Construction of retaining walls on a steep slope by Gyropress Method

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ABSTRACT

Road widening works were planned for a highway running through mountainous areas to alleviate traffic congestion. The region is characterized by mountains, with the existing road flanked by steep slopes on both sides. This situation made it challenging to secure construction yards and access roads for the project. To address these difficulties, the press-in piling method, especially in conjunction with the GRB System™, was considered highly advantageous as it does not require extensive construction yards. For this particular site, the construction of two rows of steel pipe retaining walls was planned and executed using the Gyropress Method™ to create the construction access roads. The pair of column-row continuous walls constructed with a total of 274 steel tubular piles was completed in approximately 6 months. This paper describes the details of construction using the Gyropress Method, along with examples of high-precision quality control utilizing Implant NAVI™. Additionally, it introduces innovations such as the construction of safe working scaffolds synchronized with the progress of the construction.

Key words: *Retaining wall, Gyropress Method, Tubular pile, GRB System, Implant NAVI,*

1. Outline of the project

1.1. Place

The Kobotoke Tunnel, the site in question, is located at the western edge of Hachioji City in Tokyo and serves as the border with Kanagawa Prefecture. It is located approximately 50 km west of the Tokyo city center.

1.2. Background and objectives of the project

The Chuo Expressway is a highway that runs from Tokyo to Nagoya, passing through Kanagawa, Yamanashi, and Nagano prefectures in the west direction from Tokyo. In the vicinity of the Kobotoke Tunnel on the Chuo Expressway, this road always becomes a site of long traffic jams during weekends and tourism seasons. The road widening works were planned to alleviate this frequent traffic congestion. The area is a mountainous region, and the existing road has steep slopes on its sides. Consequently, it was challenging to establish construction yards and access roads for the project. To address these difficulties, the press-in piling method, especially when combined with the GRB System, was deemed highly favorable as it does not require extensive construction yards. For this particular site, the construction of two rows of steel pipe retaining walls was planned and executed using the Gyropress Method to create the construction access road.

2. Structural type and piling method

2.1. Site condition

This project involves constructing an access road on the slope of the valley side of a highway running through the mountains, intended for highway widening works. The uphill lanes and shoulders of the operational highway are on steep slopes, where it is impossible to install large-scale work platforms. To establish the access roads in this area through embankment and excavation, it was necessary to construct a retaining wall for the embankment on the valley side of the access roads.

2.2. Ground condition

Fig. 1 shows the soil profile and SPT *N*-values at the site. The soil up to a depth of 9 m consists of silt and gravel fill, containing angular cobbles with a maximum diameter of about 110mm. From a depth of 9 m to approximately 13m, the material is a talus deposit of silt and gravel, primarily composed of angular cobble with a maximum diameter of about 80 mm. Both strata indicate SPT *N*-values of about 10 to 20. Below this lies a layer of shale, with an extrapolated SPT *N*-value exceeding 1500.

