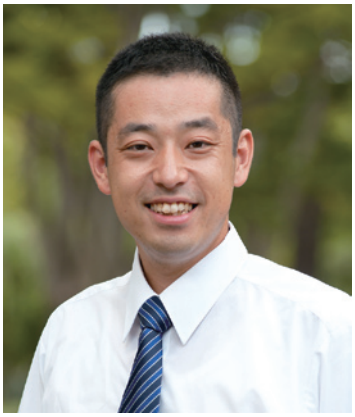


Railways in Japan began to attach more importance tunnel upkeep and maintenance after they experienced accidents due to deterioration and failures of concrete linings in 1999. In Japan, railway tunnels are all subject to regular and general inspections. This requires railway operators to expend considerable manpower and time, particularly as tunnels are numerous and are scattered across the country. Most of the inspections are carried out manually and problems occur with differences in judgment between inspectors. Inspectors normally rely on manual measurement in monitoring deterioration (sometimes known as metamorphosis) of concrete.

As a first step to raise the quality and consistency of judging tunnel soundness, and to make the inspection objective and automated, RTRI developed a new tunnel soundness diagnosis system (TUNOS). See Fig. 1 for the total flow of the system. This system automatically extracts information on cement deterioration and crack patterns, including closures, intersection and parallelism of cracks, and judges the soundness level (α, β or γ) against flaking, while reflecting the existence or non-existence of water leaks and the results of hammering tests. Based on the results of collation with crack patterns and the possibility of deterioration to occur, the system also extracts damage due to external forces, automatically determines their causes and judges the soundness level (A, B, C or S) against the damage generated by external forces. The crack patterns are classified by the damage caused by external forces as a function of biased, plastic and vertical pressures. The system then lists combinations of possible cracks and summarizes the positions of cracks and compressive fractures (breaks) belonging to each pattern. The results of the diagnosis are output in two different formats: one is a package display of approximate soundness levels for different spans and the other is a presentation of the detailed data at a specified point when the “DETAIL” button corresponding to the point is pressed (see Fig. 2).

One reason why automatic measurement has rarely been adopted for long-term tunnel monitoring so far is because the cables between sensors and tunnel mouths require enormous amount of manpower and funding for laying and maintenance. Therefore, RTRI developed a radio system for transmission of measurement data to the tunnel mouths from the sensors installed on the lining of the tunnels. See Fig. 3 for the developed data transmission system and Fig. 4 for a radio sensor used for the system. The radio sensor, driven by FR lithium batteries is as compact as 100g in weight and 10 x 10 x 3.5cm (including batteries) in size. RTRI has used the system to measure crack widths and temperature, at approximately eight minute intervals, in an actual tunnel and confirmed its practical applicability. RTRI also implemented a long-distance transmission test using relay radio sensors at another tunnel and verified the applicability of transit data transmission. A technology to process measurement data accumulated in quantities has also been developed by RTRI as well as a method to predict deterioration in the future based on the data. The technology makes it possible to implement automatic measurement for long-term deterioration monitoring.

RTRI believes that the developed tunnel soundness diagnosis system, along with the deterioration monitoring technique to use radio sensors introduced above, will effectively contribute to a high level of upkeep and maintenance of railway tunnels.

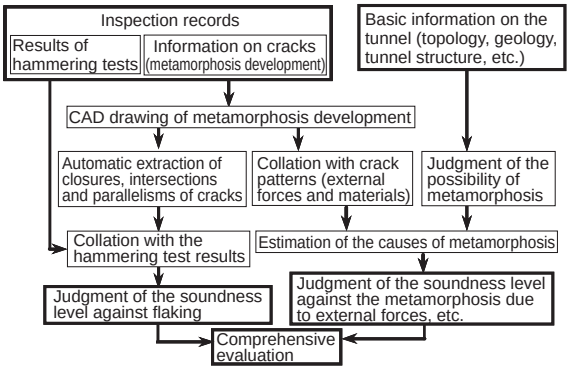
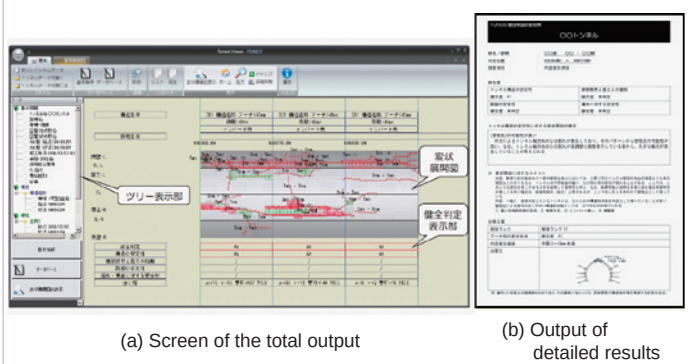


Fig. 1 The total flow of the soundness diagnosis system



(a) Screen of the total output (b) Output of detailed results

Fig. 2 Examples of the display screen of the diagnosis results

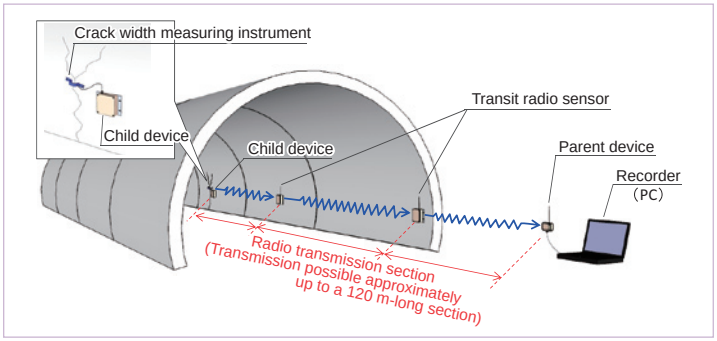


Fig. 3 Monitoring system to use radio sensors

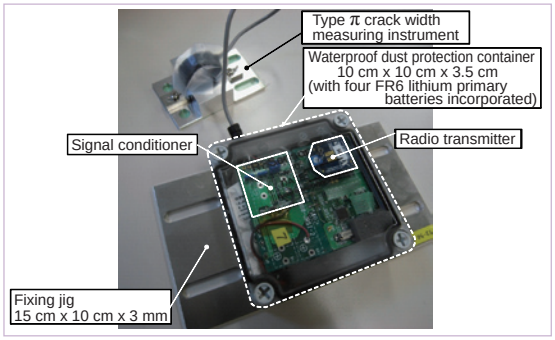


Fig. 4 Developed radio sensor