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Press-in piling applications: Permanent stabilization of an active-landslide-slope

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ABSTRACT: The road surface of a national highway failed in Japan, due to a landslide caused by typhoons. For the restoration of the road, the installation of steel tubular piles with ground anchors was selected to protect traffic safety in consideration of the possible occurrence of soil mass erosion and loss at the toe of the slope. In this construction project, the quick restoration of one-way alternating traffic was required by installing the piles without delay. Furthermore, installing the piles into the bedrock (bearing stratum) was a technical challenge. To address the requirement and technical issue, the rotary press-in piling (Gyropress Method) and the Non-staging System were selected. This paper aims to review the applicability of press-in piling technology to the pile installation on an active-landslide-slope by reporting the outlines of the disaster rehabilitation work, design of permanent measures, and the construction plan and implementation.

1 INTRODUCTION

In Japan, natural disasters are increasing and serious damage has been caused by record-breaking heavy rainfall brought by very large typhoons such as the typhoon that hit the Boso Peninsula and another that moved through eastern Japan in 2019. It is an urgent issue to restore damaged urban infrastructure quickly and make reconstructed structures stronger against disasters than before. Walk-on-pile type press-in piling is one of the piling methods that can overcome this issue effectively. In particular, the rotary press-in piling (Gyropress Method), one of the press-in piling methods that rotates a steel tubular pile with pile toe ring bits and press-in into the ground, and the Non-staging System, a system of press-in piling methods that allows all necessary construction machines and equipment to be operated on the previously installed piles so that it is suitable for sites with various constraints, such as on slopes, irregular ground, and water, are increasingly being selected at many construction sites.

In the section of national highway No. 19 reported in this paper (hereinafter referred to as Route 19) in the Minochi district, Shinshushinmachi, a road surface failure occurred because of a landslide caused by Typhoon Nos. 21 (Asian name: *Lan*) and 22 (Asian name: *Saola*) in 2017. The damaged section of the highway needed to allow at least one-way alternating traffic during rehabilitation work to serve as an emergency transportation route in the post-disaster period. Under such conditions, steel tubular piles with ground anchors were installed using the aforementioned technologies as a permanent measure. The details of the rehabilitation work are described as follows.

2 OUTLINE OF DAMAGE

2.1 *Outlines of Route 19 in the Minochi district, Shinshushinmachi*

Route 19 runs 272.6 km from Nagoya City, Aichi Prefecture to Nagano City, Nagano Prefecture. It runs through precipitous mountains along the Sai River between Ikusaka Village and Nagano City, Nagano Prefecture. In addition, the ground is not firm enough in this section. Therefore, the section is vulnerable to natural disasters such as landslides, debris flow, and slope toe scouring, and disaster-prevention projects have been conducted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

The Minochi district, Shinshushinmachi, reported in this paper is located at an elbow of the Sai River (a first-class river) passing under Route 19 (Figure 1).

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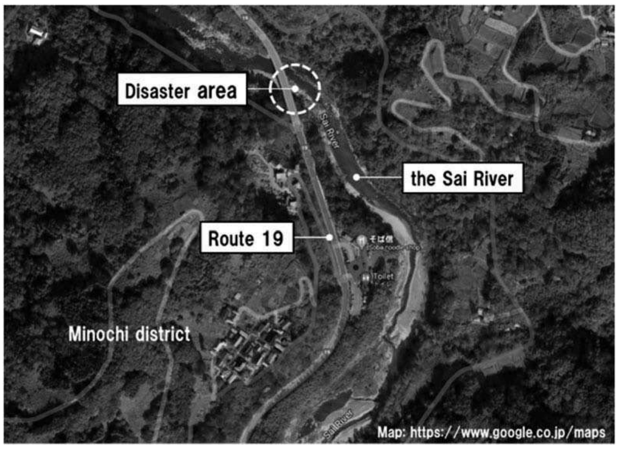

Figure 1. Site location (Map: https://www.google.co.jp/maps).

2.2 *Weather conditions brought by Typhoon Nos. 21 and 22*

2.2.1 *Typhoon No. 21*

Typhoon No. 21 (Asian name: *Lan*) made landfall near Omaezaki City, Shizuoka Prefecture, on 23 October 2017, at about 3 a.m. with an extremely large size and strength and proceeded through the Tokai and Kanto regions north-east-ward while maintaining its storm area before reaching off the coast of Fukushima Prefecture on the same day at 9 a.m. It transformed into an extratropical cyclone in the east of Hokkaido. Its central pressure was 950 hPa, and the maximum wind speed was 40m/s at the time of landfall. It was the first time for Japan to be directly hit by such a super-scale typhoon since 1991 (NLMO, 2017).

