Case history of the press-in piling method on stabilization of a highly unstable steep embankment

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ABSTRACT

In April 2020, a disaster occurred in the Katakake area of Toyama Prefecture, involving the collapse of the surface layer of a strong wind-exposed zone. This event caused significant damage to the major National Route 41 (Toyama-Takayama Connecting Road), leading to road closures and substantial disruptions to essential services. As a permanent countermeasure, continuous steel pipe walls were selected for the upper and mid-slope sections, and they were constructed using the Non-Staging System Gyropress Method™. Furthermore, high construction accuracy was achieved by utilizing an automatic measuring tool called Implant NAVI™. This paper introduces a case where the adoption of the pressing method during the disaster contributed to the swift restoration of societal functions.

Key words: *Gyropress Method, Landslide, Continuous pile wall*

1. INTRODUCTION

In recent years, Japan has experienced an increase in damages caused by natural disasters. Particularly, the frequent occurrence of human casualties and significant societal effects due to rapid heavy rainfall-induced landslides is noteworthy. The topography of Japan's land is characterized by rich undulations, with mountainous areas, including volcanic regions and hills, covering approximately 75% of the country's total area. As a result, many settlements are dispersed in mountainous regions, and numerous roads are constructed in these hilly terrains. Therefore, landslides in hilly areas often cause severe damage to transportation infrastructure.

Disaster recovery efforts require prompt, safe, and comprehensive responses in environments where the site conditions are not fully secure to prevent secondary disasters. Furthermore, the aim is to avoid additional harm to individuals through unsafe work practices.

This paper introduces a case of road disaster recovery utilizing the characteristics of press-in construction methods. It is our hope that this report can contribute as a guide for establishing permanent countermeasures in disaster recovery.

2. OVERVIEW OF THE DISASTER[1]

2.1. Location

A disaster occurred in the Katakake area located in Funami, Toyama City, Toyama Prefecture. (Figure 1) The slope near National Route 41, adjacent to the Jinzu River, a first-class river, collapsed due to a combination of factors. This road serves as a crucial national roadway connecting Toyama City in Toyama Prefecture and Nagoya City in Aichi Prefecture, with a total length of 270 km, acting as a vital logistics artery. (Figure 2)

2.2. Status of damage

In April 2020, a large-scale slope collapse occurred. The collapsed slope, measuring 40 meters in length, and 20 meters in width, (Figure 3), affected the active National Route 41 running along the crest of the slope. Due to the ongoing risk of further collapses, approximately 2.7 km of the road near the border between Toyama and Gifu Prefectures was closed to traffic. Approximately 50 days after the disaster, a temporary road was restored, and the road closure was lifted. However, this was only a temporary solution; permanent measures needed to be taken that would not disrupt traffic on the restored road.

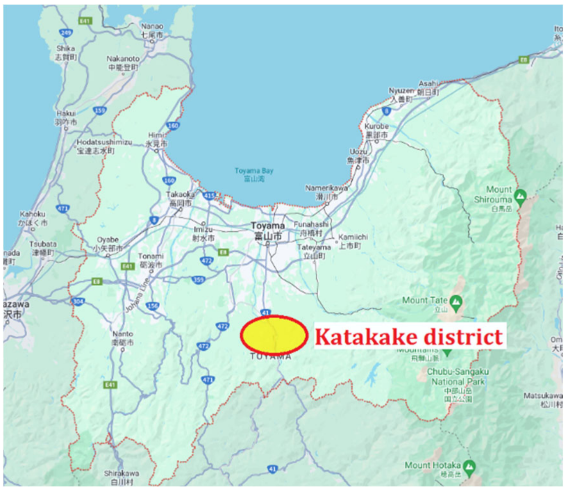

Figure 1. Location map

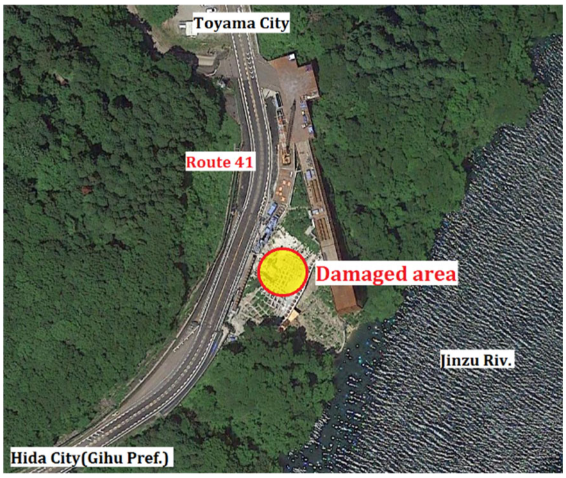

Figure 2. Damaged area

Figure 3. Status of damage[1]

