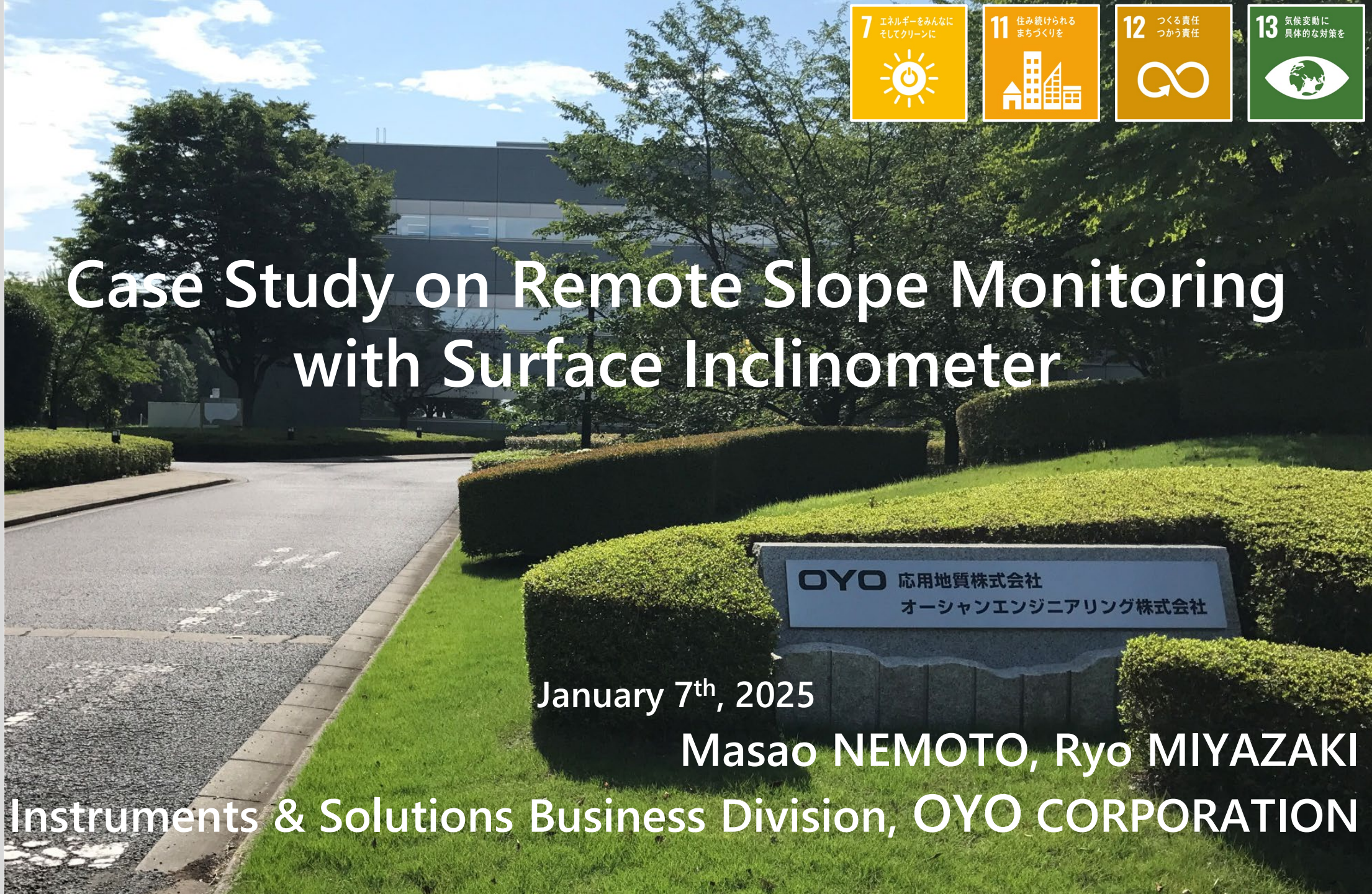
Case Study on Remote Slope Monitoring with Surface Inclinometer



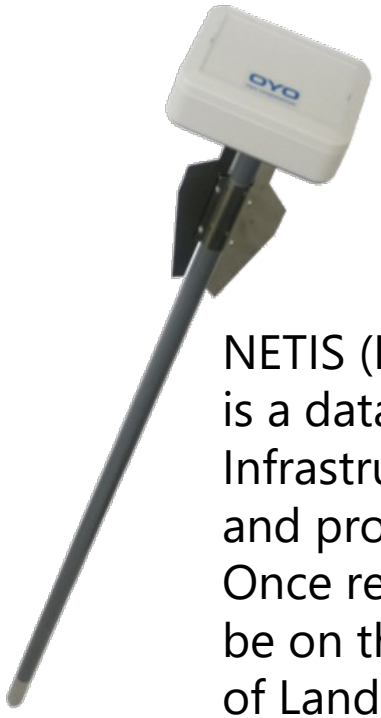
January 7th, 2025

Masao NEMOTO, Ryo MIYAZAKI
Instruments & Solutions Business Division, OYO CORPORATION

Today's Introduction: 2 Types of Surface Inclinometers

◆Clinopole◆

For disaster situations and construction management



国土交通省 新技術情報提供システム
NETIS 登録製品
登録番号：QS-240007-A

NETIS (New Technology Information System) is a database managed by Ministry of Land, Infrastructure, Transport and Tourism to share and provide information on new technologies. Once registered to NETIS, the technology will be on the list of public works of the Ministry of Land, Infrastructure and Transport and local governments.

◆Clinopole NEO◆

For preventive maintenance and area-wide monitoring

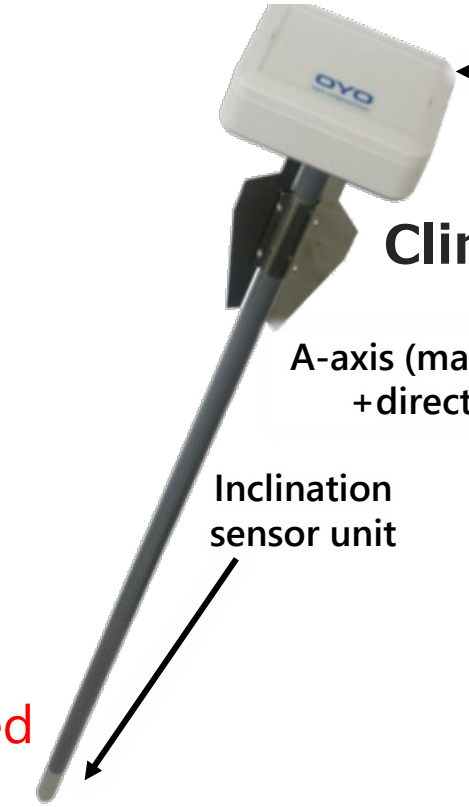
1．Clinopole

(1) Overview of Clinopole

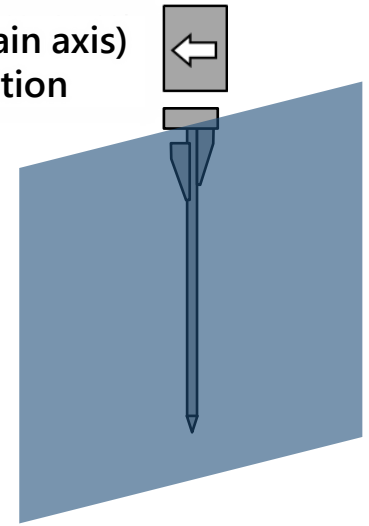
Frequent slope disasters
→Identifying area-wide hazards by multi-point monitoring.

- Clinopole is **inclinometer for ground**. Burying a sensor part 1m **avoids temperature affect and enables precise data acquisition**.
- **Easy installation by simply inserting** integrated communication module and sensor **into the ground**
- 2-level settings allow automatic adjustment of data acquisition and transmission frequency, **along with alarm email options**
- **Runs for up to 5 years** on a dedicated lithium battery
- Released in April 2020, patented in June 2023, and NETIS(New Technology Information System) registered in July 2024

Clinopole Appearance



Clinopole Installation Image



(2) Types of Clinopoles

Beyond the standard model, we offer a diverse range of Clinopoles to meet various site conditions

For rock
(50cm, vertical)

Features)
The 50 cm insertion makes this model **suitable for hard-to-drill rock and retaining walls**

For horizontal
(50cm,horizontal)

Features)
Horizontally set built-in sensor enables this model to **measure in horizontal holes**

For snow load
(separated link)

Features)
By splitting the link and sensor units, burying the sensor, and elevating the link unit, this model **guarantees stable data traffic during heavy snowfall**

For sheet pile
(100cm, separated)

Features)
A separable design suitable for the sheet pile shape enables **deformation measurement while maintaining inclinometer resolution**

(3) Clinopole Installation Instructions

Ground：Soft → Ground：Hard

1. Drilling with T-Pole
Unconsolidated Soil(0th basin)

- ✓ Use a soil rod to find points allow 1m insertion, then manually insert a T-pole.
- ✓ If it is too hard, use a single pipe for drilling.

2. Drilling with Single Pipe
Embankment Soil

- ✓ Use a φ25 single pipe and a metal hammer.
- ✓ Hit the hammer vertically to insert the pipe into the ground for drilling.

3. Drilling with Hammer Drill
Weathered Rock like Cut Slope

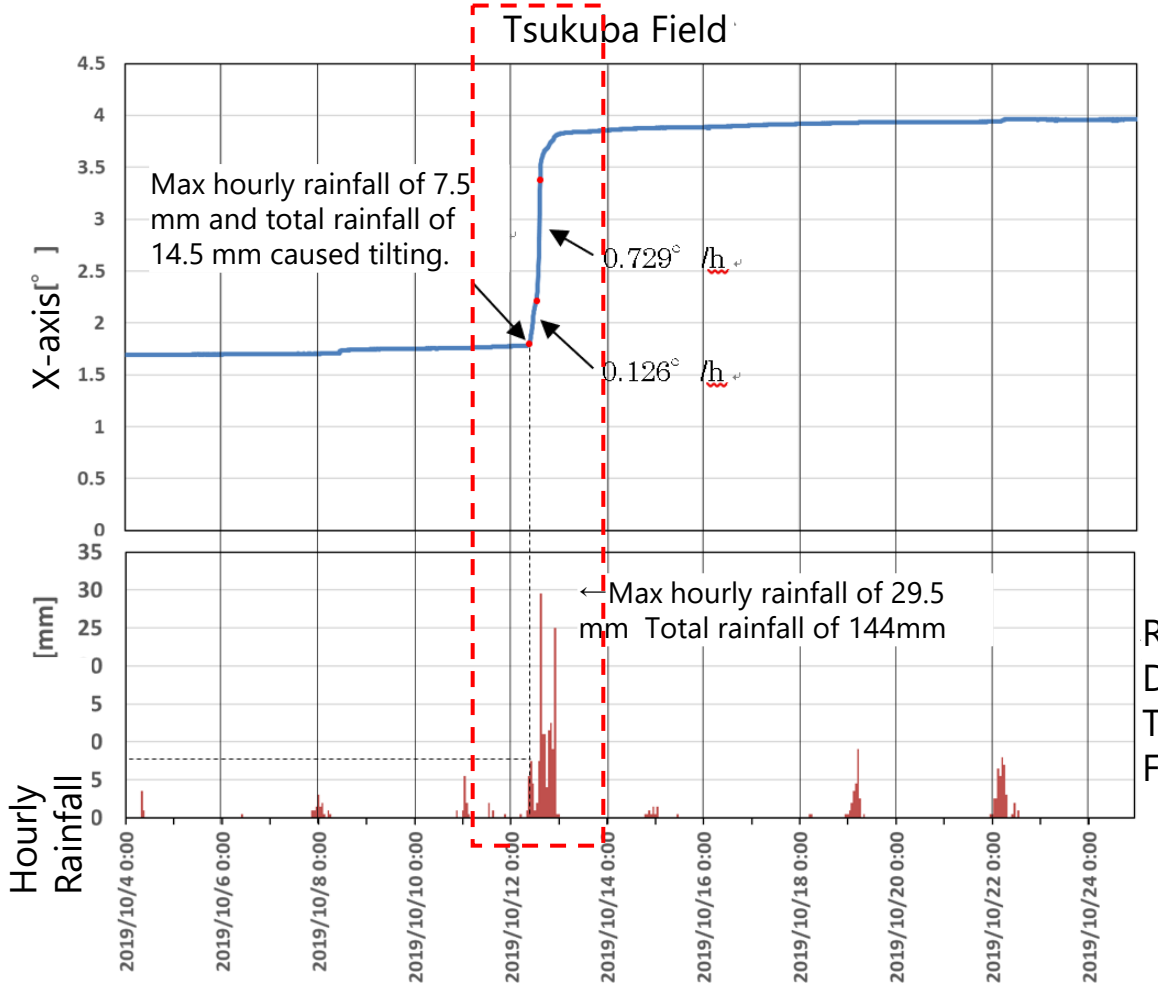
- ✓ Use a hammer drill equipped with a φ26 bit for drilling.
- ✓ A compressor serves as the power source for the drill.