Because of this typhoon and a front stimulated by it, Nagano Prefecture was hit by intense rainfall, mainly in its north and south areas. A rainfall of 112.0mm/h was recorded in Shinshushinmachi where the site of the road failure was located.

2.2.2 *Typhoon No. 22*

Typhoon No. 22 (Asian name: *Saola*) which occurred near the Mariana Islands moved northward in the Okinawa region with its storm area on 28 October 2017, and proceeded northeast over the south sea of Honshu island on the 29th while maintaining its power. It became an extratropical cyclone off the Sanriku coast on 30 October 2017, at midnight. A central pressure of 975 hPa and a maximum wind speed of 30m/s were recorded.

Unlike Typhoon No. 21, not many areas were hit by intense rainfall because the path of the typhoon was far off the coast. However, Miyazaki Prefecture received record-breaking heavy rain (NLMO, 2017).

It was unusual for multiple typhoons to make landfall or approach Japan in a short period of time in late October. Because of the weather brought about by Typhoon Nos. 21 and 22, road surface failures occurred in the area in this report due to a landslide.

2.2.3 *Circumstances of damage*

A landslide with a width of 40m, slope length of 40m, and a slip surface depth of 10m occurred in the Minochi district, Shinshushinmachi. The top of the landslide was located on the road, and a bridge (Mizushino Bridge) was beside it. The end of the landslide was found to have reached the riverbed of the Sai River. Because of this landslide, stepwise cracking occurred in the part of Route 19 from its centre line to a 2m distance toward the mountainside.

For a while after the landslide, the river side slope of the road was moving at a speed of a few centimetres a day. Then, the speed quickly increased to 10-70 cm a day due to the rise of groundwater level and riverbed erosion at the lower end of the slope due to rainfall (Kusatani et al. 2019).

3 DESIGN OF PERMANENT MEASURES

3.1 *Design of permanent measures*1)3)

The following three plans were proposed and considered as permanent measures for the disaster site (Kusatani et al. 2019).

3.1.1 *Counterweight fill method*

The principle of the counterweight fill method is to increase a resistance against the land sliding force by forming an embankment at the lower end of the sliding soil mass (Figure 2) (JASDM,2020). If there is a potential sliding plane in the slope under the embankment, it may induce the occurrence of the landslide. For this reason, the stability of the foundation of the embankment needs to be examined when considering a counterweight embankment.

If the permeable layer of groundwater lies at a shallow depth in the embankment section, or if the groundwater seeps out at the lower end of the landslide slope, the handling of the groundwater shall be considered because there is a risk of increased instability of the slope due to the blockage of groundwater outlets by the embankment or its load, or the rise of the groundwater level on the back of the slope.

In addition, the toe of the landslide slope was too adjacent to the Sai River, and large-scale earthwork would be required within the river, which would have a large impact on the surrounding environment. As a result, the counterweight fill method was determined not to be suitable for this site.

3.1.2 *Installation of a prefabricated platform*

An idea to install a prefabricated platform in the sunken part to act as a road was discussed.

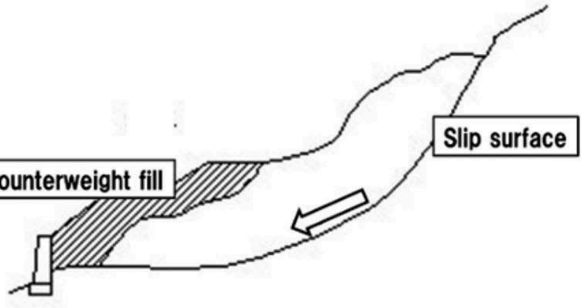

Figure 2. Counterweight fill method.

This idea was determined not to be suitable for this site because continuous movement of the landslide slope was observed, even after the initial landslide, and it was difficult to secure a workspace on the landslide slope for the installation of the prefabricated platform.

3.1.3 *Installation of steel tubular piles with ground anchors*

Piling work is planned for the purpose of adding shear and bending resistance to the ground by inserting piles into the rigid ground so that those resistance forces will be able to directly bear the sliding force of the sliding soil mass. Steel tubular piles (hereinafter referred to as tubular pile) are typically often used in landslide-prone areas. The use of tubular piles with an outside diameter of over 1000mm has been started recently, which is applicable to civil work sites that require a large resistance force against landslides. In addition, it is possible to integrally stabilize the tubular piles and the ground by installing an anchor on the pile head (Figure 3) so that the load acting on the anchor head will be transmitted to the anchored ground via the tension member (JASDM,2020).