2.3. Cause of disaster

The cause of the disaster was determined to be the result of a combination of factors that had accumulated.

1. Ground conditions comprising weathered surface layer and stiff soil layer are complex (Figure 4)
2. Changes in natural conditions due to sustained heavy rainfall.

To address the previously mentioned factors, it was determined that a fundamental solution could not be achieved through the restoration of the collapsed surface layer. Therefore, structural configurations capable of accommodating the rigid deep-layered supporting ground were considered.

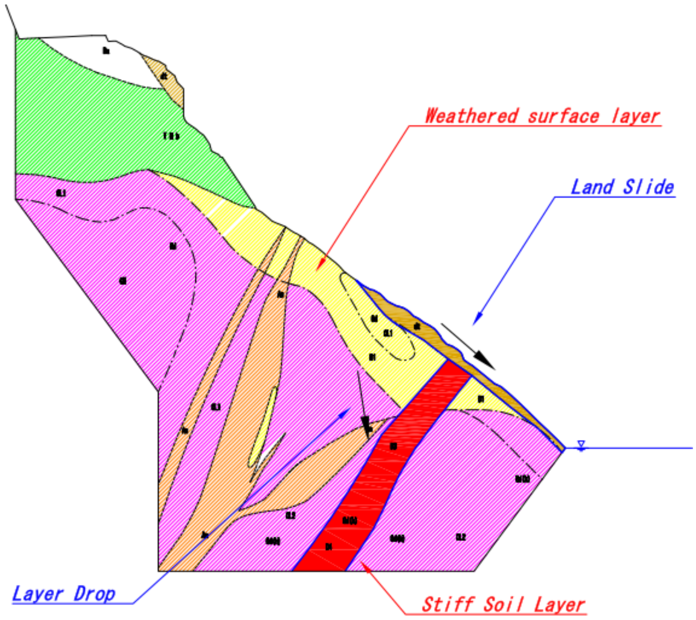

Figure 4. Geological profile

3. STRUCTUAL TYPE

3.1. Structural comparison

In the context of permanent measures, it was necessary to address three factors as key considerations, and an evaluation selection was conducted (Table 1).

As evaluation criteria, the suppression of deep-layered deformations, achievement of early recovery, and ensuring safety during operations were identified, leading to the assessment of structural type. Through discussions, the installation of restraining piles in the form of continuous walls method using steel pipe piles was selected as one of the permanent countermeasures.

Table 1. Structural comparison and evaluation

Method	Suppress deformations of deep-layer	Productivity	Safety of working
Loading berm method	By embankment at the bottom row of the slope. Good	Most time consuming as it requires a temporary platform. Poor	High risk. Excavation required of the collapsed slope-end. Poor
Surface ground anchor method	Ineffective. Poor	- -	After the installation of steel pipe piles, safety. Good
Continuous pile walls method	By reaching the supporting ground with piles. Good	The fastest for not require a temporary platforms. Good	The safest. No need to enter the collapsed area. Good

3.2. Structural type

In this project, steel pipe continuous walls were installed as restraining piles on the head and middle slope rows of the collapsed slope (Figure 5).

