■R&D Topics : Inspection, Monitoring, and Diagnostics Technologies

■R&D Theme : R&D of Early Warning Monitoring System of Slope Failure Based on Multi-point Tilt Change and Volumetric Water Content

■Principal Investigator : Lin Wang (Chuo Kaihatsu Corporation)

R&D Objectives and Subjects

SIP Cross-ministerial Strategic Innovation Promotion Program

Objectives

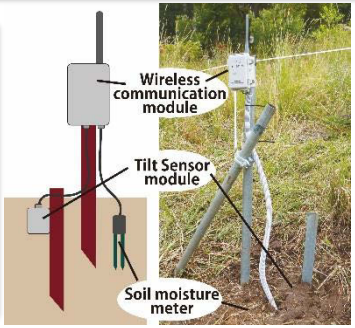
Research and develop a highly accurate, multi-point early-warning system for slope failure using low-cost tilt sensors.

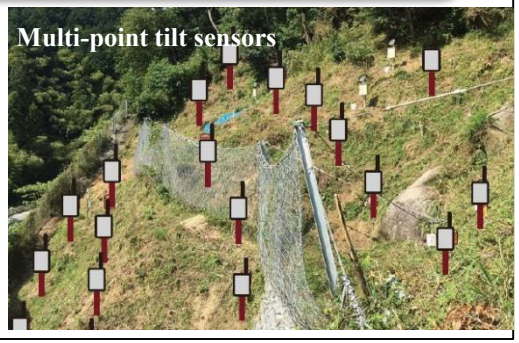
Extensometer

- Difficult to install.
- Expensive to set up numerous units on a single slope.
- Sensitive only to regional movement.

Multi-point Monitoring System using Tilt Sensor

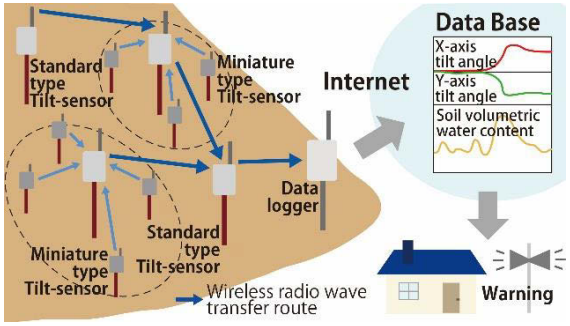
- Easy to install.
- Low cost of equipment and installation.
- Sensitive to movement of whole area.

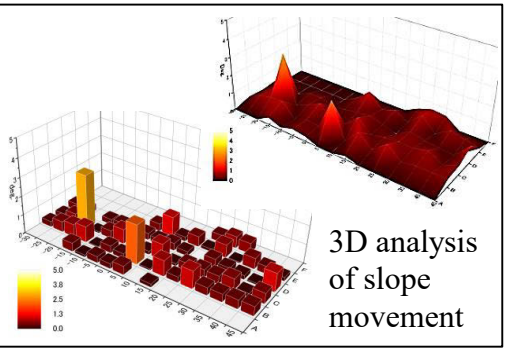




Subjects (2014-2016)

- Low-cost, easily-installed tilt sensors.
  ⇒ **Realized low cost multi-point measurement.**
- Prediction of slope deformation by multi-point measurements.
  ⇒ **Realized high-precision, stable, early warning slope failure system.**





3D analysis of slope movement

Current Accomplishments (1/2) 2014-2016

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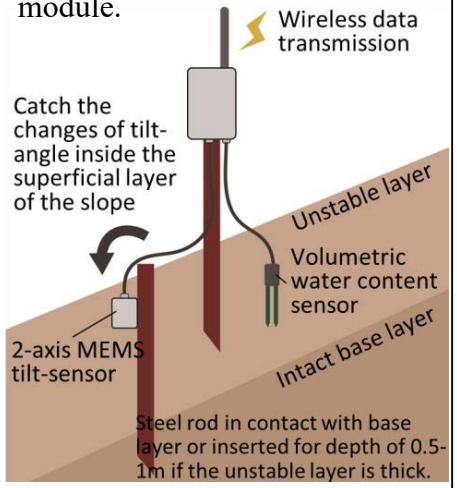
1. Easy installation