With this structure, the safety of the road can be ensured even if the soil mass on the river side at the lower end of the landslide slope is lost by erosion. Furthermore, it was considered possible to install tubular piles without a temporary platform on the slope, if the rotary press-in piling and the Non-staging System described below, which would enable the installation of tubular piles into the bearing stratum (stratified sandstone, CM class), were used in combination. On the basis of this consideration, the installation of steel tubular piles with ground anchors was selected as a permanent measure.

3.2 *Guidelines and manuals for designing tubular piles with ground anchors*

The following literatures were consulted for the structural design of a retaining wall composed of tubular piles with ground anchors in the construction reported in this paper.

- Japan Association for Slope Disaster Management (JASDM) 2003. *Design Manual for Landslide Prevention Steel Pile Retaining Wall* (in Japanese)
- Japan Association for Slope Disaster Management (JASDM) 2008. *Design Manual for Landslide Prevention Technologies* (in Japanese)
- Japanese Geotechnical Association (JGA) 2013. *Ground Anchor Design and Construction Standards, Commentary* (in Japanese)
- Japan Road Association (JRA) 2010. *Road Earthwork - Embankment Construction Guide-lines* (in Japanese)
- Japan Road Association (JRA) 2012. *Road Earthwork - Retaining Wall Construction Guidelines* (in Japanese)

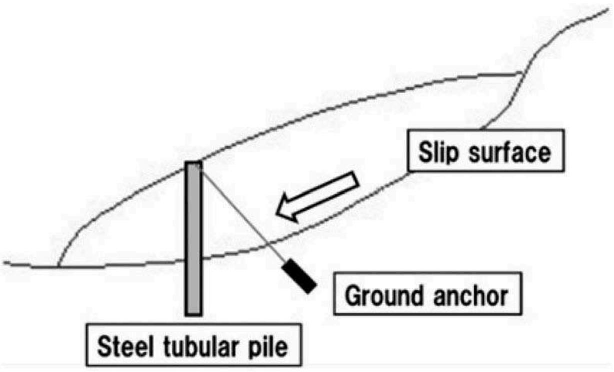

Figure 3. Steel tubular pile with ground anchor.

4 INTRODUCTION OF TUBULAR PILE INSTALLATION METHOD

4.1 *Rotary press-in piling (Gyropress Method)*

Rotary press-in piling is a piling method to press-in a tubular pile with pile toe ring bits while rotating it. It is applicable not only to granular and cohesive soils but also to hard ground such as rock and obstacles (e.g. reinforced concrete) because the rotated piles cut and penetrate into the ground to the specified pile toe depth (Figures 4 and 5). The applicable range of the outside diameter of a tubular pile is from 600 to 2,500mm.

In addition, equal angle steels or small diameter steel pipes can be installed by rotary press-in piling machinery in the gaps between the installed piles to prevent soil loss, and to ensure the watertightness of the cofferdam (IPA, 2020).

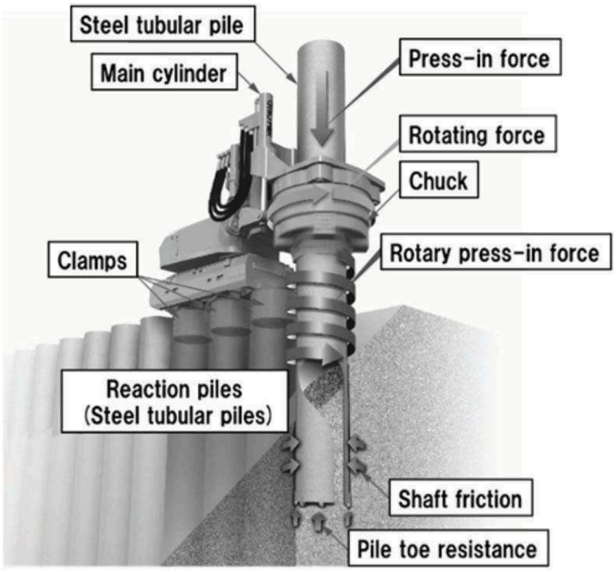

Figure 4. Rotary press-in piling (Gyropress Method).

