Predicting Landslides a Few Months in Advance of Their Occurrence by Observing the Chemical Composition of Groundwater

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To provide customers with safe and comfortable rail services, long-term remote sensing technologies have been developed to protect railway lines against the consequences of abnormal climate activity such as heavy rainfall which can cause serious disasters on the ground, including landslides. Thanks to a technique using chemical sensors, ground disasters or landslides can be predicted a few months before they occur.

In recent years, climate has changed throughout the world, especially in Asia and Europe, resulting in changing patterns of rainfall. Thus, even in Japan, sudden, torrential falls of rain have been observed frequently during the last 10 years. Japan Railways (JR) provides railway services all over Japan, where over 50% of routes are located in mountains or on the coast with steep cliffs immediately behind the tracks. In the meantime, weather forecasting services have improved to such an extent that it is possible to estimate in advance when and where localized torrential rainfall will occur. In parallel, the relationship between precipitation and the risk of ground disasters including landslides has been confirmed. In this situation, however, the information from such sources warning us to be aware of possible ground disasters affecting railway tracks comes at short notice, mostly just before the incidents caused by heavy rainfall.

Furthermore, it is not always the case that engineers are standing by all the time watching for such disasters close to the location where the disaster occurs. Instead, they are typically some distance away from the site, and it would normally take at least one hour to visit the site for a check. So this traditional method of dealing with the problem is of no help to railway customers who may need to make alternative travel arrangements if their rail service is affected. To ensure that rail travel remains safe and that customers are protected from natural disasters, therefore, a long-term remote observation system is needed to predict the next occurrence of a ground disaster.

Basically, current technologies to predict ground disasters are all based on the method where the distortion or displacement of the ground is measured directly where it may affect structures or railway tracks. However, detection in this manner will give information only on the current movement of the ground or conditions just a few days prior to disasters. Since this method is effective only when a disaster is likely to occur imminently, it is impossible to organize alternative transport services in advance to avoid natural disasters. What is more important is to know more easily when such a natural disaster is likely to happen, or within how many weeks or months.

To overcome the lack of such information, which would not normally be available using conventional technologies for predicting disasters, an important technique has been developed involving the use of a chemical sensor, which has never been used before for ground disaster detection work. Chemical sensors or ion-selective electrodes can be used to monitor the chemical compositions of the groundwater seeping from the ground where landslides are anticipated. The groundwater contains inorganic ions that originate from soil particles in the ground. The concentration of the ions does not change while the ground remains stable. However, it changes when deep and virgin ground is distorted, resulting in the displacement of the surface ground, which leads to a landslide. Certain specific ions in the groundwater, therefore, indicate the possibility of a landslide by an increase in their concentration. The changes in concentration are more easily observable than when displacement is detected on the surface of the ground. This is because the groundwater seeps out from the ground continuously and rapidly. In contrast, the distortion inside the ground takes a long time to cause displacement of the surface. It turns out that the groundwater composition suggests the occurrence of a ground displacement event such as a landslide well before it occurs. Actually, the latest result showed that the increases in specific ion concentrations occurred four times, each time observing a ground displacement a few months thereafter, while the composition of the groundwater was being continuously monitored for 700 days with a prediction system at an inspection site on a JR service line. This is shown in Fig. 1.

Sensors used in this system are remotely controlled at a JR track maintenance office to give dispatchers and civil engineers information that may indicate the likelihood of natural ground disasters in the future. This is illustrated in Fig. 2. Once they receive this information, they can easily arrange for railway embankments or cuttings to be reinforced, find alternative routes for passengers and cancel train services. What is most important is to predict the occurrence of natural disasters easily well in advance of the event, but it is not essential to predict exactly when they will occur. By obtaining disaster information in advance, all arrangements can be made to protect rail services because sufficient time is available. Non-availability of information in advance will only surprise railroad operators. On the other hand, if the information is available, they will and can be prepared to ensure that safer, more reliable and comfortable transport services are available for customers with enough time guaranteed by the prediction system.

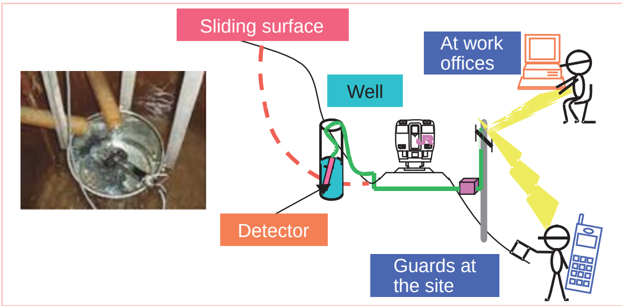

Fig. 1 The telecommunication system to successfully send information on the groundwater composition on demand to workers in charge of and responsible for train operation. The chemical sensor immersed in the groundwater in the well periodically determines the concentrations of ions in the groundwater. The signals from the electrodes are processed to save the data in a data logger, which are transmitted to the relevant workers through the public telecommunication service.

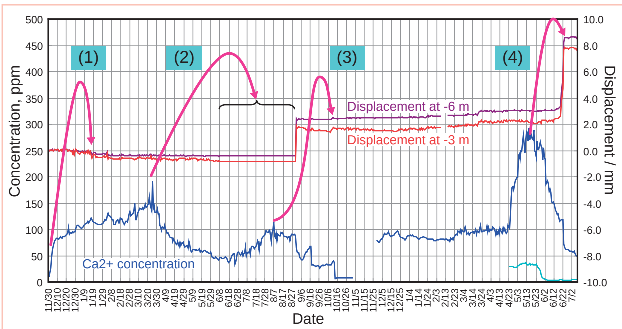

Fig. 2 Changes in the groundwater composition and ground movement