※The above represents a standard case; however, the appropriate drilling method should be adopted based on the actual ground conditions and work environment.

(4) Observation Results Case Studies

Demonstration Experiment at the Test Field of OYO's Tsukuba Office
Observation Results from an Artificially Constructed Creep Slope

An Artificially Constructed Creep Slope



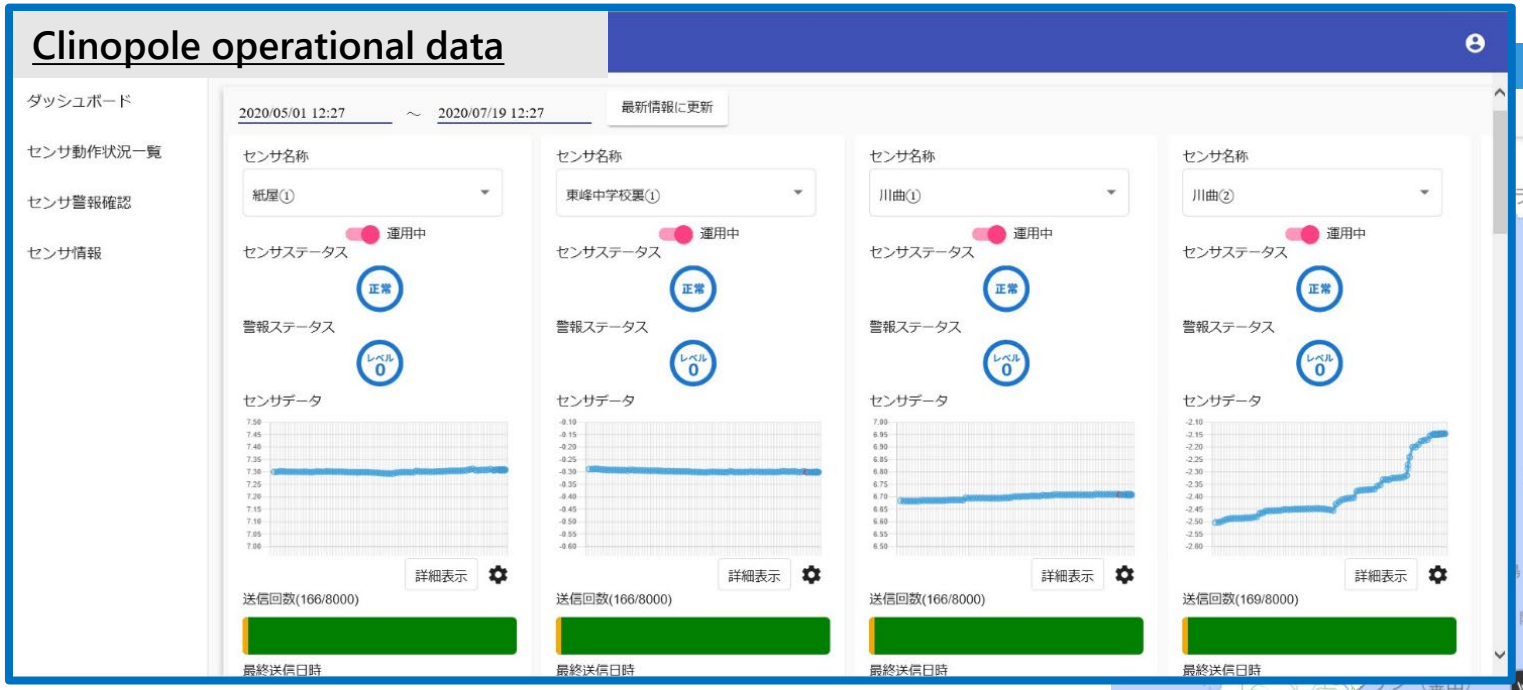
⇒The movement of the ground is captured when it tilts due to rainfall.

Rain Gauge Data from Tsukuba Field

(5) Data Check on OYO Cloud

Data can be checked (value / graph) and downloaded in CSV format.
The installation locations of the clinopoles are marked on the map, allowing for an area-wide understanding of the situation.

Clinopole operational data



Area-wide monitoring by mapping

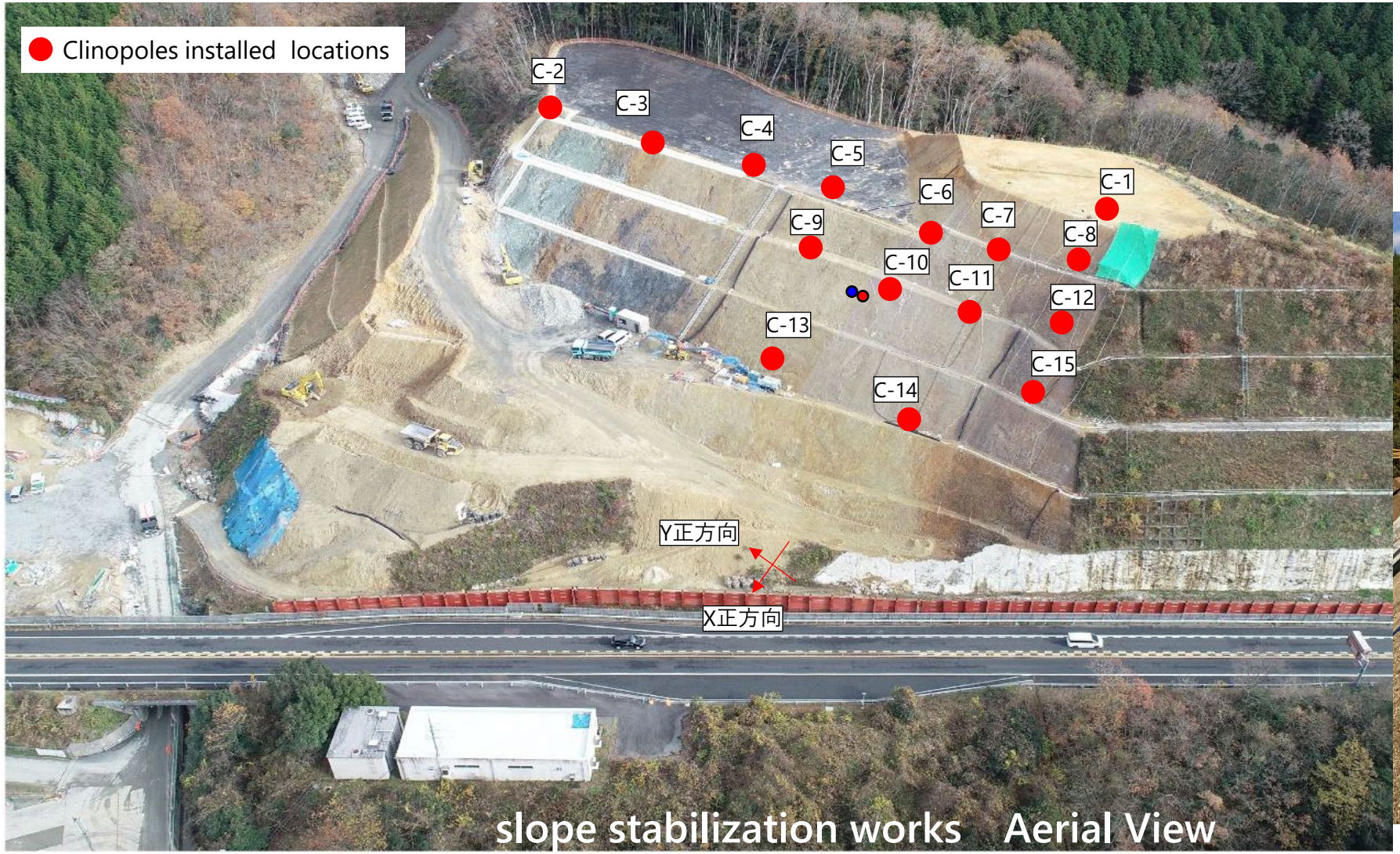
Case Study: Safety Monitoring for Embankment Reinforcement Works (Rock Bolts)

- Clinopoles have been installed at multiple points on the embankment slope to assess their applicability in **safety management** (monitoring embankment behavior) **during construction**. (150 Clinopoles at 5m intervals in a 750m monitoring target area).

Reg. ver.

Case Study：Long Slope Construction Management (Road)

Reg. ver.

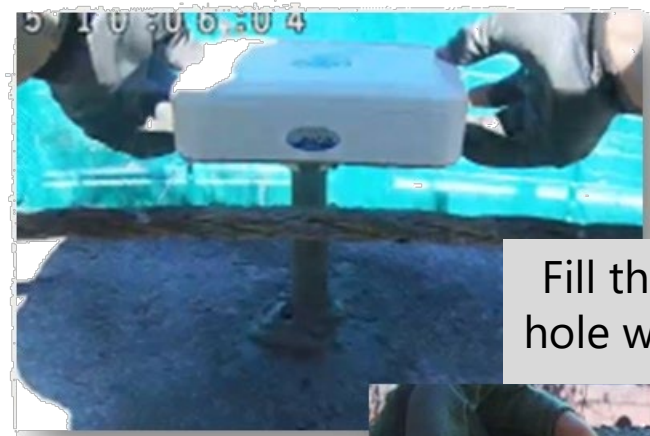


slope stabilization works Aerial View

Case Study：Monitoring Displacement of Retaining Walls Along the Road

- At the site where clinopoles were installed to monitor slope movements, when trying to lift traffic regulations, it was discovered that the retaining wall was gradually tilting. **To monitor the behavior of the retaining wall**, Clinopole for rock has been installed.