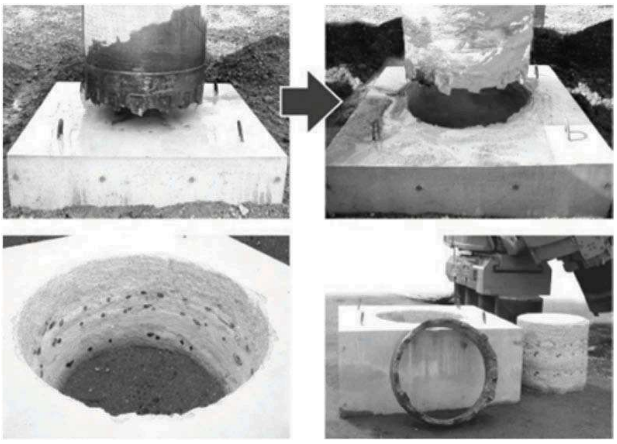

Figure 5. Cutting the reinforced concrete with the rotary press-in piling.

4.2 *Non-staging system*

By using the Non-staging System, which enables all the piling processes including the pile transportation, pitching, and press-in piling to be carried out on the installed piles, areas affected by the piling work can be limited to those occupied by the machines operated on the installed piles, and those used for the initial construction base. Furthermore, the machines are self-supporting by gripping the installed pile, and the risk of falling is extremely low (IPA, 2020).

The machine layout of the Non-staging System used at the construction site in this report is shown in Figure 6.

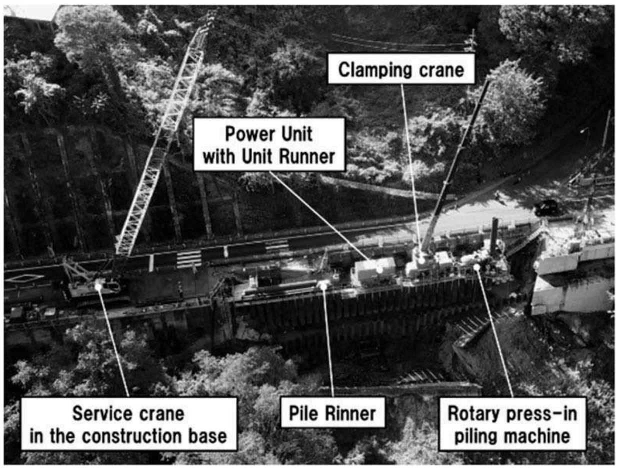

Figure 6. Machine layout of the Non-staging System.

5 DETAILS OF TUBULAR PILE INSTALLATION

5.1 *Construction plan*

The disaster rehabilitation work for Route 19 in the Minochi district, Shinshushinmachi, conducted in 2018 is reported. In this work, the installation of tubular piles (total 42 of SKK400 made piles with an outside diameter of 800mm and a length of 31.5m, two splices per pile) was planned as a permanent measure because the height difference between the ground surface after the landslide and the newly planned road surface was as large as 12.6m. In addition, removal of existing structures such as the cutting and crushing of road pavement and temporary work of traffic control equipment were also planned. In addition, the construction of a temporary earth retaining wall (500mm wide U-shaped steel sheet piles with a length of 11.5m, type SP-V L, 40 piles) was planned as an additional emergency measure in the other area away from the tubular pile wall.

At the stage of the construction planning, the implementation of the following works in 7 months from the middle of May to the beginning of December in 2018 was planned: detailed planning, structure design review, site reconnaissance, preparatory work such as land surveys, removal of structures, installation of tubular piles, and temporary work. (as an emergency measure, a temporary earth retaining wall was planned to be constructed in October). Estimated work periods were 2 months for the manufacture of tubular piles and 2.5 months for their installation among these works. Note that this paper explains the installation of tubular piles and does not deal with the work for closure piles and ground anchor installations.

5.2 *Ground condition*

A typical cross-sectional view of the installation of steel tubular piles with ground anchors that was created on the basis of existing geological survey materials and the result of a Standard Penetration Test (Figure 7) is shown in Figure 8.

Pressing in tubular piles into the bearing stratum (stratified sandstone, CM class) to a depth by at least 1 diameter (m), so-called 1D, was a mandatory requirement.

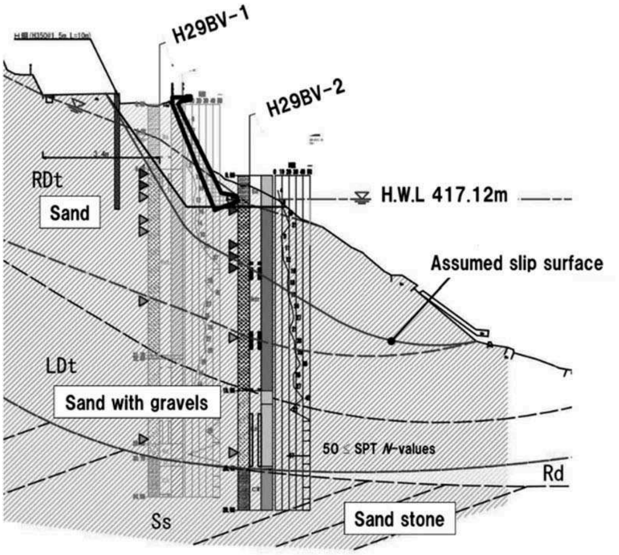

Figure 7. Cross section of soil layers.