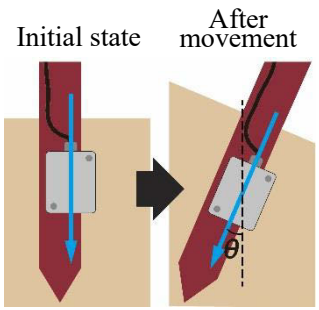
Effective, rapid, and convenient installation of sensors by inserting a steel pole into the slope and affixing the sensor module.

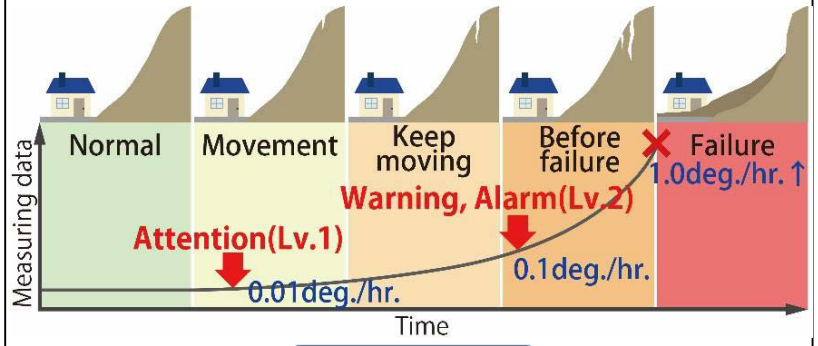


In-field efficiency

2. Established method of evaluating risk and warnings for a dangerous slope

Based on detected behavior and by adopting a conservative approach, it is proposed that a precaution for slope failure be issued when the tilt rate reaches 0.01° per hour and a warning of slope failure be issued at a tilt rate of 0.1° per hour.

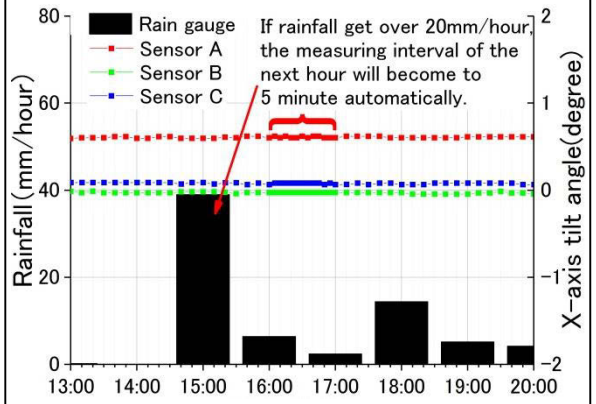




Real-time quantification of slope risk

3. Risk-based automation of measurement interval

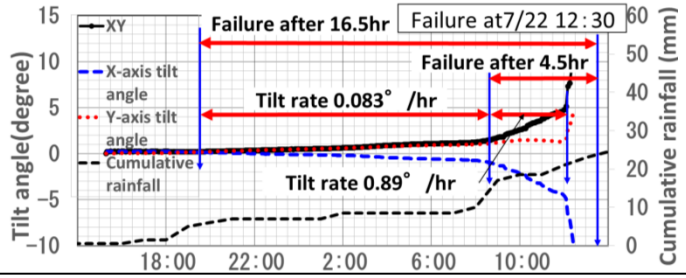
The risk of slope failure increases during heavy rainfall, and thus the system is set up to automatically shorten the time interval (an optional setting) of measurement when rainfall exceeds 20 mm per hour.