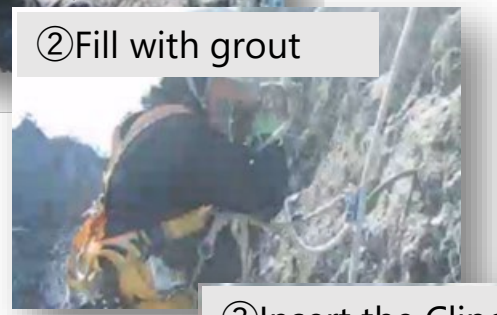
Rock ver.
(50cm)

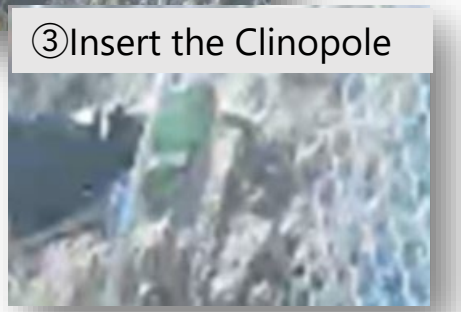


Fill the drilled hole with grout

Case Study：Monitoring Displacement of Bedrock Along the Road

- To **monitor the deformation of the rock mass located above the tunnel** along the road, horizontal clinopoles have been installed. This application is also valuable for construction management during rock excavation processes.





Case Study: ☞Comparison of data with another inclinometer

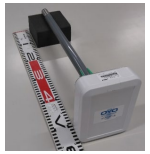
With data from the horizontal Clinopole under POC, we have confirmed stable rock slope tilt measurements unaffected by temperature (Tilt less than 0.005°). **More stable rock monitoring is possible** with its stable measurement values and performance (resolution).

i-sensor Inclinometer・Rock surface data

Data with temp-dependent amp of 0.03° ~ 0.06°

After confirming that the data changes after the earthquake are within the temp amp range, presence of change can be confirmed (after 24 h or later).

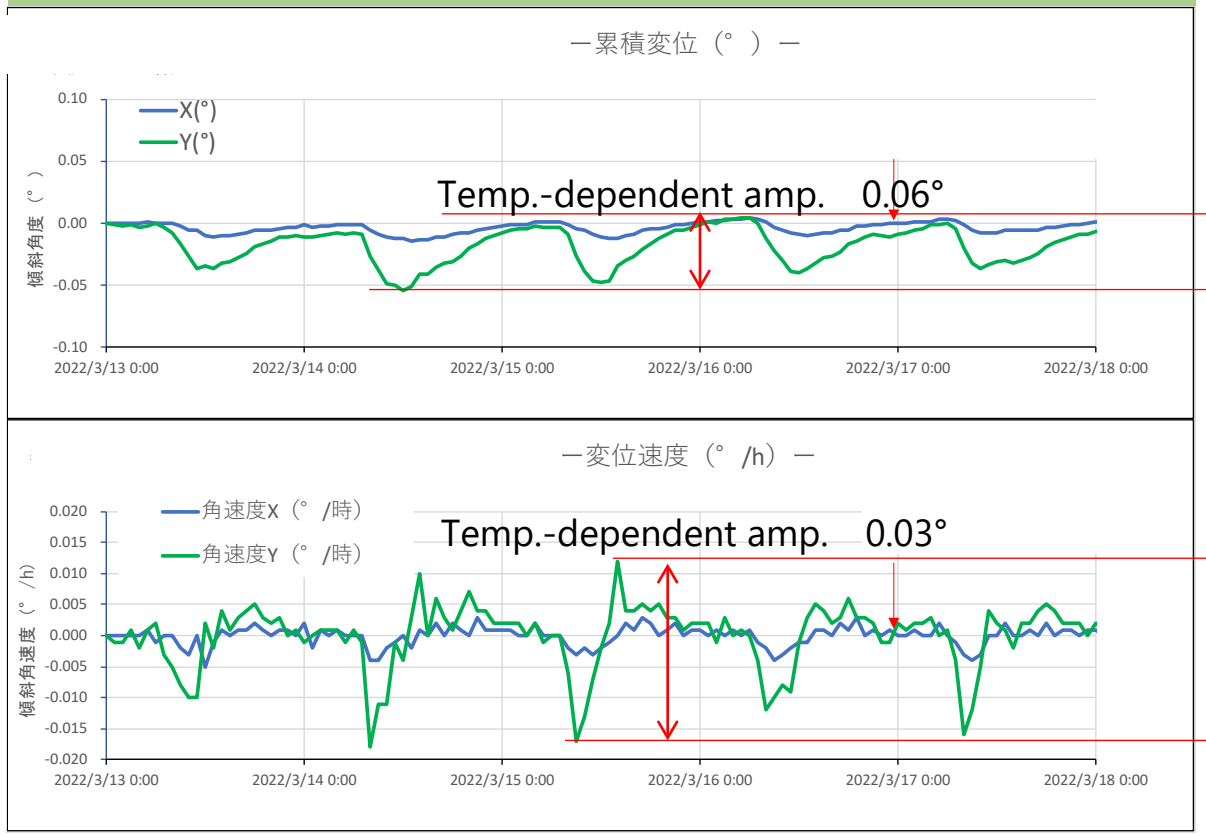
Clinopole（Hori. Ver.）・In rock（d＝50cm）data



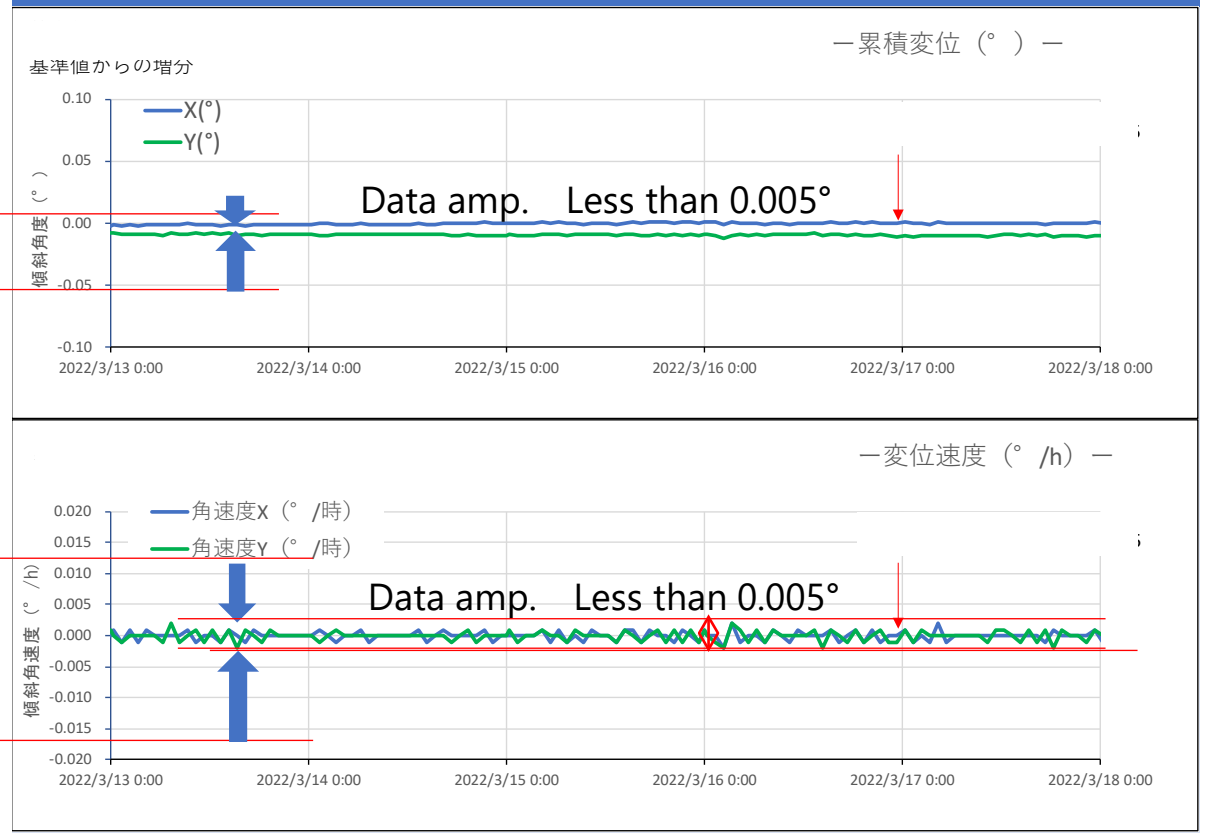
Data amplitude is less than 0.005°

Temperature-dependent data noise (amplitude) is 1/15 ~ 1/80 of conventional inclinometers (left).

＜地盤傾斜計　傾斜変位



＜傾斜変位



Case Study: POC by NIED (1/3)

- Dec. 2023：Rainfall Experiments Using Full-Scale Embankments at the Large Rainfall Testing Facility
  ⇒Joint Research and experiment by the National Research Institute for Earth Science and Disaster Prevention (NIED) and OYO
- Sep. 2024：Results were presented at the Technical Forum of the Japan Geotechnical Consultants Association (JGCS) 2024 in Niigata.
  ⇒Title Factors Influencing the Prediction of Collapse Time in Slope Failure Monitoring Using Inclination Sensors
  Presenters Mitsuru YABE, Masao NEMOTO, Takanori ISIKAWA and Michito MORIKAWA, OYO
  Naoki SAKAI, NIED