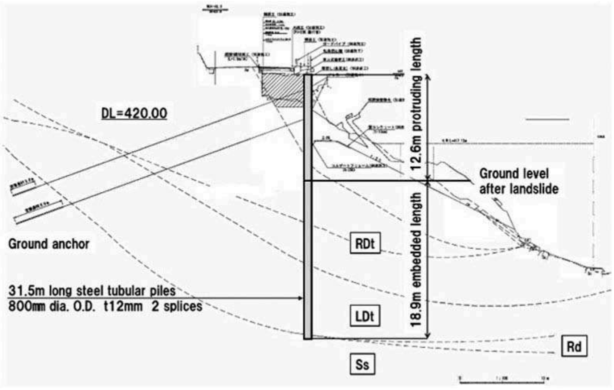

Figure 8. Typical cross section of the installation of tubular piles with ground anchors.

5.3 *Pile installation procedures*

Tubular piles were installed according to the following procedures:

[1] Secure spaces for a crawler crane and tubular pile storage on the river side of the road by allocating traffic control guards and allowing only one-way alternating traffic.
[2] Install a crawler crane (70 ton lifting capacity class) at the secured space, and carry equipment for the installation of reaction piles in the initial piling location.
[3] Press-in steel sheet piles as reaction piles (Figure 9).
[4] Remove equipment used for the installation of reaction piles, and carry equipment for the installation of tubular piles in the initial piling location by a truck and a crane.
[5] Install a Reaction Stand for tubular pile press-in work, and fix it to the reaction piles (Figure 10).
[6] Assemble the rotary press-in piling machine (hereinafter referred to as Gyro Piler), which was carried in the site in three parts, on the Reaction Stand (Figure 11).
[7] Install 15 tubular piles using the Gyro Piler and the crawler crane.
[8] Install the Non-staging System (such as clamping crane, Pile Runner, and transportation trackway) on the installed tubular piles (Figure 12).
[9] Install 37 tubular piles using the Non-staging System (Figure 13).
[10] Have all the equipment used for the installation of the tubular piles self-walk backward to the position within the outreach of the crawler crane after the completion of all piles installation.
[11] Dismantle and remove all equipment.

The construction was completed in 7 months from May 10 to December 5, 2018, according to the original plan.

5.4 *Quality control*

5.4.1 *Steel tubular piles*

A quality inspection was performed on prefabricated piles after tubular piles were delivered to the site from a steel manufacturer.

A visual inspection was performed at the site to make sure there were no defects such as deformations. Inspection results of tubular pile dimensions (actual measurements and pass/fail assessments against the tolerances) are shown in Table 1 for pile Nos.1, 10, 20, 30, and 40 as typical examples. On the basis of the inspection results, it was confirmed that the outside diameter, thickness, and length of all tubular piles met the Japanese Industrial Standards.

Figure 9. Installation of reaction piles.

Figure 10. Installation of a Reaction Stand for tubular piles.

Figure 11. Assembly of a Gyro Piler.

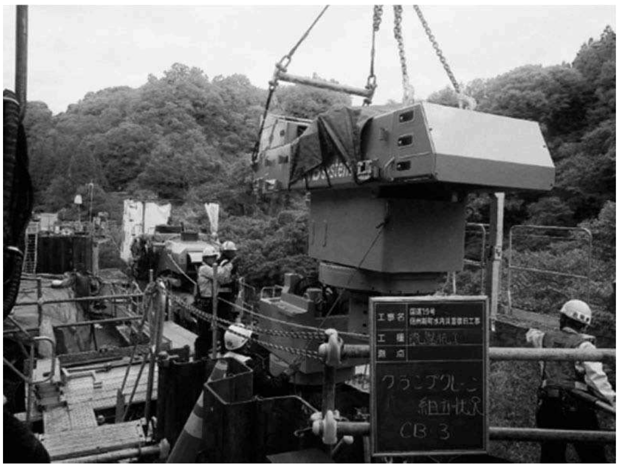

Figure 12. Assembly of a clamping crane.

Figure 13. Steel tubular pile installation using the Non-staging System.