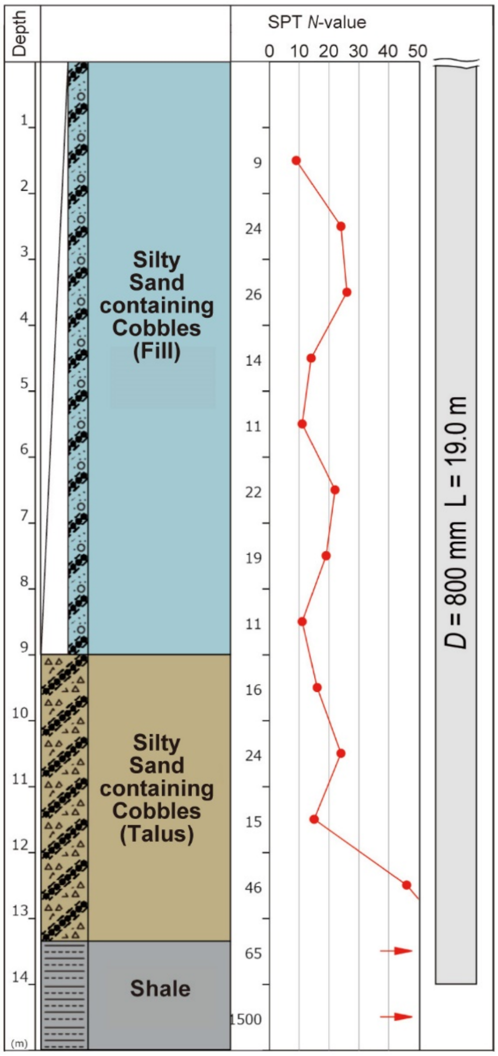

Fig. 1 Soil profile together with SPT *N*-values

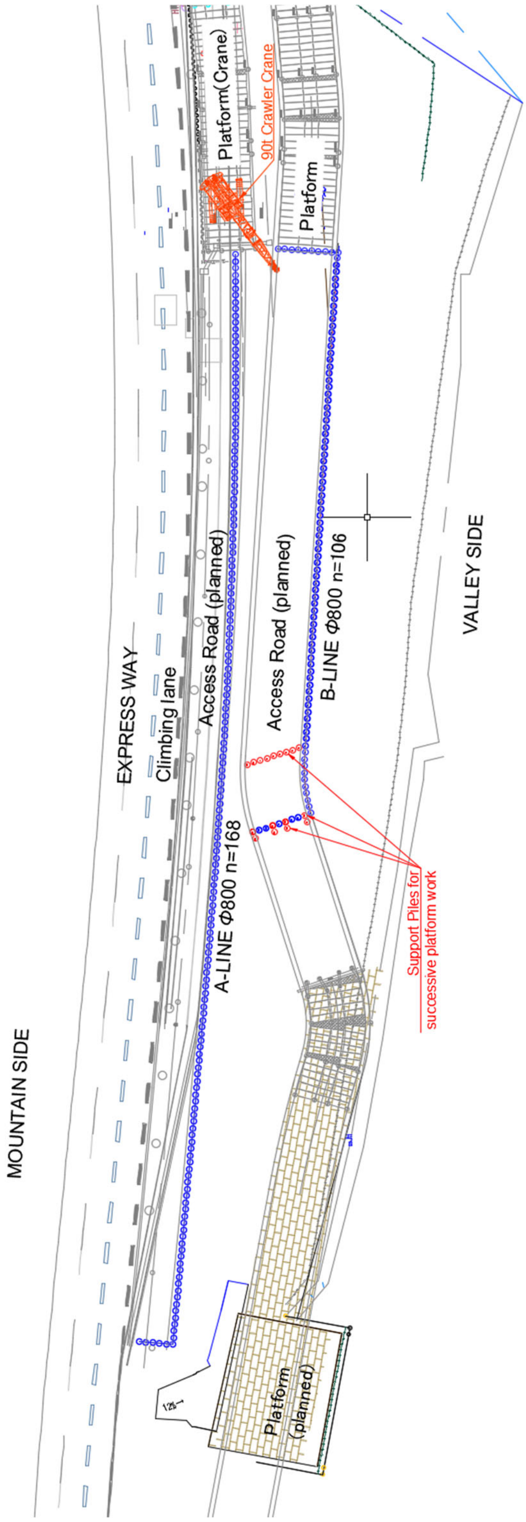

Fig. 2 Layout of the tubular piles

2.3. Structural type

Fig. 2 shows the layout of the site. To construct two access roads, steel pipe piles are installed into the slope on each side of the valley for retaining purposes. The piles, steel pipe piles with a diameter of 800 mm, are installed at a pitch of 1000 mm. The length of the piles for A-Line ranges from 12.5 m to 14.1 m, and for B-Line, it ranges from 7.0 m to 23.5 m. B-Line includes support piles that will serve as the foundation for a platform to be constructed later. From the ground surface to the top of the pile, there is a protrusion of 4 to 6 meters. Later, to prevent backfill material from spilling out between the piles, steel angles are inserted into the ground for more than 500 mm between the piles, and the upper part of the angle is welded to the steel pipe.

Due to the slope rising from right to left in the figure, the initial design had the pile heads positioned according to the slope of the road surface. However, due to the specifications of the piler and the clamp crane, it was necessary to reduce the inclination of the pile head levels to stay within the limit values of step construction and to raise the pile head on the starting side during construction. This problem was adjusted by cutting the pile heads after construction.

On the terminal side of B-Line, bearing piles for the structure were also installed because the access road connects to the platform. The section beyond the breakpoint consists of steel pipe piles used for installation of the bearing piles, and these bearing piles were installed to the shale layer. Piles used for moving the piler, other than the bearing piles, were extracted while retreating and later reused as piles for A-Line.

2.4. Piling method

As mentioned earlier, the top 9 meters of the geological strata of this area were formed by backfill during the construction of the expressway, and there were concerns about the presence of cobbles and boulders larger than those shown in the borehole log. The Gyropress Method, a rotational cutting method capable of dealing with these obstacles, was adopted. Additionally, because the site is located on a slope and there is insufficient working area, the use of the GRB System was essential.