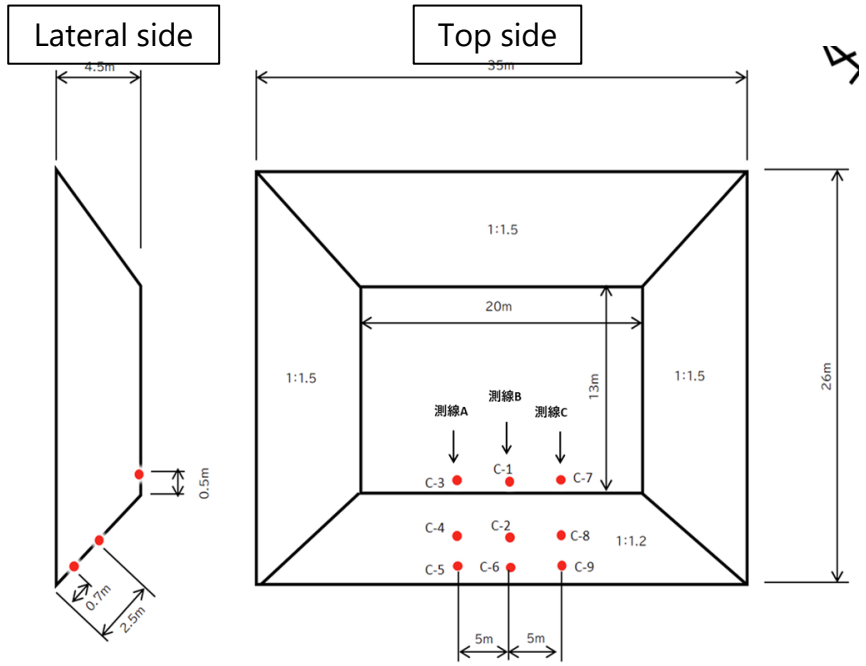


Fig.1 Schematic Diagram of Experimental Embankment

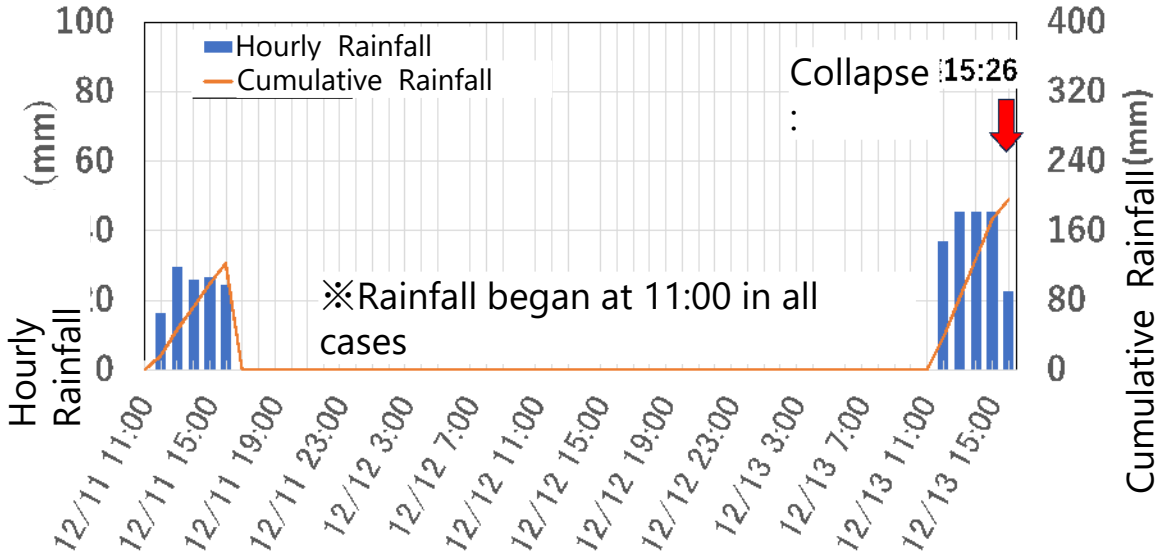


Fig.2 Rainfall Condition in the experiment

Case Study: POC by NIED (2/3)

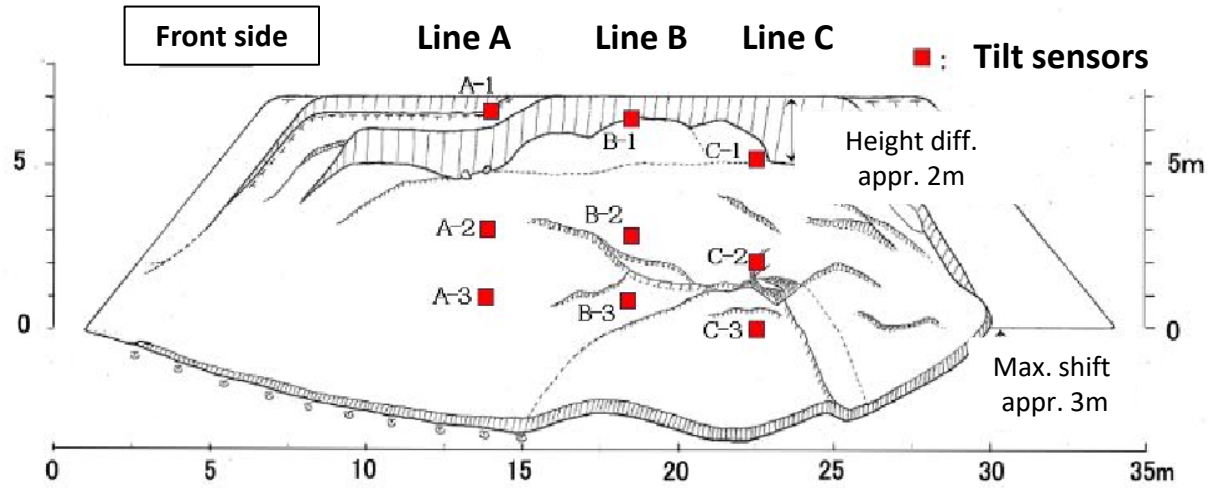


Fig.3 Sketch after the Slope Collapse

Tab.1 Sensor Deployment Locations and Collapse Safety Time

Excess Scale of Tilting rate of Slope	Overtime/Failure Safety Time (min)※Time to failure 15:26					
	Line A		Line B		Line C	
	A-1 (Top)		B-1 (Top)		C-1 (Top)	
0.02°/hour	12:20	186	11:50	216	14:10	76
0.1°/hour	15:10	16	15:00	26	14:50	36
	A-2 (Mid)		B-2（Mid）		C-2 (Mid)	
0.02°/hour	11:50	216	13:30	116	13:40	106
0.1°/hour	15:10	16	15:00	26	15:00	26
	A-3 (Toe)		B-3 (Toe)		C-3 (Toe)	
0.02°/hour	13:00	146	11:40	226	12:00	206
0.1°/hour	15:20	6	13:50	96	14:00	86

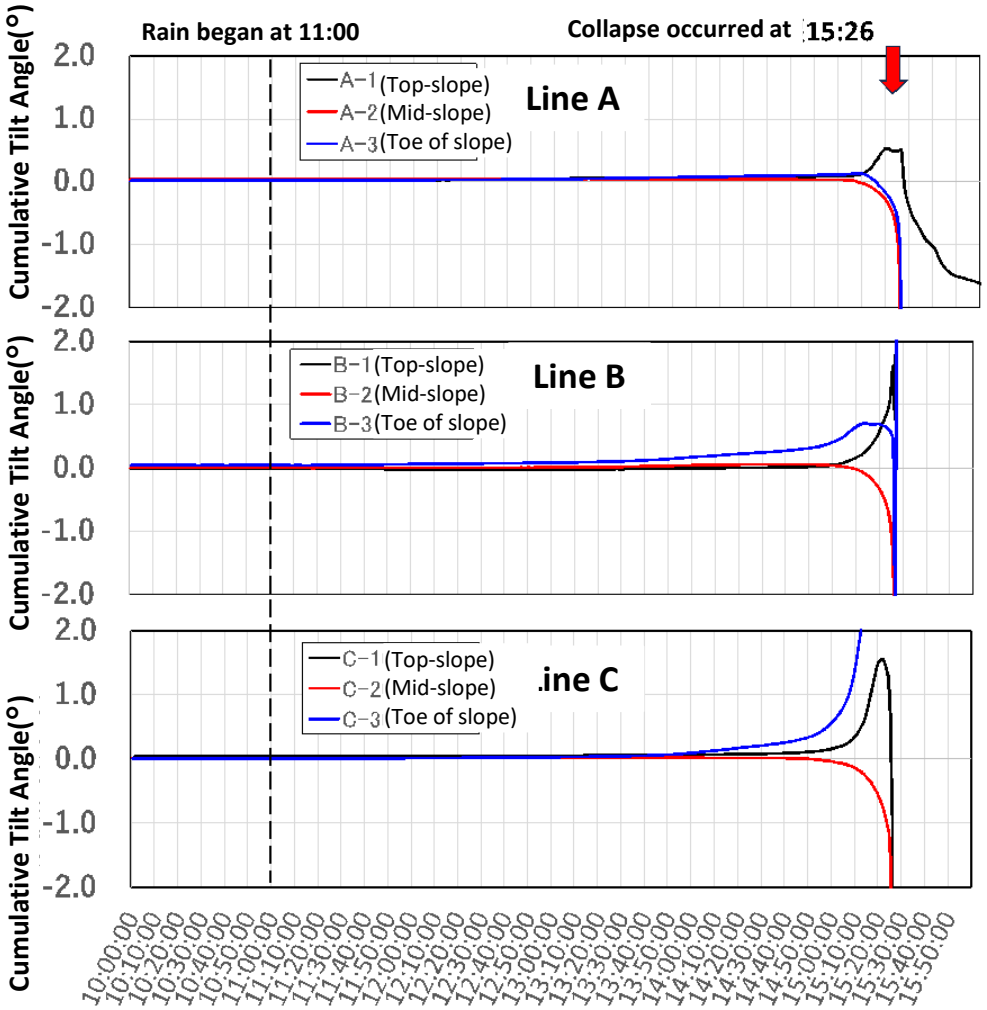


Fig.4 Cumulative Tilt Angle Changes Over Time for the inclination Sensors on each measurement line

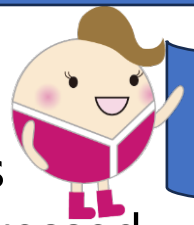
Case Study: POC by NIED (3/3)

2．Clinopole NEO

(1) Overview of Clinopole NEO

Clinopole NEO

➤ A surface inclinometer capable of low-cost multipoint measurement with 1set of 20 sensors to measure ground slope.



Released：April 2024

Concept

- Significantly affordable **than Clinopole and other competitors**
- Through DX **labor shortages** and **decarbonization** will be addressed
- **Aim to establish preventive maintenance as** a new technology proposal
- Joint development with West Nippon Expressway Engineering Chugoku Co., Ltd

Sensor (Setup Ex)
Unlike Clinopole, Clinopole NEO's communication and sensor units are separated; the com is above ground and the sensor is buried.

Controller (Setup Ex)
Place the controller under the solar panels

(2) Deployment Cases

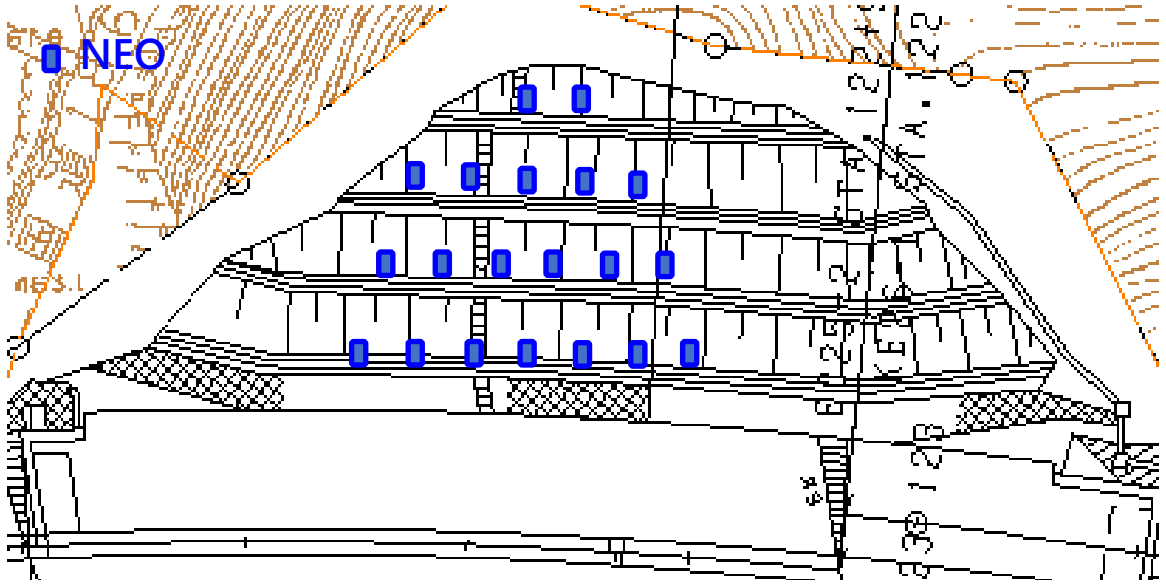
(3) Application Cases

1. Road Administrators

(1) NEXCO (Highway admin in Japan)