5.4.2 *Welded splices of steel tubular piles*

Tubular piles with a length of 31.5m were needed because they had to reach the bearing stratum. For this reason, the tubular piles were transported to the site in three parts, each of them having a length of 9.0, 10.5, and 12.0m, respectively, and spliced by self-shielded arc welding.

Inspection points and the results of welded splices formed along the circumference of the tubular pile are shown in Figure 14 and Table 2 for pile Nos.1, 10, 20, 30, 40, and 41 as typical examples. A visual inspection and a dye penetrant test were performed on every welded splice, and an ultrasonic test was performed on a welded splice randomly selected from every 20 splices. The outlines of the dye penetrant test and ultrasonic test are shown in Tables 3 and 4.

Table 1. Actual values of steel tubular piles dimensions.

Pile No.	Pile Parts	Diameter (mm)	Thickness (mm)	Length (mm)	Total length (mm)	Assesment
0	Bottom	801	12.22	12.029	31.588	Pass
	Middle	800	12.25	9.026		
	Upper	800	12.2	10.533		
1	Bottom	799	12.12	10.535	31.603	Pass
	Middle	802	12.11	9.032		
	Upper	801	12.13	12.036		
10	Bottom	800	12.09	12.03	31.590	Pass
	Middle	800	12.2	9.03		
	Upper	801	12.08	10.53		
20	Bottom	800	12.07	12.035	31.608	Pass
	Middle	800	12.11	9.035		
	Upper	801	12.09	10.538		
30	Bottom	800	12.19	12.04	31.594	Pass
	Middle	800	12.24	9.027		
	Upper	801	12.15	10.527		
40	Bottom	801	12.23	12.035	31.595	Pass
	Middle	800	12.26	9.025		
	Upper	800	12.29	10.535		

- Tolerance (Japan Industrial Standards JIS A5330-1994)Outside diameter: ±0.5%, thickness: -0.8 mm (no tolerance specified on the plus side) Length: No tolerance specified on the plus side
- Designed dimensions of the tubular pileOutside diameter: 800 mm, thickness: 12 mmLength: 12.0 m/10.5 m, 9.0 m, and 10.5 m/12.0 m for the bottom, middle, and upper parts, respectively

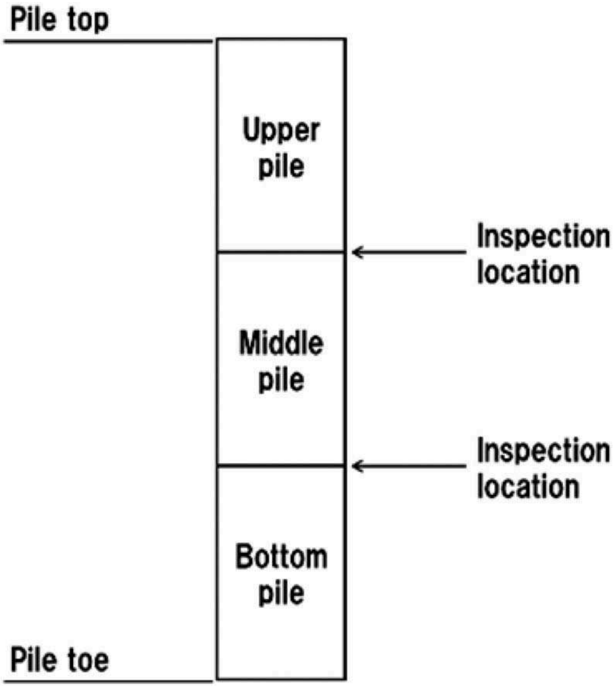

Figure 14. Inspection location of welded splices.

Table 2. Inspection results of each welding part.

Pile No.	Splice No.	Welding location	Visual inspection	Dye penetrate test	Ultrasonic test
1	1	Bottom-Middle	Pass	Pass	
	2	Middle-Upper	Pass	Pass	
10	19	Bottom-Middle	Pass	Pass	
	20	Middle-Upper	Pass	Pass	
20	39	Bottom-Middle	Pass	Pass	
	40	Middle-Upper	Pass	Pass	
30	59	Bottom-Middle	Pass	Pass	
	60	Middle-Upper	Pass	Pass	
40	79	Bottom-Middle	Pass	Pass (C)	Pass (C)
	80	Middle-Upper	Pass	Pass (C)	

- Descriptions with the index (C) are results of inspections performed by certified personnel.
- The dye penetrant test was performed on every welded splice and performed by certified personnel on more than 10% of them. As for the ultrasonic test, it was performed by certified personnel on a welded splice randomly selected from every 20 splices.