Improved accuracy

Utilization example

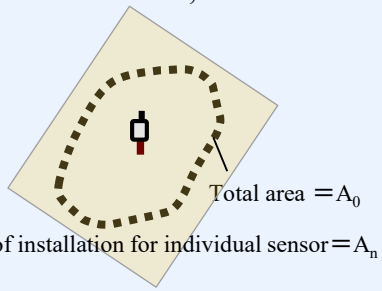
At other field sites, the tilt rate increased toward failure within a relatively short time before slope failure. Tilt rate is thus inversely proportional to the remaining time until failure.



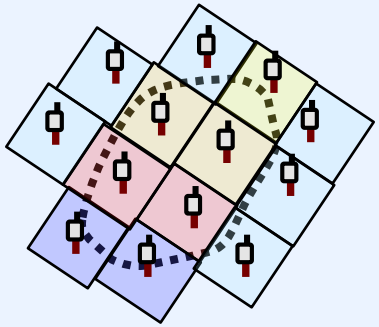
Early warning can be issued based on the relationship between tilt rate and remaining time to failure.

4. Construction of a stable early warning system using multi-point measurements

1 Single sensor ⇒ False warning issue can easily be caused by local movement, animal contact, etc.:



Suitable sensor intervals for multi-point measurement reduces the coverage of each sensor, thus improving system accuracy:

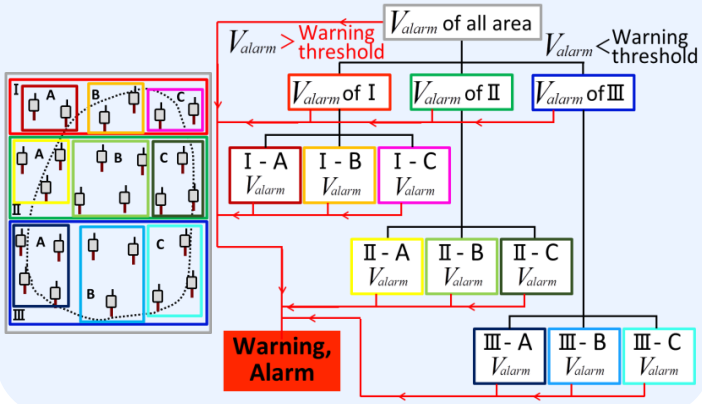


2 Warning threshold based on behavior of multiple sensors:

$$V_{alarm} = \sum_{n=1}^{N}\left(|V_n| \times \frac{A_n}{A_0} \times \partial_n\right)$$

V_n = Tilt rate (X-axis) of each sensor (deg./hr.), If >1.0, V_n=1.0.
A_n = Area of installation for individual sensor.
A_0 = Total area of installed sensor array.
∂_n = Coefficient to be decided by the geological, soil, and vegetation conditions at installation point.

3 Reliable management of warning issuance based on numerous monitoring zones and multi-point measurements:



Realized high-precision and stable early-warning system for slope failure

Flow of utilization

1. Easy installation
2. Established method of evaluating risk and warnings for a dangerous slope
3. Risk-based automation of measurement interval
4. Construction of a stable early warning system using multi-point measurements

Realized early-warning system based on spatial and temporal analysis of entire slope behavior

Slope Failure Early-Warning Monitoring System Based on Multi-point Tilt Measurement and Water Content

International Support

Technical Service

- Early warning of slope failure
- Prevention of secondary disaster
- Assess pre-failure phenomena of slopes
- Dynamic monitoring of landslides in mountainous areas
- Application to Internet of Things and trends in Big data

Joint Research by Local Autonomies and Private Enterprise

Numerical targets

- Installation time reduction of about 60%.
- Economic improvement of about 40% by reducing equipment and installation costs.

Users

Local autonomies, Regional Bureaus of MLIT, Private businesses, International supporting organizations, etc.

Cooperation with Regional Bureau of MLIT to develop research results

Places of use

To fulfill a role of early warning for disaster prevention by using the results of research and develop for natural slope, road works, cutting slope works, and rock fall.

High-precision and stable early-warning system for slope failure.

→Realized early-warning system based on spatial and temporal analysis of entire slope behavior.