(2) MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

(3) Local Government

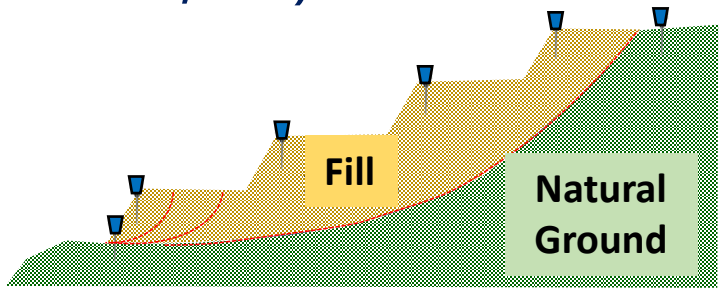


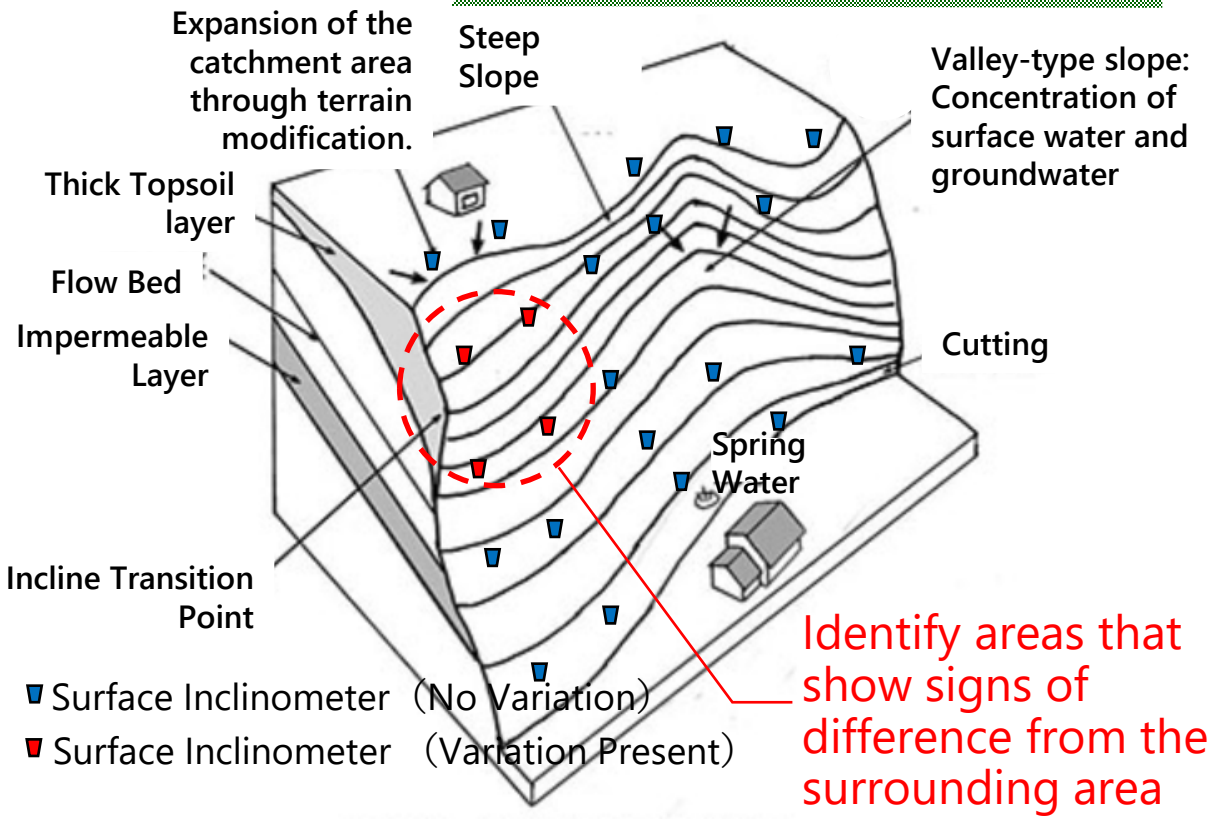
2. Slope (Steep Slopes, Embankments, etc.) Admin

(1)Local Government

(2)Private Sector

(3) Railway Companies





(4) Features and Selling Points of the Product

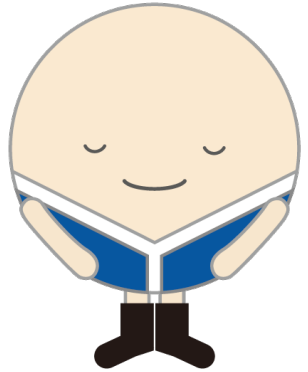
【Clinopole NEO】		【Clinopole】
1 set: 20 pcs	Sales Unit	1 pc
For 1 set (20 sensors)	Price	For 1 pc
Unavailable	Measurement Interval / Mode Change Function	Available
Preventive maintenance	Application	Disaster and Construction Management

Controller

Sensor

(5) Introduction Video for Clinopole NEO at OYO Fair

Thank you for your attention



References

The dimensions and morphology of landslides and collapses

$L/W = 0.5 \sim 2.9$ (Avg. 1.24)

$L/D = 2.8 \sim 19.2$ (Avg. 7.39)

$W/D = 3.0 \sim 10.7$ (Avg. 6.08)

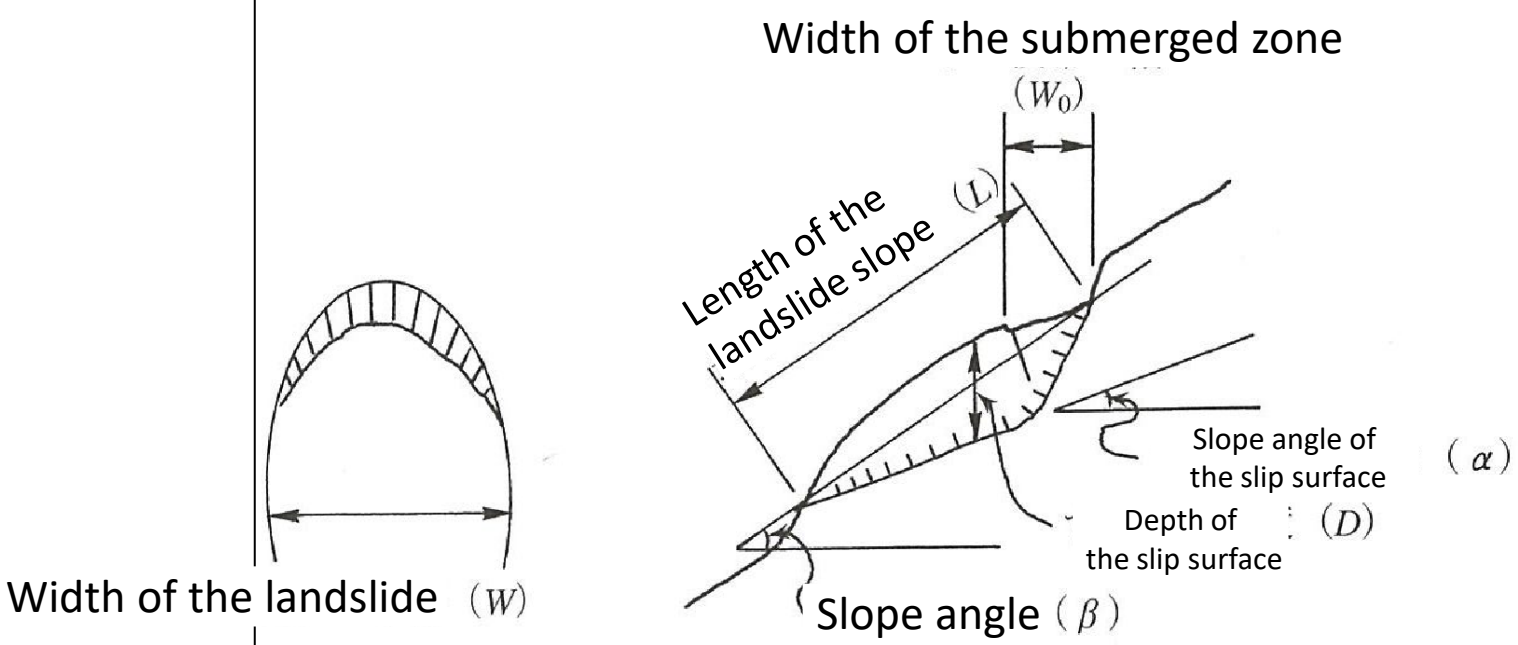


Fig. 4.18 Names of landslide shape

Quoted from 'Design and Construction Points of Cut Slopes' (by Masashi Ueno, Riko Shuppan, p. 70).

Comparison with surface inclinometers from other manufactures

Item	Clinopole OYO	Clinopole NEO (WNEE Chugoku・OYO)	Ground-Fixed Type Inclinometer, N Corp.	Buried Type Inclinometer, C Corp.	Self-Standing Type Inclinometer, M Corp.	PileType Inclinometer, L Corp.	PileType Inclinometer, A Corp.	ScatterType Inclinometer, O Corp.
Key-Features	● High resolution allows for the measurement of small values. ● Installing the sensor 1 meter below the surface **minimizes the effect of temperature**. ● **Installation is simple**. ● Registration and settings **can be done remotely.**	● High resolution allows for the measurement of small values. ● Installing the sensor 0.8 meter below the surface **minimizes the effect of temperature**. ● **Installation is simple.** ● Registration and settings **can be done remotely.**	● Measurements can be started simply by attaching the sensor box to the measurement target.	● Simple, cost-effective, and high measurement accuracy. ● Easy to install.	●Capable of measuring inclination direction and angle. ●Composite (vector) measurements can also be displayed. ●Easy to install. ●Easy to change the number of units. ●Data check and collection can be dome remotely.	● Easy installation and cost effective by combining existing piles with MEMS technology. ● 1 gateway can communicate with up to 16 sensor piles.	●Simple and easy to install	●No commercial power supply is needed. ●Easy to install. ●The mesh network provides strong resistance to communication disruptions.
Measurement Items	Inclination (2-axis) Temperature	Inclination (2-axis) Temperature	Inclination 3-axis, shock GPS positioning, temperature Azimuth	Inclination	Inclination Azimuth Temperature	Inclination 2-axis Temperature Battery voltage	Acceleration Temperature	X/Y axis inclination angles Composite inclination angle Sensor temperature
Resolution	0.001°	0.001°	0.06°	0.02°	0.025°	0.04°	–	0.01°
Communication Function	LTE Cat.M1(LTE-M)	Cloud⇔Controller:LTE Cat.M1(LTE-M) Controller⇔Sensor：Bluetooth®	Sigfox	Wireless standards: ARIB, STD-T67 compliant , range approx. 600m	Specific low-power wireless ~100m between sub-devices; max 200m to master device	Specific low-power wireless, 426MHz band, 10mW Range: 100～300m	LoRaWAN v.1.0.2 Range：appr. 3km	Docomo, au, and other satellite communication networks, connected via band 920MHz specific low-power wireless
Power Supply	Dedicated lithium disposable battery： approx. 5 years	Dedicated lithium disposable battery： approx. 5 years	Dedicated lithium disposable battery： approx. 2 years (1-hour transmission interval)	4 AA batteries: approx. 1 year	Master device：DC12V Sub-device： 4 lithium batteries (Max. 6 months)	Dedicated lithium disposable battery: approx. 1 year (1-hour transmission interval)	Dedicated lithium disposable battery： approx. 3 years	2 lithium batteries for 1 year of operation; solar power unit included
Data Storage	In-house cloud service	In-house cloud service	In-house cloud service	In-house cloud service	Cloud service		In-house cloud service	In-house cloud service
Power and Communication etc.	No need for AC power		In outside of Sigfox coverage, routers and base stations need AC power	Gateway is needed	It can tell which way it's tilted. ~100m between sub-devices; max 200m to master device	Gateway is needed	Gateway is needed	Gateway is needed