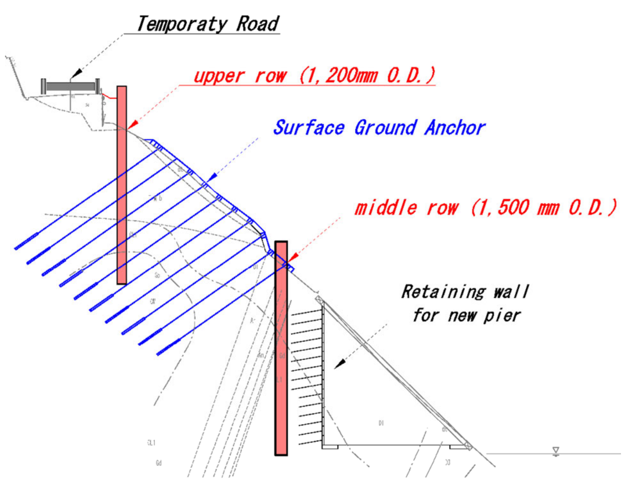

Figure 5. Structural cross section

The middle row was installed to ensure the stability of the slope face. Additionally, to serve the purpose of preventing potential minor collapses, it was chosen to protrude about 3 m from the current ground surface. The steel pipe's outer diameter is 1500 mm, and a total of 21 pipes were installed.

The upper row was installed to suppress displacements at the crest of the slope where the National Route 41 runs. A total of 18 pipes with an outer diameter of 1200 mm were installed (Table 2).

Table 2. Pile specifications

[Upper row] 18 piles
1,200 mm O.D., t 12 mm, maximum length 25.0 m Tensile strength: 490 N/mm^2 Number of joins: 2 joints(welding) Number of cutting bits: 21 pieces Purpose: Suppressing displacement at the top of slope
[Middle row] 21piles
1,500 mm O.D., t 18 mm, maximum length 30.5 m Tensile strength: 570 N/mm^2 Number of joins: 2 joints(welding) Number of cutting bits: 27 pieces Purpose: Suppress variations of deep-layer

The construction order involved first installing the middle row to prevent the expansion of damage from collapse, followed by the installation of the upper row. After the completion of all continuous steel pipe walls, ground anchor work was conducted to prevent surface ground displacement.

4. ADVANTAGES OF PRESS-IN METHOD

The continuous steel pipe walls were installed using the Gyropress Method (Figure 6 and 7). Additionally, Non-Staging Method, called GRB System™, was employed for the construction, where a CLAMP CRANE™, similar to the press-in machine, moved autonomously over the steel pipes to supply them to the press-in machine. The rationale for selecting this method is outlined below.

Figure 6. Machine layout (daytime)

Figure 7. Machine layout (night time)

4.1. Ground Condition

The deep-layer supporting ground targeted for press-in is granite with a uniaxial compressive strength of 500 kN/m^2, requiring adaptation to hard ground (Figure 8). The Gyropress Method involves attaching a cutting bit to the tip of the steel pipe pile and penetrating the ground by rotating the pile (Figure 9).

By selecting appropriate bits that match the ground conditions, it is possible to adapt to hard ground. For this project, 21 cutting bits were chosen for the upper row (Figure 10), while 27 cutting bits were selected for the middle row.

4.2. Productivity

In conventional steel pipe pile construction, it is common to require ground preparation or temporary steel platforms for crawler movement of heavy machinery. However, with the press-in method, the primary heavy machinery can autonomously move over the installed steel pipe piles to proceed with the construction, making it possible to omit the step of setting up working spaces.