3. Press-in piling

3.1. Layout

Fig. 2 also shows the layout of the piling work. The platform where the crane is installed is also used as a stockyard and workshop for materials, where pipe processing and unloading of materials were conducted. The delivery of materials was managed by temporarily regulating the uphill lanes of the operational expressway and stopping the delivery vehicles in the lane for unloading.

On the starting side, the range in which alternate operation of the crawler crane was possible involved the installation of steel pipe piles using the same crane. Beyond that point, a clamp crane was installed, and construction was carried out using the GRB System (**Fig. 3**).

For this project, GYRO PILER F401, UNIT RUNNER UR5, CLAMP CRANE CB3 and PILE RUNNER PR2 were used. The specification of the F401 is as shown in **Table 1**.

Table 1 Specifications of theSILENT PILER, F401

Max. Press-in Force*	1500 kN
Max. Extraction Force*	1600 kN
Chuck Rotation Torque	900 kNm
Max. Chuck Rotation Velocity	11.0 rpm
Chuck Stroke	1000 mm
Press-in Speed	0.7 to 4.9 m/min
Extraction Speed	0.7 to 3.5 m/min

* for gyration use

Fig. 3 Setting of GRB System (B-Line)

3.2. Piling data

Fig. 4 shows an example of the press-in data obtained during the operation of Pile B103. This pile was used as a bearing pile for the platform and was embedded 3.2 meters into the shale layer, which serves as the bearing layer. From the diagram, it can be observed that both the pressing force and the extraction force increase upon entering the shale layer. The extrapolated SPT *N*-value was 1500, but this did not significantly hinder the rotary cutting process.

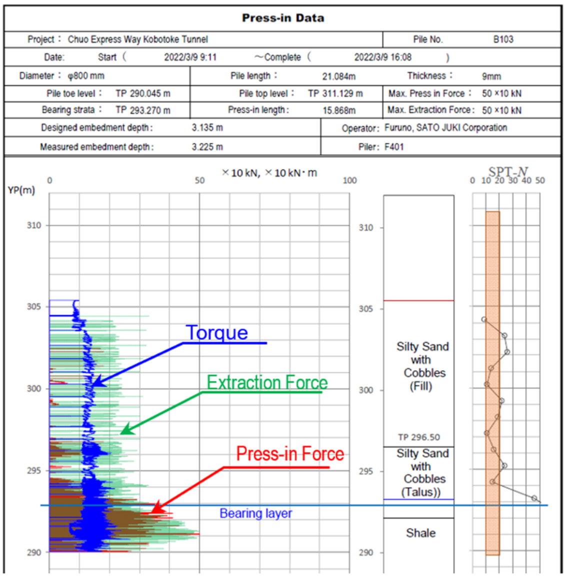

Fig. 4 Press-in data obtained from Pile B103

3.3. Productivity

Table 2 presents an example of the record of pile construction procedures and the required time. At this site, the average 2 to 3 piles were installed per day. Including the days for staging, it took 7 months to construct all 274 piles.

3.4. Encountered difficulties

In this project, high-level construction was one of the challenges. Normally, reaction frames are fixed by installation of steel sheet piles on both sides and attaching the reaction frame to the top of the steel sheet piles with bolts and welding. However, at this site, the top end height exceeding 5 meters from the ground level was considered too high for steel sheet piles to provide sufficient rigidity. Therefore, instead of steel sheet piles, four 400H H-shaped steels were driven into the ground on each side using a vibratory hammer, and the reaction frame was attached to these, enabling stable initial pressing (**Fig. 5**).

Table 2 Example of cycle time table (B-Line)