Patent Registration for Clinopole

特　許　証
(CERTIFICATE OF PATENT)

特許第７３０１４８５号
(PATENT NUMBER)

発明の名称 (TITLE OF THE INVENTION)　表層崩壊の検出方法及びこれに用いる表層傾斜計

特許権者 (PATENTEE)　東京都千代田区神田美土代町７番地
応用地質株式会社

発明者 (INVENTOR)　石川　貴規
小澤　健志

その他別紙記載

出願番号 (APPLICATION NUMBER)　特願２０２１－０６３８９１
出願日 (FILING DATE)　令和　３年　４月　５日(April 5, 2021)
登録日 (REGISTRATION DATE)　令和　５年　６月２３日(June 23, 2023)

この発明は、特許するものと確定し、特許原簿に登録されたことを証する。
(THIS IS TO CERTIFY THAT THE PATENT IS REGISTERED ON THE REGISTER OF THE JAPAN PATENT OFFICE.)

令和　５年　６月２３日(June 23, 2023)

特許庁長官
(COMMISSIONER, JAPAN PATENT OFFICE)
濱野幸一

特　許　証
(CERTIFICATE OF PATENT)
(続紙　１)

特許第７３０１４８５号(PATENT NUMBER)
特願２０２１－０６３８９１(APPLICATION NUMBER)

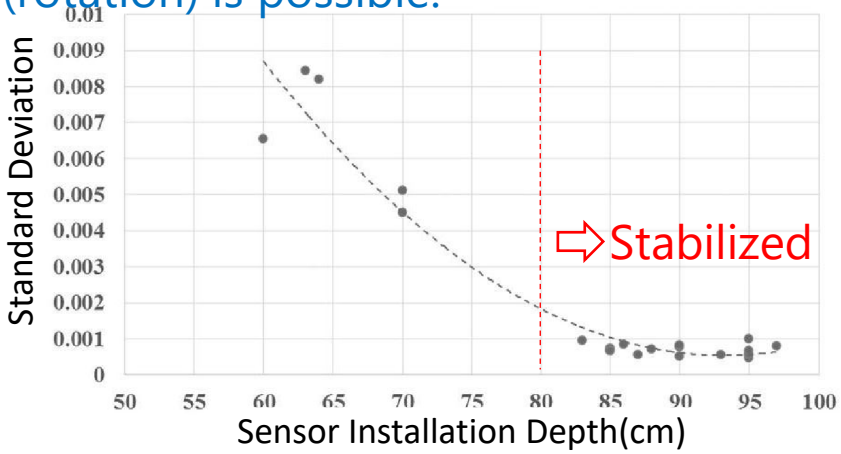
発明者 (INVENTOR)　今野　信一

[以下余白]

Patent Certificate

【Patent Claims】

1) A method for detecting surface failure using a surface inclinometer.
2) It includes a sensor, main body, and communication unit.
3) Possible to detect inclination of unconsolidated soil layers that flow due to creep during surface failure.
4) By installing the sensor unit at a depth of 80 cm or more, data variability caused by changes in natural environmental conditions such as temperature can be minimized, thereby enhancing measurement accuracy.
5) With the 3 blades which ensure pressure forces resulting from the movement of soil downward in the direction of the slope, precise detection of creep (rotation) is possible.



Graph of Sensor Installation Depth vs. Standard Deviation
Diagram Associated with 4)

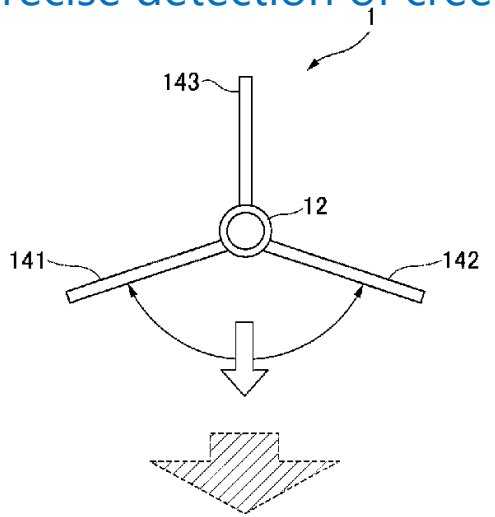
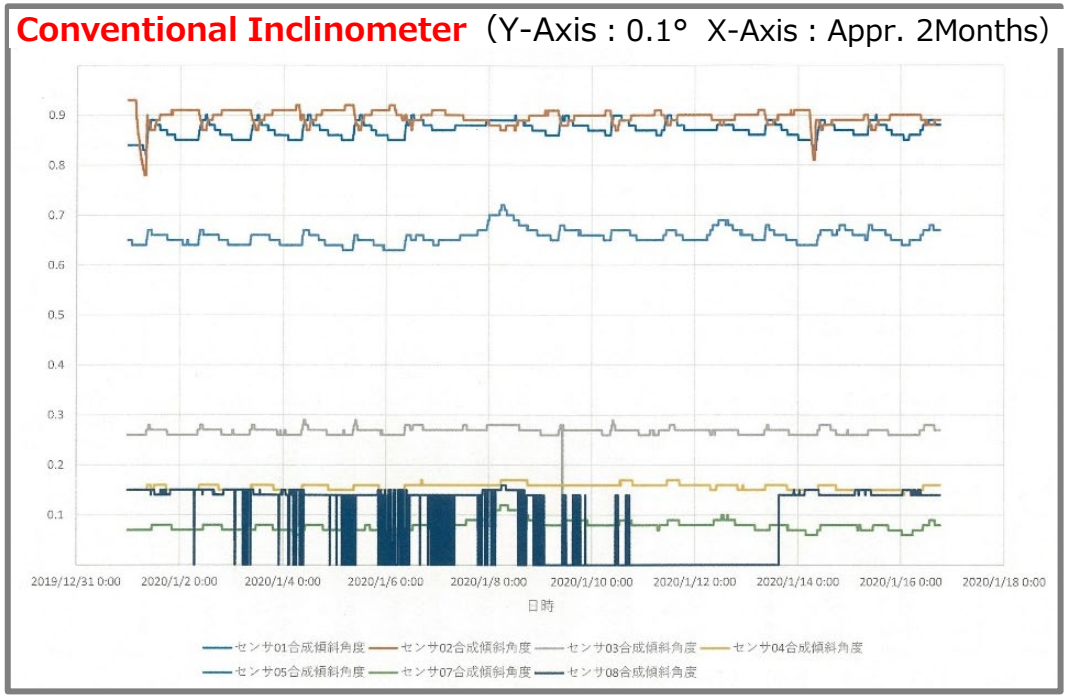


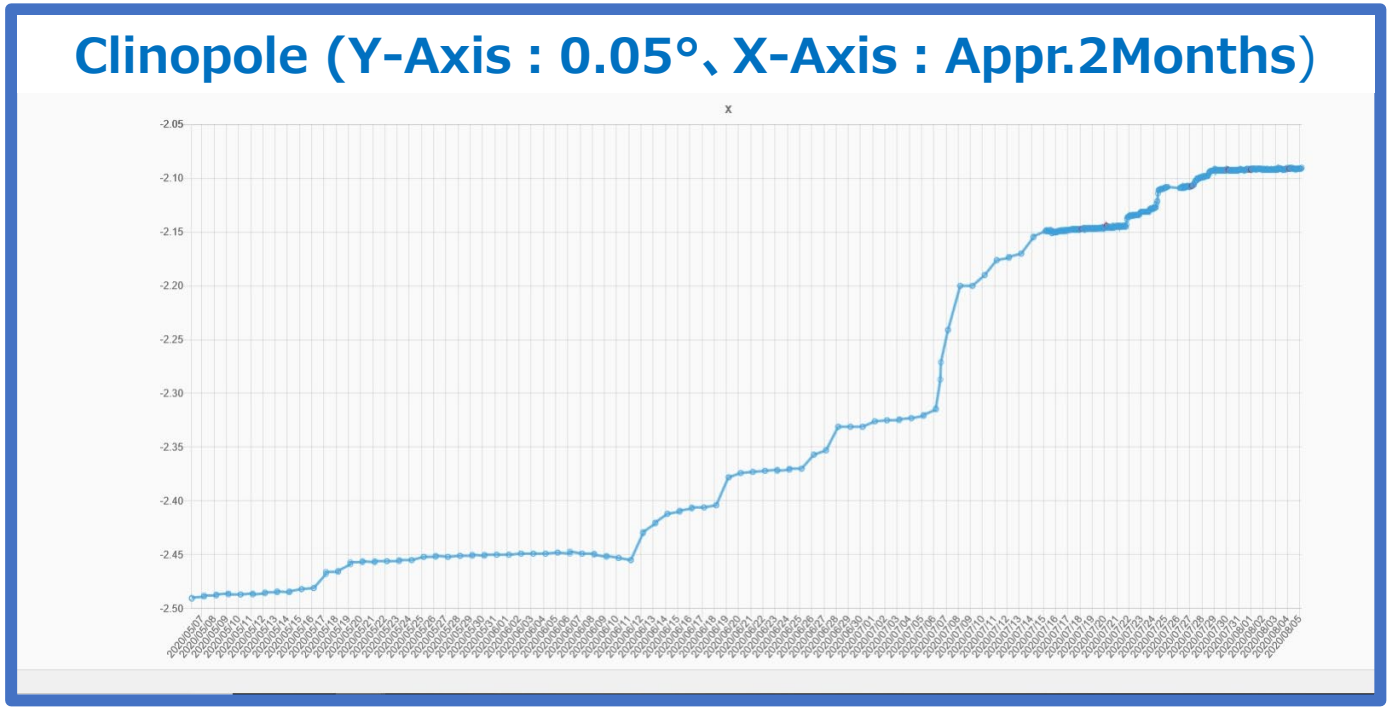
Diagram Associated with 5)

Comparing Conventional Inclinometer and Clinopole

Conventional Inclinometer (Y-Axis : 0.1° X-Axis : Appr. 2Months)



Clinopole (Y-Axis : 0.05°、X-Axis : Appr.2Months)