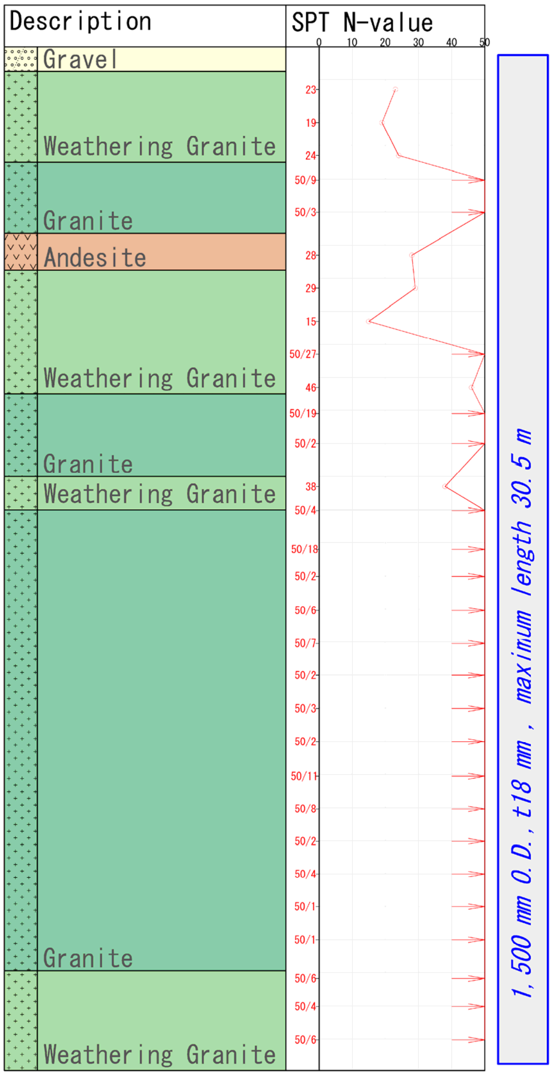

Figure 8. Borehole logs: Case middle row

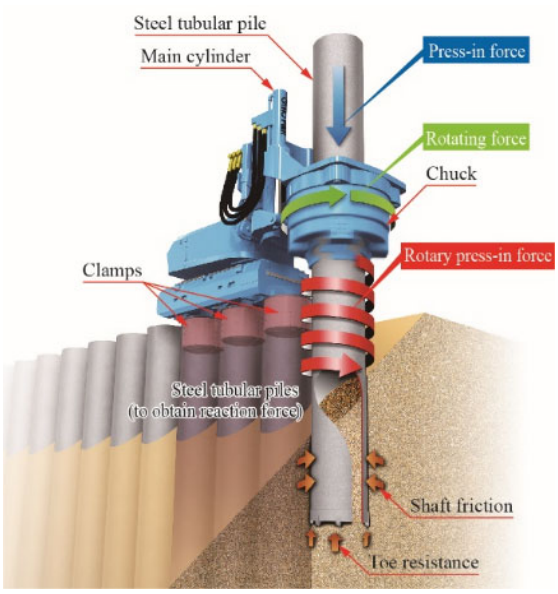

Figure 9. Gyropress Method[2]

Figure 10. Cutting bits (upper row)

Additionally, with the introduction of the GRB System, all work such as hoisting, material transportation, and more, can be carried out on steel pipe piles, making it suitable for construction in harsh conditions such as above water or on slopes. (Figure 11). The introduction of this system greatly contributes to streamlining the temporary processes involved in pile installation.

4.3. Safety of working

The collapsed area retained the existing structure, concrete covering, anchor steel wire, and rebar. Under these conditions, there was a risk that the construction of steel pipe piles could result in interference with the existing materials, potentially causing damage to the toes of the steel pipe piles. To mitigate this risk, it was necessary to remove or crush the existing materials before pile driving. However, entering the slope for removal work posed a danger due to the potential for further collapse. In this project, removal work was carried out using a core barrel with a GYRO PILER™ to minimize the excavated area just before driving the steel pipe piles, helping reduce the risk of collapse during construction (Figure 12). Immediate pile driving after removal also contributed to suppressing potential collapses induced by the removal work.

5. ICT-TECHNOLOGY

In this project, the management of piling conditions during construction presented challenges. Traditional piling construction involves initially marking the designated positions of piles on the ground. Afterwards, workers are placed near these marking points to measure distances and inclinations, thus managing the conditions.

However, the ground condition for this project involved a slope where there was a potential for further collapse, making it unsafe to have workers constantly stationed on the slope.

