Pilot Implementation of Infrastructure Monitoring Solution for Global Deployment

- Field Application in Railway Sector using Zero-Energy IoT Series -

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In recent years, disaster risks such as landslides, floods, and infrastructure collapses are on the rise around the world due to the intensification of natural disasters caused by climate changes, and aging infrastructures. This has increased the need for inspections and repairs of social infrastructures, as well as on-site assessment in the event of a disaster, raising issues with cost, labor, and ensuring the safety of on-site workers.

OKI has been supporting infrastructure maintenance/management and disaster response operations with the development of its Zero-Energy IoT Series (hereinafter referred to as the ZE-IoT Series) infrastructure monitoring system that can remotely monitor the integrity of social infrastructures, such as railways, roads, and water resources, as well as on-site conditions in the event of a disaster. Based on the proven track record with infrastructure operators in Japan, OKI aims to expand its solution globally. OKI has already conducted field experiments of disaster prevention monitoring using the ZE-IoT Series with railway operators in Indonesia and Turkey, confirming its practicality under local operating conditions and its evaluation/acceptability by infrastructure managers. This article provides an overview of the ZE-IoT Series for global expansion, details of the field experiments, and future issues and outlooks.

ZE-IoT Series Overview

The ZE-IoT Series is an infrastructure monitoring system that features easy installation and requires no external power supply or communication wiring. Its high-precision measurement capabilities, high-sensitivity camera imaging, and environmental resistance for outdoor operation ensure high accuracy and reliability in supporting infrastructure maintenance.

Using the ZE-IoT Series, infrastructure operators can remotely monitor various aspects of infrastructures such as change in river levels, slope inclinations, and bridges' natural frequencies. Additionally, the high-sensitivity camera also provides clear images that allow visual confirmation of on-site conditions, day and night. The obtained sensor data and images can be viewed via the cloud on a PC or smartphone browser. Automatic notification can also be sent out when an abnormality is detected, therefore in addition to routine maintenance/inspection, rapid situation assessment and timely response become possible in the event of a disaster. The ZE-IoT Series system configuration is shown in **Figure 1.**

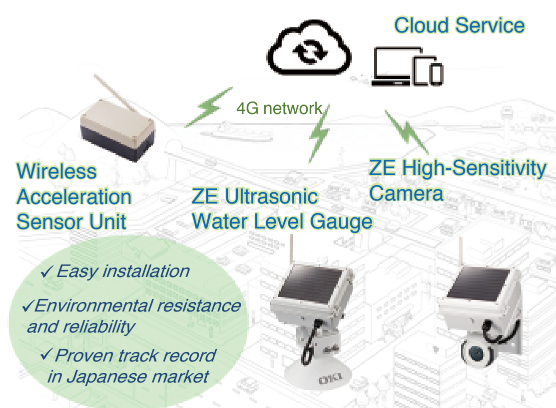

Figure 1. System Configuration

Global ZE-IoT Series

Based on the ZE-IoT Series for Japan, OKI studied the requirements for a global ZE-IoT Series to be used in infrastructure monitoring field experiments in Indonesia and Turkey, followed by commercial deployment, and expansion to other countries. Requirements differ from those in Japan due to the laws, regulations, and data communication service environments of each country. In particular, the wireless communication functionality of the ZE-IoT Series needed to be compatible with data communication services that are widely available in each country and also be power efficient. Therefore, NB-IoT was adopted as the new wireless communication method. Three types of devices were used in the field experiments in each country. The external appearance (**Photo 1**) and features of each device are shown below.

Photo 1. Left: Wireless Acceleration Sensor Unit, Center: ZE Ultrasonic Water Level Gauge, Right: ZE High-Sensitivity Camera

(1) Wireless Acceleration Sensor Unit

The device is battery-powered and compatible with NB-IoT communication, eliminating the need for an external power source or wiring. Its compact, waterproof and dustproof housing makes it easy to install at outdoor sites. It measures tilt angles in two directions in increments of 0.01°, enabling it to monitor minute structural displacements. The device's software processes acceleration data into a frequency spectrum, automatically calculating the natural frequency and transmitting the data. Under typical operating conditions and tilt measurements taken every 10 minutes, the battery lasts over five years.