Table 3. Specification of dye penetrant test.

Applicable standard	JIS-Z-2343	Criterion	There is no serious defect occurred by cracks and so forth.
Dye penetrant	Penetrant	R-1AH NT	
	Developer	R-1SH NT	
	Remover	R-1MH NT	
	Manufacture	Eishin Kagaku Co.,Ltd.	
Method & condition	Temperature	30 ℃	
	Pre-cleaning	Solvent cleaning with wire brush	
	Penetrant time	10 min or longer	
	Developing time	10 min or longer	

Table 4. Specification of ultrasonic test (RSEC, 2020).

• Ultrasonic flow meter		
Name	RYOSHO UI-S7	
Serial number	U107AS7164	
Inspection date	2017.11.30	
Amplitude linearity	JIS-Z-2353	+0.5%, -1.1%
time linearity	JIS-Z-2352	
Amplitude linearity line	JIS-Z-2353	+0.5%, -1.1%
DAC No use	Rejection	Off
• Probe		
Manufacture	PROBE-KGK	
Serial number / Name	XA3666･ 5Z10x10A70	
Inspection date	30 November 2017	
STB, Angle of refrection, Probe index	70° 10mm	
Dead area	3mm	
Resolution, A2sensitivity	4mm, 25.5dB	
• Condition		
Surface state	Texture after removing spatters	
Test piece	STB-3A, RB-41	
Penetrant range	0~1.0skip	
Requirement of sensitivity	RB-41 H1000 80%	
Correction of sensitivity	0 dB	
Criterion	JIS-Z-3060	

5.5 *Quality control of installed steel tubular piles*

Quality control was conducted on the following construction parameters concerning dimensional accuracy in order to control the compliance of the installed tubular piles with the standards and criteria specified by the client/owner: a) height of the top level, b) embedded depth, c) deviation in plan and d) inclination (KRDB, 2020).

5.5.1 *Height of the pile top level*

The height of the pile top level was designed for each tubular pile as a specified level (design value) according to the undulation of the surface of the national highway running parallel to the arrangement of the piles. In this project, the height of each tubular pile at the end of the press-in work was controlled using an elevation-measuring instrument (Total Station) to meet the reference levels (control values) within ±50.00 mm tolerance.

The control value and actual measurements (mean value, maximum plus and minus values, and standard deviation) of the installed piles' height are shown in Table 5. The height levels ranged from -18.00 to 12.00mm with a mean of -4.00mm and a standard deviation of +6.51mm. The data demonstrated that tubular pile installation by rotary press-in piling could achieve high accuracy to the specified levels.

5.5.2 *Embedded depth*

Inspection results of the embedded depth of the tubular piles are shown in Table 6. It was a mandatory requirement to achieve the specified embedded depth, and all the installed tubular piles were found to have met the control value.

5.5.3 *Deviation in plan*

Inspection results of the deviation in plan of the tubular piles installed at this site are shown in Table 7.

The required control value was within 100mm. The measurement data showed that the deviations in plan were in a range of 7.00 to 74.00mm with a mean of 30.00mm and a standard deviation of ±19.69, which demonstrated the sufficient piling accuracy.

5.5.4 *Inclination*

Measurement results of the inclination of the installed tubular piles are shown in Table 8. The control value of inclination was within ±1%.

Table 5. Assessment: Height of pile top levels.

Item	Unit	Control value	Mean value	Max. value	Min. value	Standard deviation	Sample No.	Assesment
Pile top level	mm	±50	-4	12	-18	±6.51	42	Pass

Table 6. Assessment: Embedded depths.

Item	Unit	Control value	Mean value	Max. value	Min. value	Standard deviation	Sample No.	Assesment
Embedded length	mm	18900 or over	19003	19035	18964	±13.06	42	Pass

Table 7. Assessment: Deviations in plan.

Item	Unit	Control value	Mean value	Max. value	Min. value	Standard deviation	Sample No.	Assesment
Deviation in plan	mm	100	30	74	7	±19.69	42	Pass

Table 8. Assessment: Inclinations.

Item	Unit	Control value	Mean value	Max. value	Min. value	Standard deviation	Sample No.	Assesment
Inclination	%	1.00	0.20	0.60	0.00	±0.16	42	Pass

The measurement data showed that the inclination of each of the installed tubular piles was in a range of 0 to 0.6% with a mean of 0.2% and a standard deviation of ±0.16, which demonstrated the successful installation of the tubular piles with sufficient verticality.