Cycle Time							
Project:	Chuo Express way Kobotoke tunnel						Pile B2
Date time	Start : 2022/3/25 13:20				End:		2022/3/25 17:53
Diameter:	800 mm		Type:	C	Thick:		9 mm
Pile length	17.6 m	(Lower : 13.1 m + Upper : 4.5 m)				Press-in length	14.2 m
Pile top level	Designed	308.678					
	Measured	308.678					
Equipment:		F401			Op:		Shuji Furuno, SATO JUKI Corp.
Date	Time			Duration (min)	Elapsed time (Min)	Toe level (m)	Procedure
2022 / 3 / 25	13:20	~	13:31	11	11		Installation Lower Pile
	13:31	~	14:00	29	40	0.0	Implant Navi, Pile Center setting
	15:15	~	15:28	13	53	6.5	Gyration Press-in
	15:28	~	15:50	22	75		Upper pile installation
	15:50	~	16:00	10	85		Pre-welding inspection
	16:00	~	16:18	18	103		Welding
	16:18	~	16:35	17	120		Penetrant Test
	16:35	~	17:00	25	145	12.5	Gyration Press-in
	17:00	~	17:08	8	153		Follower
	17:08	~	17:22	14	167	14.2	Gyration Press-in
	17:22	~	17:33	11	178		Pile top plate welding
	17:43	~	17:49	6	184		Moving forward
	17:49	~	17:53	4	188		Follower removal
Total duration		188 min			Welding Time		18 min

Fig. 5 Reaction frame set on the H-shaped beams

In the high-level construction, securing safe access paths for workers to the operation points can be difficult. Therefore, a method was adopted where brackets were welded near the top of each pile after installation, and safe pathways were extended as construction progressed. These created safe pathways could be used as secure working platforms for transporting piles with the GRB System and working with the clamp crane, providing convenience to subsequent workers as well. By modifying parts of the piling stage, innovative solutions were also applied to welding work at the base of the scaffolding (**Fig.**

6, Fig. 7).

Fig. 6 The stage modified for welding work

Fig. 7 Looking up at the work passage

In the Gyropress Method, it is common to install internal piping to deliver lubricating water to the tip of the pile. Typically, the connection of the pipes is done through welding work. At this site, which is adjacent to the expressway, care was taken to prevent any fire or smoke from posing a danger to passing vehicles. A method of connecting pipes pre-threaded and using sockets was adopted. This approach not only shortened the time required for piping work but also received positive feedback for its safety aspects.

4. Additional data

In the quality control and conformance management of piles at this site, the Implant NAVI system (**Fig. 8**) was used to measure and record data for all piles. This system likely facilitated precise tracking and management of pile installation parameters, ensuring that each pile met the specified requirements and standards for the project. The usefulness of the Implant NAVI system was particularly appreciated in this project due to the high elevation points of the piles and the steep slope of the site, which allowed for measurements to be taken from a distance. This capability is crucial in challenging terrain, where direct access to the pile points may be difficult or unsafe, demonstrating the system's adaptability and effectiveness in ensuring quality control under such conditions.

The measurements indicated that all the piles installed in this project had an inclination within 1/300 and the eccentricity did not exceed 10 mm as shown in data sheets (**Figs. 9, 10, 11**). The acceptable values for this project were 1/200 and 80 mm, respectively. The ability to monitor these parameters during installation contributed significantly to the construction of high-quality piles. This level of precision ensures structural stability and longevity, demonstrating the effectiveness of using real-time monitoring technologies like Implant NAVI in maintaining strict quality control during pile installation. (**Fig. 8**)

Fig. 8 Monitoring using Implant NAVI

Figs. 12, 13, 14 are photographs of the construction progress. They show the operation status of the GRB System, the delivery of piles, the completion of B-Line pile installation. And as seen in **Fig. 15**, the completion of the construction.