(2) ZE Ultrasonic Water Level Gauge

Powered by solar energy and compatible with NB-IoT communication, the device can be quickly installed without the need for an external power source or wiring. The ultrasonic system measures water level without contact (accuracy of ±10mm) and is suitable for installation on the top of bridges and culverts. It can operate for more than nine days without sunlight, supporting remote monitoring and operational decisions when water levels begin to rise.

(3) ZE High-Sensitivity Camera

Powered by solar energy and compatible with NB-IoT communication, OKI's proprietary low-power, high-sensitivity camera module captures clear images even in dark environments such as at night. It can operate for more than nine days without sunlight, ensuring uninterrupted image captures during disasters.

The details and results of the field experiments conducted in Indonesia and Turkey are described below.

Field Experiment in Indonesia

In Indonesia, the effects of climate change have led to an increase in natural disasters, such as landslides and river flooding caused by heavy rain, affecting the operation of critical infrastructures, including railways. This necessitates the introduction of an infrastructure monitoring solution that enables early detection of abnormalities for a rapid response.

As part of the JICA Small and Medium-Sized Enterprise/ SDGs Business Support Project - Business Development Demonstration Project - adopted jointly with East Japan Railway Company (JR East), OKI collaborated with PT Kereta Api Indonesia (Indonesia Railways Company) to conduct a field experiment of railway disaster prevention monitoring using the ZE-IoT Series, which has a proven track record in Japan.

In the experiment, wireless acceleration sensor units and ZE high-sensitivity cameras were installed on a slope along the railway line. The experiment verified the local acceptability of the ZE-IoT Series remote monitoring from the perspectives of high-precision data collection, power saving, and ease of installation, as well as its effectiveness in safe and efficient maintenance.

The experiment was conducted in the Purwakarta area, with the devices installed on a slope considered to be at high risk of disaster during heavy rains. Two wireless acceleration sensor units were attached with stainless steel bands to poles fixed to the bamboo fence laid at the bottom of the slope to monitor the fence's tilt when sediments accumulate. A third wireless acceleration sensor unit was similarly attached to a pole erected at the top of the slope to monitor slope displacement. A ZE high-sensitivity camera was attached with stainless steel bands to a nearby electric pole to remotely monitor the condition of the slope via images. **Figure 2** shows the locations of the installed devices.

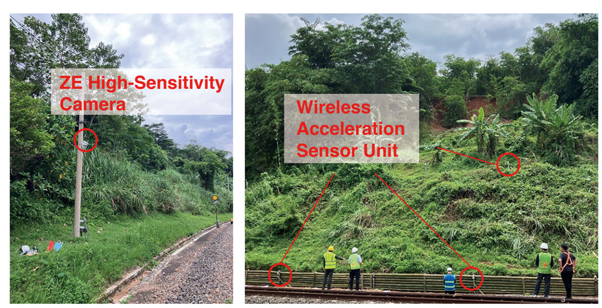

Figure 2. Device Locations for Indonesia's Slope Monitoring

Collected data is stored in the cloud to allow infrastructure managers to view images and graphs of tilt data on their PC or smartphone browsers. Thresholds can also be set to issue warnings. An example of the monitoring screen is shown in **Figure 3**.

The results of the field experiment confirmed that by being able to remotely obtain stable, highly accurate tilt data, infrastructure managers can monitor slope conditions as highly accurate measurement data without having to travel to dangerous sites. Additionally, the ZE high-sensitivity camera was able to obtain clear images both day and night. Monitoring images captured at the actual site are shown in **Figure 4**.