5.6 *Originality and ingenuity in piling and progress management work*

5.6.1 *Use of pile roller for tubular piles*

It was necessary to crane the tubular piles with care because the work space available right next to the one-way alternative traffic was extremely limited. The way to solve this issue with originality and ingenuity was the use of a Pile Roller for tubular piles (Figure 15).

By using a Pile Roller, the tubular piles were able to be lifted smoothly with reduced friction between metallic objects. In addition, the range of the crane and lifted piles' movement could be minimized so that safety was enhanced.

5.6.2 *Use of acrylic board for measuring pile deviation*

In order to perform the measurement of the deviation in the plan of the installed tubular piles quickly, an acrylic measuring board was used instead of a traditional measurement using a wooden board (Yamaguchi et al. 2019). On this acrylic measuring board, a large circle (to be matched with the actual pile annulus), its centre and another small circle (with its centre being identical with the centre of the large circle and its radius being the maximum permissible deviation) are indicated (Figure 16).

The specified pile centre was measured using a transit. The two cross points between the pile and a line going through the specified pile centre were marked on the pile top. Then a taut line was fixed on the pile top with magnets by linking the two marks. Doing this in two directions, the specified pile centre was visualized as the cross point of the two taut lines. After that, an acrylic measuring board was placed on the pile top by matching the large circle on it with the annulus of the actual pile. As a result, the positional relationship between the specified pile centre (the cross point of the two taut lines) and the actual pile centre (the centre of the small circle on the acrylic board) was visualized. The visualized distance between the specified pile centre and the actual pile centre was easily judged as being allowable, by confirming that the visualized specified pile centre (the cross point of the two taut lines) was inside the small circle. In addition, the distance between the specified and the actual pile centres was easily measured in X and Y directions on the acrylic board by using a ruler.

In this project, the prime and piling contractors created originality and ingenuity including the aforementioned two examples and made a regional contribution through their collaborative efforts. As a result, this project was commended by the Nagano National Highway Office (of the MLIT Kanto Regional Development Bureau) along with the companies having performed it as an excellent construction that achieved significant outcomes and as excellent construction engineering companies among the constructions completed in fiscal year 2018 (NNHOKRDB, 2018).

Figure 15. Lifting a tubular pile with a Pile Roller.

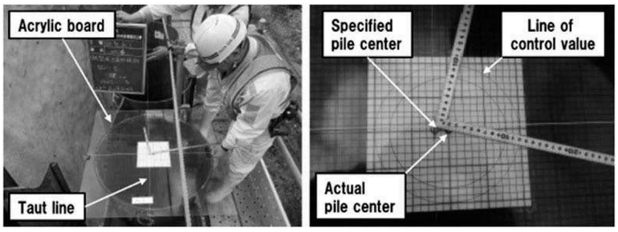

Figure 16. Acrylic measuring board and measurement of pile deviation: Left: Measuring, Right: Example. Gap between specified and actual pile centres.

6 CONCLUDING REMARKS

The following benefits were demonstrated for the installation of tubular piles with ground anchors at landslide disaster sites as a permanent measure and for the combined use of the rotary press-in piling and the Non-staging System that realized the installation of tubular piles at disaster sites:

- A continuous wall constructed with tubular piles with ground anchors is capable to prevent further landslides after the occurrence of the initial landslide even if the soil mass at the edge of the toe of the slope on the river side is lost due to erosion or other reasons.
- By using the rotary press-in piling, it is possible to press-in tubular piles into CM class stratified sandstone (bearing stratum).
- By using the Non-staging System, tubular piles can be installed at active-landslide-slope without additional structures such as a temporary platform.
- By using tubular piles manufactured in plants, it is possible to construct a high-strength and high-quality continuous wall.

- Tubular piles installed by the rotary press-in piling are capable to meet the control values of height of the top levels, embedded depths, deviations in plan and inclinations with a sufficient margin.

In disaster rehabilitation works, it is often the case that a working space is limited and a significant amount of time and costs are spent on the installation of a large-scale temporary platform and embankment. Under such conditions, effective measures need to be devised to bring about safety and security to the neighbourhood and not to disturb their economic and social activities such as traffic when proceeding with the works.

It was demonstrated that the combined use of tubular piles, rotary press-in piling, and the Non-staging System reported in this paper was capable to construct a continuous wall composed of tubular piles on an active-landslide-slope while allowing one-way alternating traffic on the road adjacent to the site. It was also demonstrated that construction cost and duration was reduced because the installation of ancillary facilities such as a temporary platform was not required.

Finally, we hope that the press-in piling application reported in this paper will serve as a reference for similar disaster recovery construction projects.

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