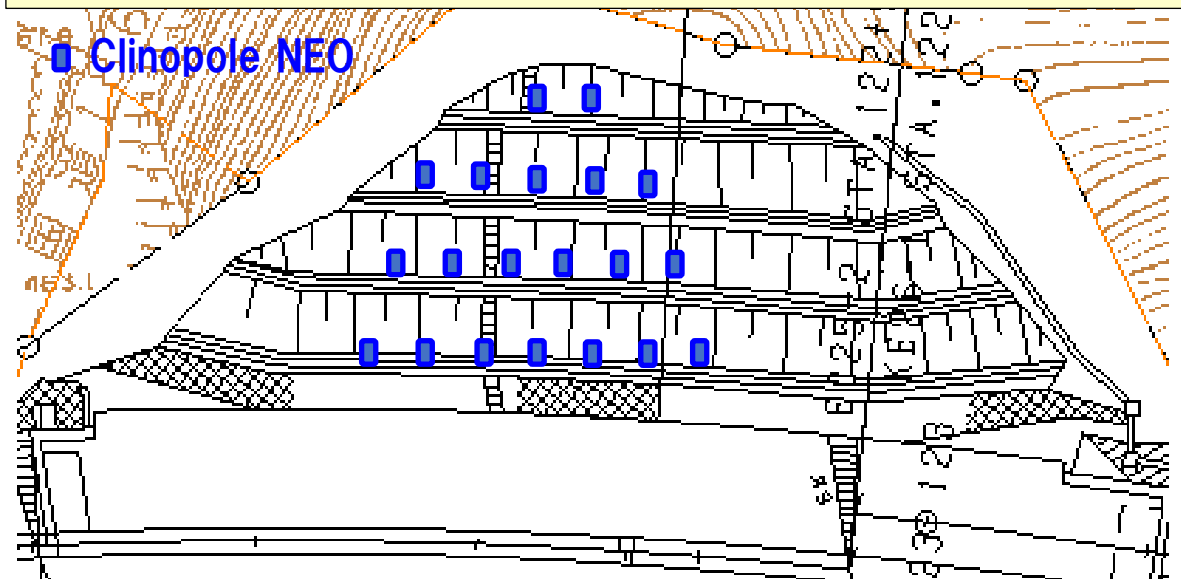
⇒Data from conventional inclinometers is directly influenced by temperature, leading to **unstable readings that fail to capture signs of potential collapse** = **Unable to make a judgment**

On the other hand, the measurement data by **Clinopole** which is unaffected by temperature, **allowing it to detect small displacements and identify signs of collapse at an early stage.**

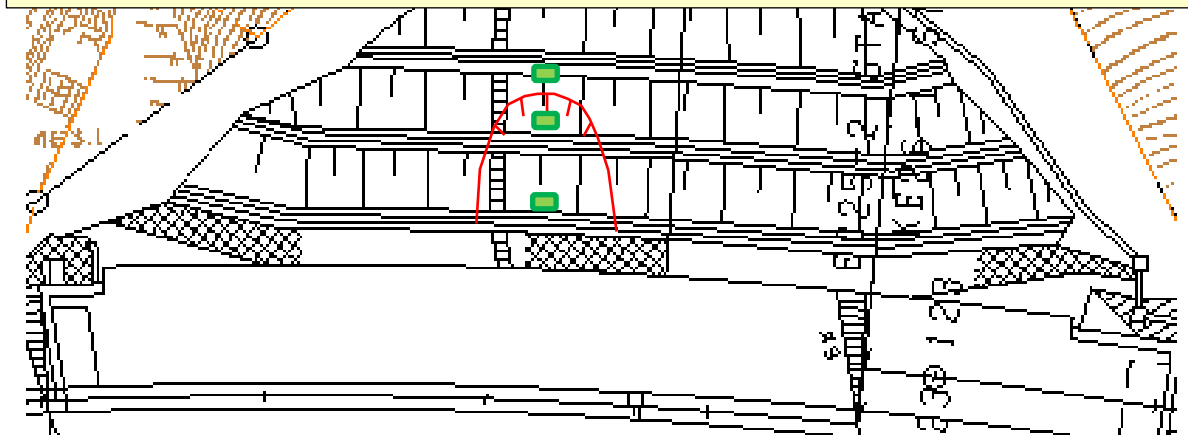
Examples of installation

- Slopes with unclear collapse areas
- For construction safety management

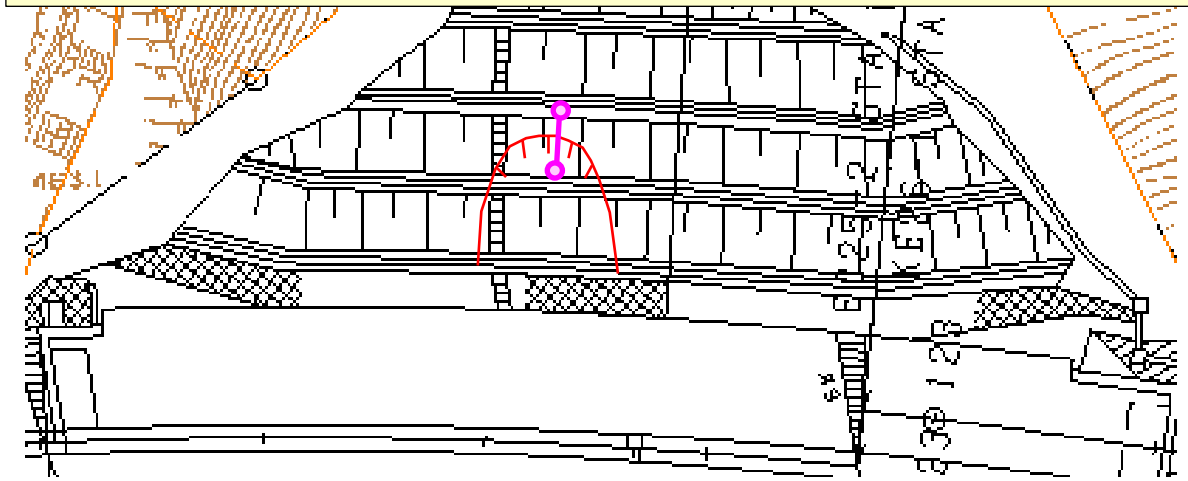
By placing multiple sensors,
the collapse area and displacement amounts will be captured!



【Clinopole】
・In the event of a clear collapse → Place at several locations around the cracks to measure displacement！



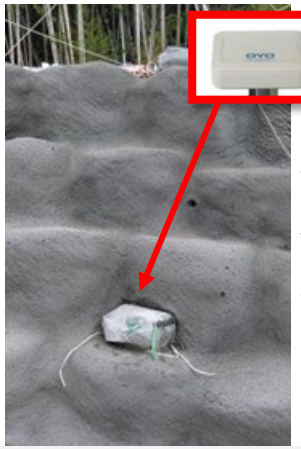
【Extensometer 】
・In the event of a clear collapse→Install across the cracks to measure displacement!



Case Study：Road Safety Monitoring for Construction Site Management

- The goal is to monitor the changes in large sandbags to **ensure the safety of construction and access roads**, while also **improving the safety of the workers** directly underneath.

Construction Site (Overview taken from the Alarm Location)



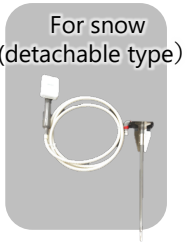
Protecting the Clinopole with a plastic box from spraying.

Clinopole Setup (After Spraying)

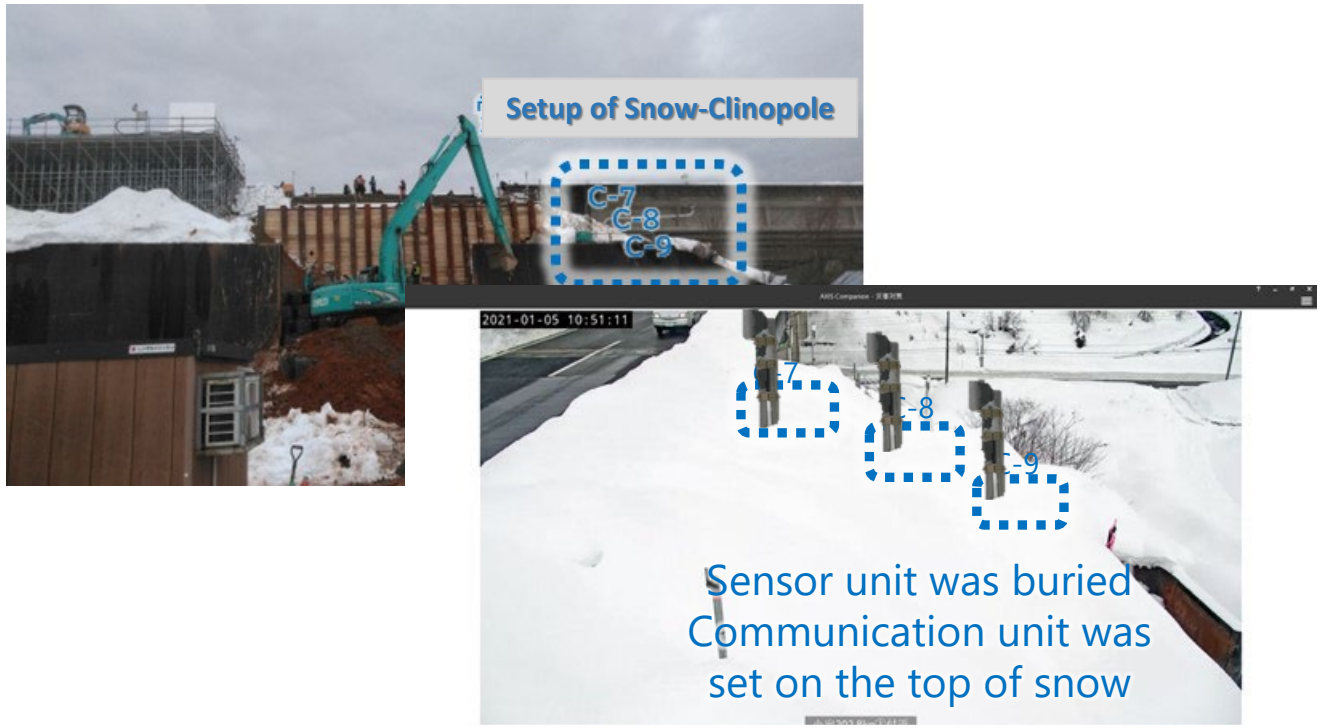
Rotating Light with Built-in Speaker (Requires AC 100V)

All-in-One Alarm System

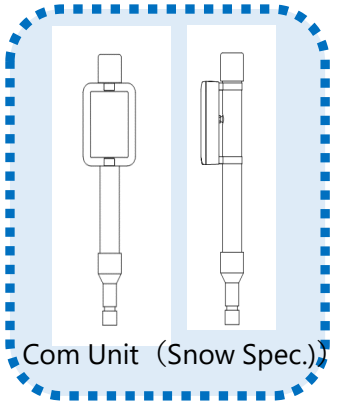
Case Study: Monitoring embankment displacement in snowy areas

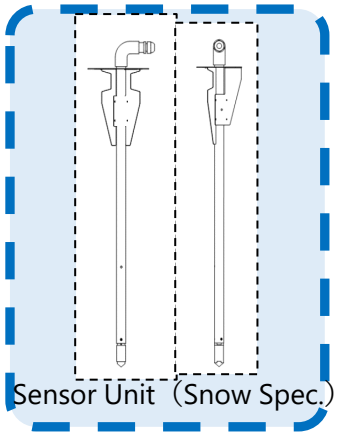


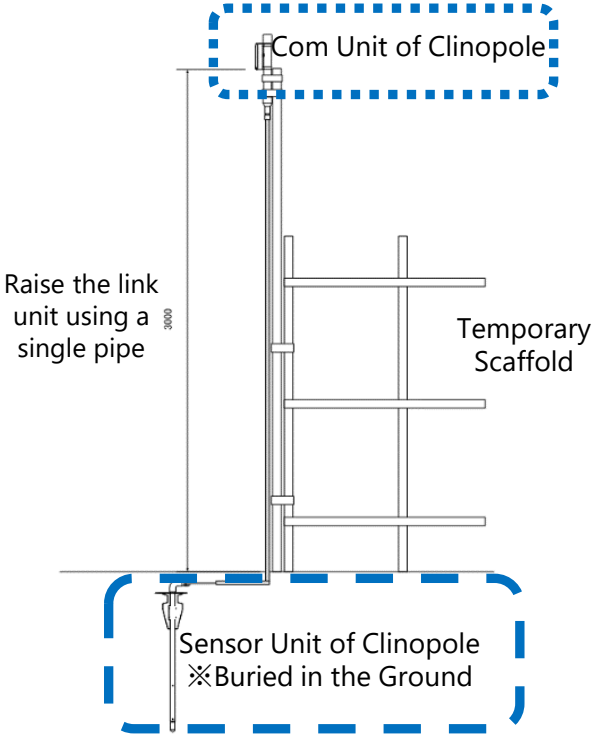
- **To monitor displacements during embankment collapse prevention work in snowy areas**, snow-applicable Clinopoles were deployed, and displacement monitoring was conducted during the winter. (Standard Clinopoles were also installed, and it was confirmed that there was no significant difference in the measurement data.)