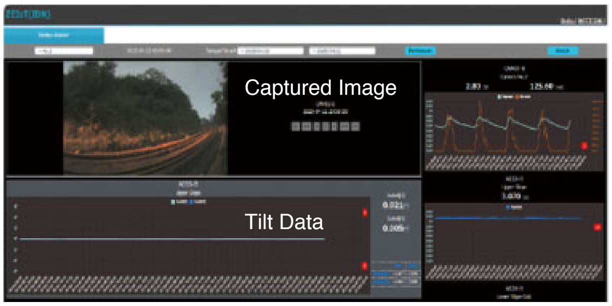

Figure 3. Monitoring Screen

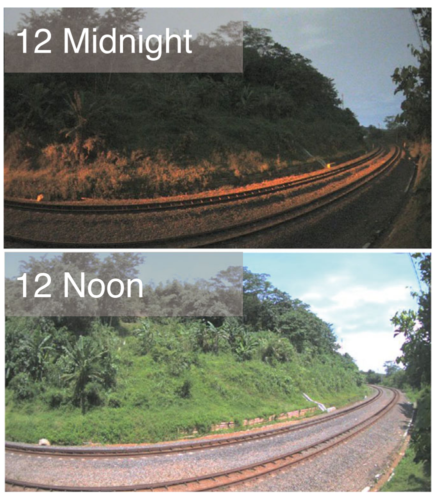

Figure 4. Monitoring Images at Midnight and Noon

The NB-IoT used by each device to send and receive data was provided by a local telecommunications carrier, ensuring stable communications. On-site power consumption measurements confirmed the energy-saving performance of each device, and the ease of installation was also confirmed for each device during the installation work. The field experiment confirmed the effectiveness of railway disaster prevention monitoring using the ZE-IoT Series, demonstrating its applicability to the Indonesia Railways Company and to other infrastructure operators and regions facing similar issues.

Field Experiment in Turkey

Together with Japan International Consultants for Transportation Co., Ltd., JR East, and Nippon Koei Co., Ltd., OKI participated in the JICA-sponsored “Data Collection Survey on Development of Disaster Prevention Capability for Railways in Türkiye,” and in collaboration with Turkish State Railways (Türkiye Cumhuriyeti Devlet Demiryolları), conducted a field experiment of railway disaster prevention monitoring using the ZE-IoT Series.

In Turkey, a variety of natural disasters, including earthquakes, heavy rain, landslides, and sinkholes, affect railway operations, therefore strengthening disaster prevention capabilities is a matter of considerable urgency. The goal of the field experiment was to confirm local acceptability and effectiveness of the ZE-IoT Series in preventing railway disasters.

Three disaster types were considered: (1) landslides and rockfalls on slopes, (2) river flooding, and (3) sinkholes. Experiments (1) and (2) were conducted on the high-speed railway line between Karabük and Filyos, and (3) on the high-speed railway line between Ankara and Karaman. The system consisted of three devices: a wireless acceleration sensor unit for detecting tilt, a ZE ultrasonic water level gauge for monitoring river levels, and a ZE high-sensitivity camera for visually monitoring the site day and night. The sensors were made to automatically issue an alert when an abnormality exceeding the threshold is detected and increase the frequency of communications, enabling a quick understanding of the situation. The results of each experiment are presented below.

(1) Landslide and Rockfall Monitoring

To detect the tilting of a fence installed at a hazardous area, a wireless acceleration sensor unit was attached to a pole fixed to the fence. Additionally, a ZE high-sensitivity camera was installed to check the on-site situation in the event of an abnormality. The locations of the installed devices are shown in **Figure 5**.

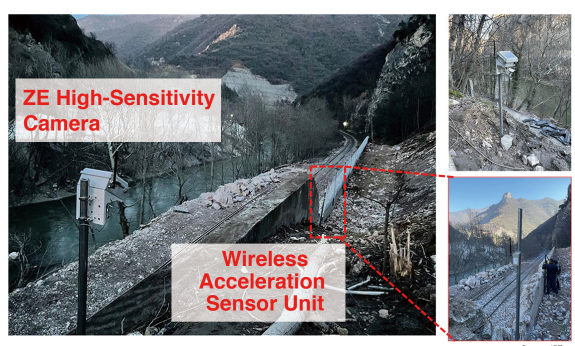

Figure 5. Device Locations for Slope Monitoring

On March 3, 2025, the system detected a tilt of 22 degrees parallel to the tracks and 6 degrees outward at this particular site. Although there was no impact on train operations, a rockfall did occur, confirming that the system functions effectively.