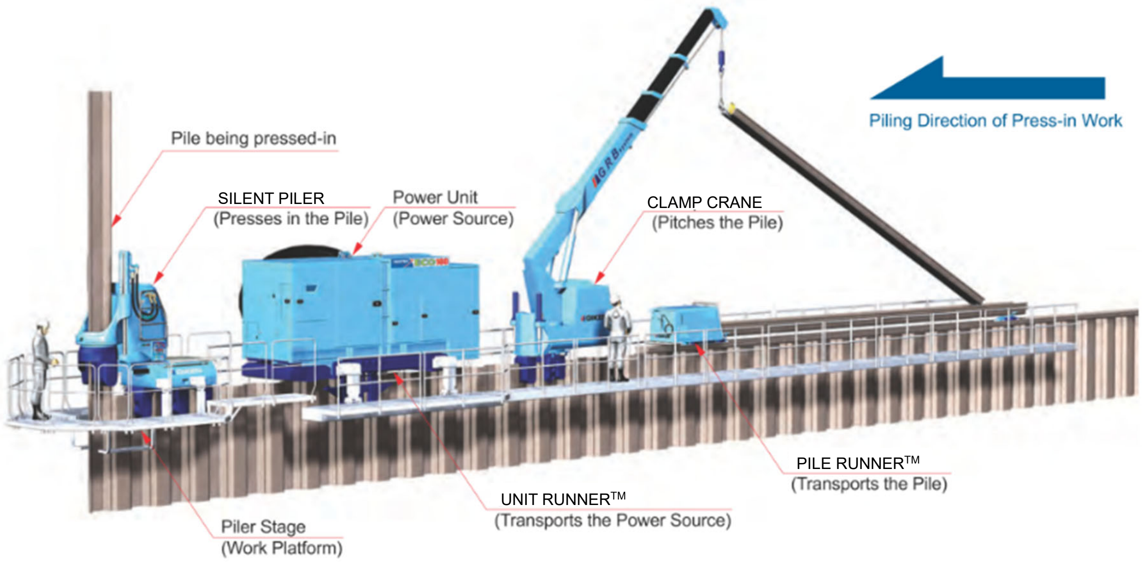

Figure 11. GRB System[3]

Figure 12. Removing work by core barrel

Therefore, Implant NAVI™, an ICT technology specialized for piling (Figure 13), was introduced to implement condition management for press-in piles. Below is an overview and introduction of the construction accuracy achieved with this technology.

5.1. Overview of Implant NAVI™

Implant NAVI™ is a tool that measures the penetration depth, displacement, and inclination of piles in real-time during construction, enabling high-precision quality management of pile construction.[4] Before and during steel pipe piling, non-prism measurements (Figure 14) are continuously conducted using a dedicated total station.

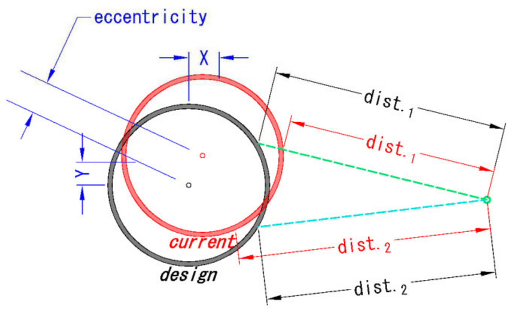

Figure 14. Measurement process

During construction, both the upper and lower ends of the steel pipe piles are surveyed at two points each, enabling the measurement of planar and inclinations errors with respect to the designated positions without interrupting the piling operation. The measurement data is transmitted to a notebook PC terminal via Bluetooth™, enabling the real-time monitoring and adjustment of the steel pipe pile's status by the operators. This simplifies the process, condensing the usual three steps of marking the pile's designated positions, manual measurements by workers, and error calculations into a single step through the implementation of Implant NAVI™. (Figure 15)