※The sensor unit and cables are waterproof, making them usable in rivers.







Installation Diagram for Snow-resistant Clinopole

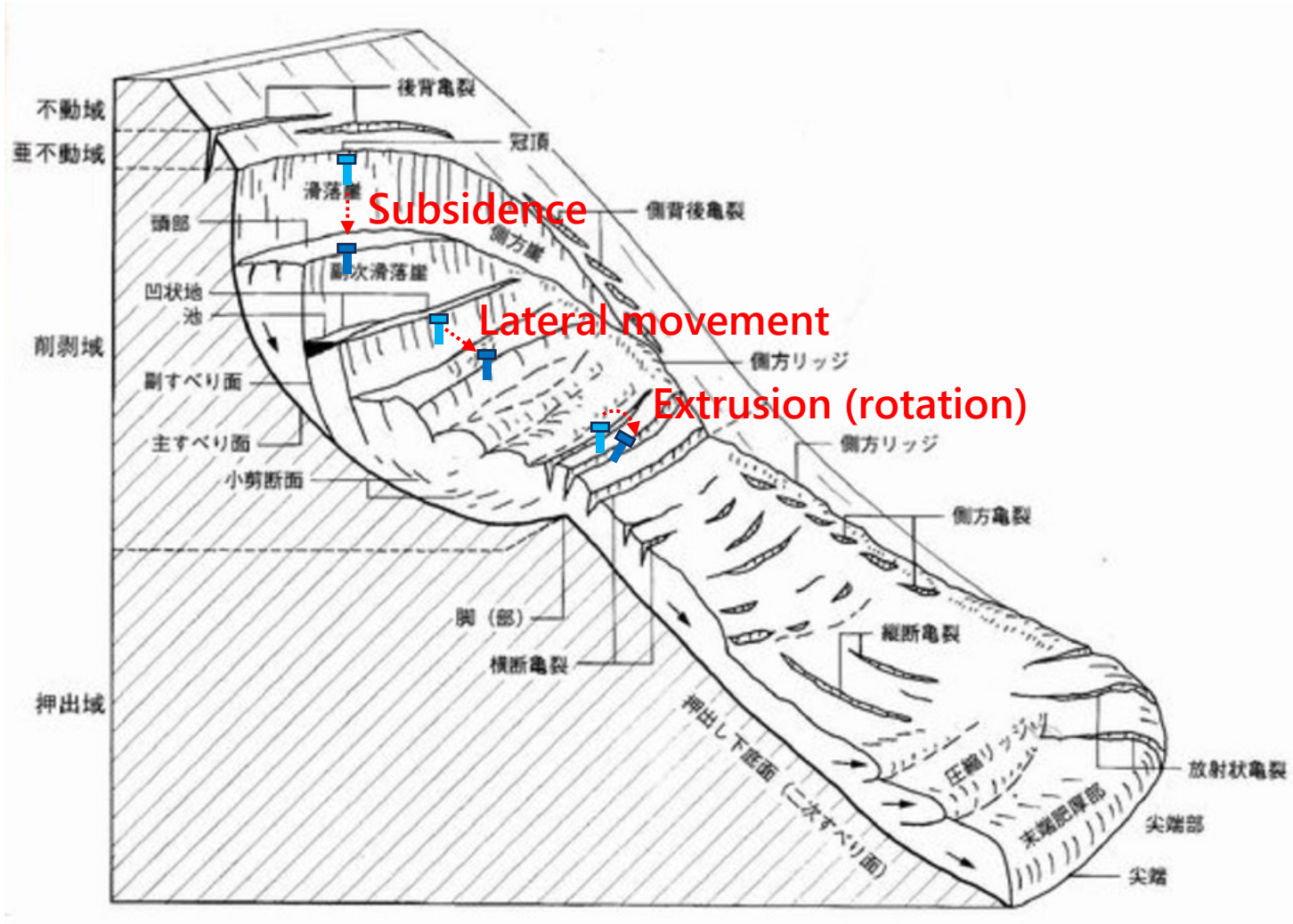
Case Study: Monitoring sheet pile displacement during ground improvement

For sheet piles (separate type)

- A Clinopole for sheet piles (Type: detachable communication unit) was installed to **monitor the displacement of sheet piles during ground improvement work** near existing structures (bridges).

By removing the wings that fix Clinopole to the ground and adapting it to the shape of the sheet piles, installing Clinopole even in locations with space constraints is possible.

Effective application to landslides



※Diagram based on 'Introduction to Reading Topographic Maps for Construction Engineers, Vol. 3: Terraces, Hills, and Mountains' by Ryusuke Suzuki, pp. 813.

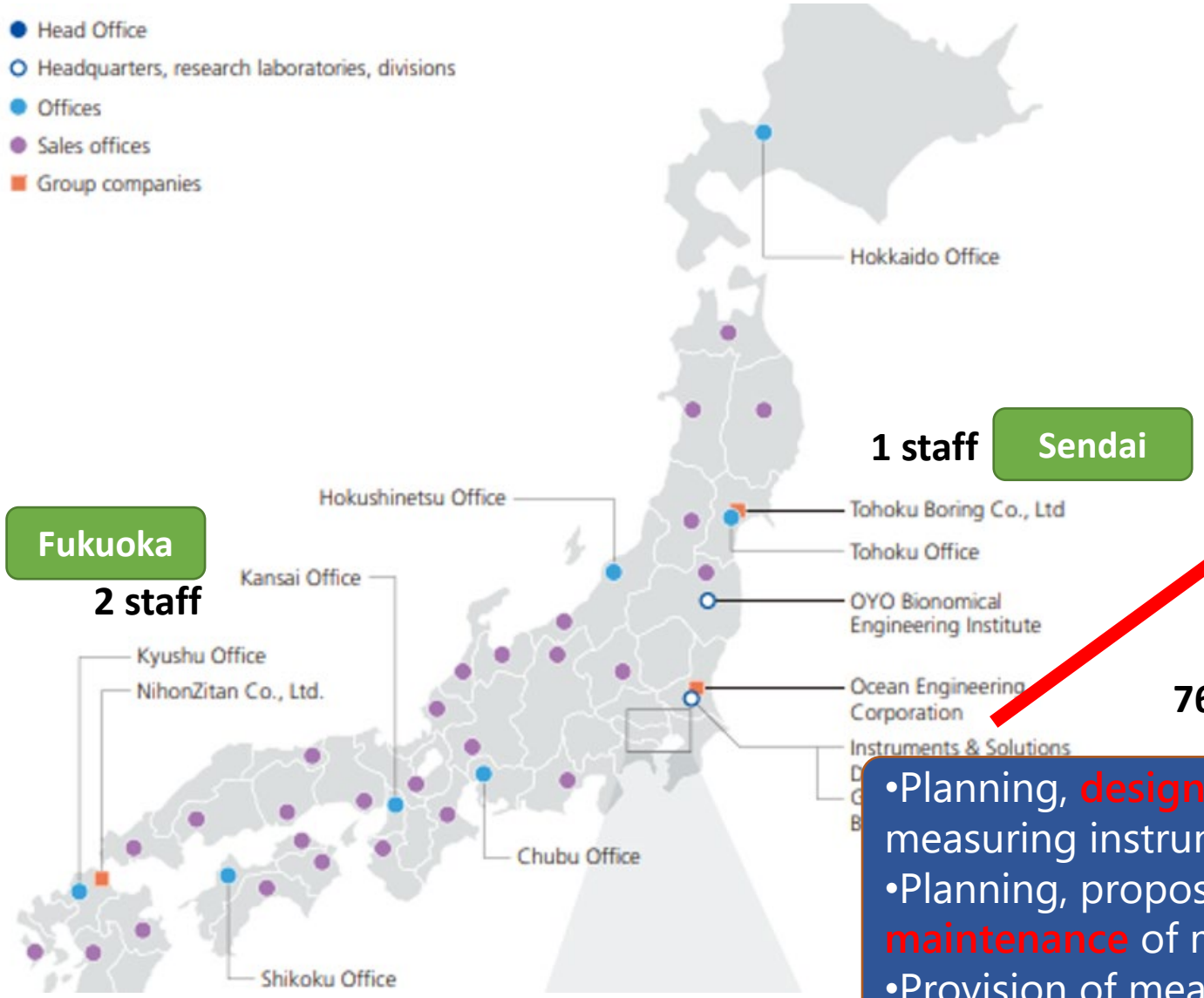
Detailed features and selling points of our products

【Clinopole NEO】		【Clinopole】
Network Type (20 sensors' data is sent to 1 controller via Bluetooth and sent to the cloud using LTE.)	Style	Standalone Type (Sent to the cloud via LTE, individually)
Separated	Link・Sensor	All-in-one
80 cm	Burial Depth	100 cm
Acceleration・Angle	Acquired Data	Angle
0.001°	Display Resolution	0.001°
1set (20 pc)	Sales Unit	1 pc
Per 1 set (20 sensors)	Price	Per 1 pc
Fixed	Interval of Measurement・Transmission	2-level setting available

Controller

Sensor

Instruments & Solutions Business Division, OYO CORPORATION



1 staff **Sendai**

Fukuoka
2 staff

76 staff **Tsukuba**

- Planning, design, manufacturing, sales, and maintenance of measuring instruments
- Planning, proposal, development, construction, sales, and maintenance of measurement systems
- Provision of measurement services (monitoring services)

History of Instruments & Solutions Business Division

- In 1957, when OYO was founded, there were no suitable measuring instruments available for ground investigation services. Consequently, the founders decided to develop our own survey measurement instruments for internal use.
- Later on, other survey companies expressed interest in acquiring the equipment we had developed, which led to the beginning of the instrument business.

A vacuum tube type handcrafted from components purchased in Akihabara
13ch Seismic (ground strength structure) exploration device (in 1957)

With Windows
48ch　Seismic exploration device