(2) River Level Monitoring

An experiment was conducted at a location where there was a risk of a culvert overflowing due to rising river levels, resulting in track flooding. A ZE ultrasonic water level gauge was installed near the culvert to remotely monitor water level changes during heavy rain, and in combination with images from a ZE high-sensitivity camera, it was confirmed that safe operation decisions could be supported without visiting the site. The locations of the installed devices are shown in **Figure 6**.

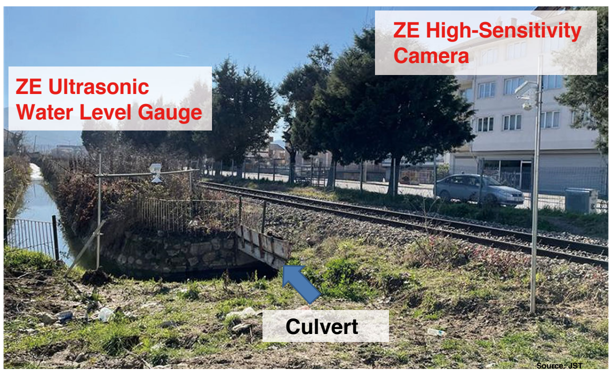

Figure 6. Device Locations for River Monitoring

(3) Sinkhole Monitoring

A surge of sinkholes in the Konya region of Turkey has forced Turkish State Railways, which operates high-speed railways, to address this risk. The cause of the sinkholes is believed to be excessive groundwater use due to a prolonged drought, and analyses suggest that warning signs such as cracks precede the occurrence of sinkholes. In the field experiment, wireless acceleration sensor units were attached to poles erected along the tracks in areas considered at high risk of sinkholes to monitor ground surface movements. A tilt threshold determined in consultation with Turkish State Railways was set, and an alarm was to be issued when an abnormality was detected. ZE high-sensitivity cameras were also combined with the acceleration sensor units in some locations to enable remote image monitoring. The field experiment demonstrated the feasibility of an efficient monitoring system that does not rely on on-site inspections.

The field experiments in Turkey also revealed the following issues:

- Lack of clear standards for threshold setting
- Standardization of alert issuance methods
- Need for an initial response system and manual when abnormality is detected
- Work quality control during restoration of a detection device

To address these issues, it will be important to adapt the system to Turkish operational standards based on Japanese operational experiences and technologies. Together with the results of these experiments, OKI will continue with work to resolve issues, and aim at improving the infrastructure safety and operation continuity of Turkish State Railways, other operators, and neighboring countries.

Conclusion and Future Outlook

This article provided an overview of the ZE-IoT Series and reported the field experiment results of railway disaster prevention monitoring in Indonesia and Turkey. In both countries, the effectiveness of each device in terms of high-precision measurement, power saving, and ease of installation was confirmed, demonstrating the potential for improving infrastructure maintenance and disaster response operations through remote monitoring. New issues were also identified, such as the need to make adjustments based on the availability of communication services in each country and the need to establish systems on issuing alerts and taking initial response. These are issues that must be addressed before a full-scale implementation.

Based on the results of these experiments, OKI will expand the scope of application for railways and other infrastructure areas. Work will also be continued on improving maintenance and disaster response capabilities by introducing additional sensors and enhancing data analysis technology. ◆◆

References

1) Hiroshi Hashizume: Zero-Energy IoT Series -Realize Remote Monitoring of Infrastructure and Disaster Site with Easy Installation, OKI Technical Review, Issue 242, Vol. 90 No.,2, February 2024

2) Japan International Cooperation Agency, Japan International Consultants for Transportation Co., Ltd., East Japan Railway Company, Nippon Koei Co., Ltd.: Data Collection Survey on Development of Disaster Prevention Capability for Railways in Türkiye (Final Report), JICA Final Report, 2024

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TIPS 【Glossary】

NB-IoT (Narrowband IoT)
A low-power, narrowband cellular communication standard designed for IoT (Internet of Things) devices.

culvert
A reinforced concrete structure used for waterways, drainage channels, and passageways under railways and roads.

sinkhole
A hole-like topography formed when the ground surface suddenly collapses due to groundwater outflow or soil erosion. It can seriously affect the safety of infrastructures such as railways and roads.