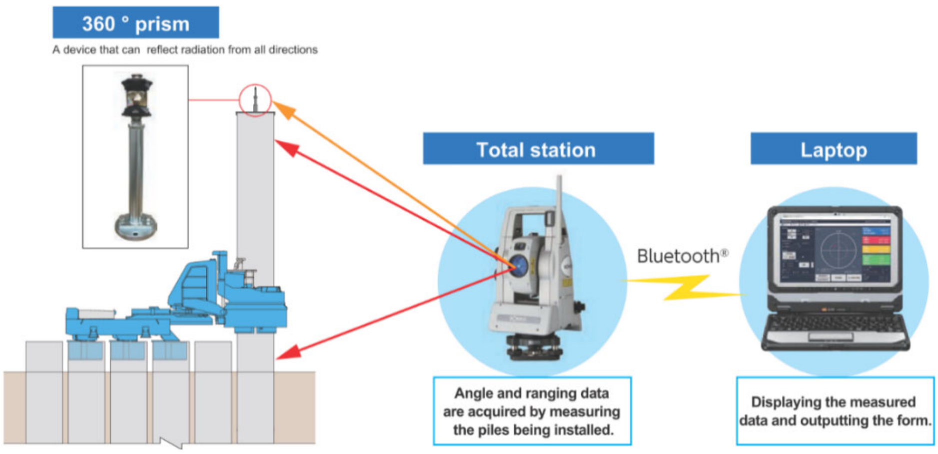

Figure 13. Implant NAVI™

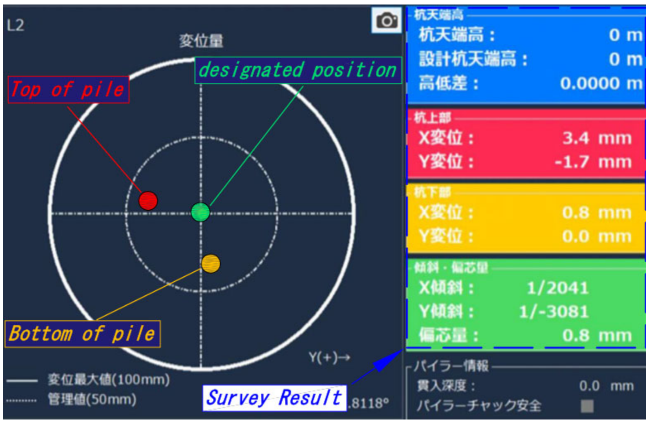

Figure 15. Management monitor

5.2. Piling accuracy

The entire surveying process during piling on this site was conducted using Implant NAVI. This project aimed to maintain the constructed accuracy within a 50% tolerance of the allowable error set by the client. After completion, the constructed form of the steel pipe piles was examined, revealing a maximum eccentricity of 41 mm (within the target value 50 mm) and a maximum difference in reference height of -16 mm(within the target value -25 mm). (Figure 16). This result indicate that high construction accuracy was achieved through quality control using Implant NAVI™.

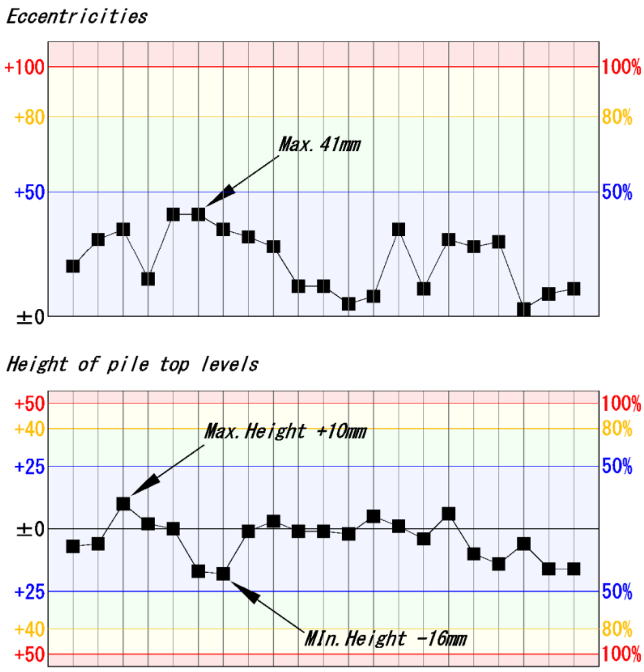

Figure 16. Measurement results

6. Concluding remarks

The implementation of the Gyropress Method™ using a GRB System served as the main strategy for stabilizing the collapsed slope. This approach revealed the following advantages:

1. The Gyropress Method allows for rotational pressing even in hard ground layers with a compressive strength of 500 kN/m^2
2. It is possible to carry out work even with existing concrete structures. The use of core barrel for removal purposes enables the integration of the usually separate processes of removal and installation into a single operation.
3. In situations requiring rapid recovery, such as during disasters, the use of the GRB System™ allows for the omission of the construction of temporary structures, expediting the recovery schedule.
4. Combining ICT technology (Implant NAVI) enables the realization of safe and high-quality steel pipe pile installation.

Disaster recovery operations demand work in limited spaces, and balancing safety and quality assurance can be extremely challenging. In this case study, combining the advantages of the press-in method confirmed its contribution to the early recovery of societal activities.

In conclusion, the implementation of the press-in method, as detailed in this paper, is expected to streamline recovery operations in the event of a similar disaster.

7. Acknowledgements

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