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測定結果一覧表

工事名　中央自動車小仏渋滞対策八王子地区工事用道路工事

工　種　ジャイロプレス工法

杭　種　鋼管杭

測定者　株式会社佐藤重機建設　　印

測定項目	杭／矢板の平面位置（ΔX, ΔY）（杭径中心間隔ずれ）						偏芯量 (d)	杭／矢板の傾斜（ΔX/L, ΔY/L）（傾斜角）				杭／矢板の天端高さ H		
	ΔX			ΔY			XY合成	ΔX/L		ΔY/L		H		
規格値	-100	～	+100mm	-100	～	+100mm	100mm	1/100以内		1/100以内		-50	～	+50mm
管理値	-50	～	+50mm	-50	～	+50mm	50mm	1/150以内		1/150以内		-30	～	+30mm
測点又は区別	設計値 m	実測値 m	差 mm	設計値 m	実測値 m	差 mm	実測値 mm	設計値	実測値	設計値	実測値	設計値 m	実測値 m	差 mm
b41	-39762.708	-39762.7048	3.2	-54563.823	-54563.8267	-3.7	4.9	-	1/384	-	1/465	309.578	309.5797	1.7
b42	-39762.645	-39762.6404	4.6	-54564.821	-54564.8236	-2.6	5.3	-	1/2037	-	1/1765	309.608	309.6117	3.7
b43	-39762.581	-39762.5786	2.4	-54565.819	-54565.8216	-2.6	3.6	-	1/343	-	1/521	309.638	309.6400	2.0
b44	-39762.517	-39762.5137	3.3	-54566.817	-54566.8183	-1.3	3.5	-	1/1670	-	1/677	309.668	309.6670	-1.0
b45	-39762.454	-39762.4548	-0.8	-54567.815	-54567.8146	0.4	0.9	-	1/15175	-	1/1301	309.698	309.6993	1.3
b46	-39762.390	-39762.3909	-0.9	-54568.813	-54568.8091	3.9	4.0	-	1/1124	-	1/696	309.728	309.7283	0.3
b47	-39762.327	-39762.3269	0.1	-54569.811	-54569.8106	0.4	0.4	-	1/2201	-	1/1130	309.758	309.7523	-5.7
b48	-39762.263	-39762.2485	14.5	-54570.809	-54570.8103	-1.3	14.5	-	1/294	-	1/430	309.788	309.7827	-5.3
b49	-39762.199	-39762.1984	0.6	-54571.807	-54571.8055	1.5	1.6	-	1/1317	-	1/890	309.818	309.8140	-4.0
b50	-39762.136	-39762.1373	-1.3	-54572.805	-54572.8059	-0.9	1.6	-	1/731	-	1/874	309.848	309.8410	-7.0
測定項目	杭／矢板の平面位置（ΔX, ΔY）（杭径中心間隔ずれ）						偏芯量 (d)	杭／矢板の傾斜（ΔX/L, ΔY/L）（傾斜角）				杭／矢板の天端高さ H		
	ΔX			ΔY			XY合成	ΔX/L		ΔY/L		H		
規格値	-100	～	+100mm	-100	～	+100mm	100mm	1/100以内		1/100以内		-50	～	+50mm
管理値	-50	～	+50mm	-50	～	+50mm	50mm	1/150以内		1/150以内		-30	～	+30mm
測点又は区別	設計値 m	実測値 m	差 mm	設計値 m	実測値 m	差 mm	実測値 mm	設計値	実測値	設計値	実測値	設計値	実測値	差
b51	-39762.072	-39762.0704	1.6	-54573.803	-54573.8038	-0.8	1.8	-	1/228	-	1/11873	309.878	309.8767	-1.3
b52	-39762.009	-39762.0088	0.2	-54574.801	-54574.8016	-0.6	0.6	-	1/169	-	1/458	309.908	309.9087	0.7
b53	-39761.945	-39761.9417	3.3	-54575.799	-54575.7948	4.2	5.3	-	1/909	-	1/11363	309.938	309.9373	-0.7
b54	-39761.881	-39761.8815	-0.5	-54576.797	-54576.7971	-0.1	0.5	-	1/1004	-	1/1903	309.968	309.9657	-2.3
b55	-39761.818	-39761.8209	-2.9	-54577.795	-54577.7949	0.1	2.9	-	1/2315	-	1/1130	309.998	309.9977	-0.3
b56	-39761.754	-39761.7545	-0.5	-54578.793	-54578.7899	3.0	3.0	-	1/913	-	1/2603	310.028	310.0243	-3.7
b57	-39761.691	-39761.6913	-0.3	-54579.791	-54579.7896	1.4	1.4	-	1/1083	-	1/636	310.058	310.0547	-3.3
b58	-39761.627	-39761.6262	0.8	-54580.789	-54580.7883	0.7	1.1	-	1/409	-	1/658	310.088	310.0817	-6.3
b59	-39761.563	-39761.5655	-2.5	-54581.787	-54581.7855	1.5	3.0	-	1/1228	-	1/517	310.118	310.1117	-6.3
b60	-39761.500	-39761.5006	-0.6	-54582.785	-54582.7877	-2.7	2.8	-	1/20280	-	1/255	310.148	310.1413	-6.7

略図

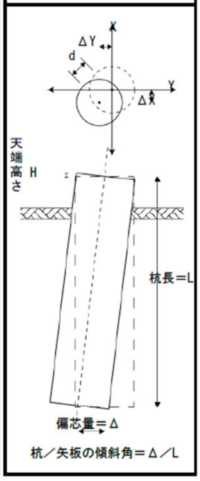

Fig. 9　Result from measurement using Implant NAVI.

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出来形管理図（工程能力図）

工　種　ジャイロプレス工法

杭　種　鋼管杭

測定者　株式会社佐藤重機建設　　印

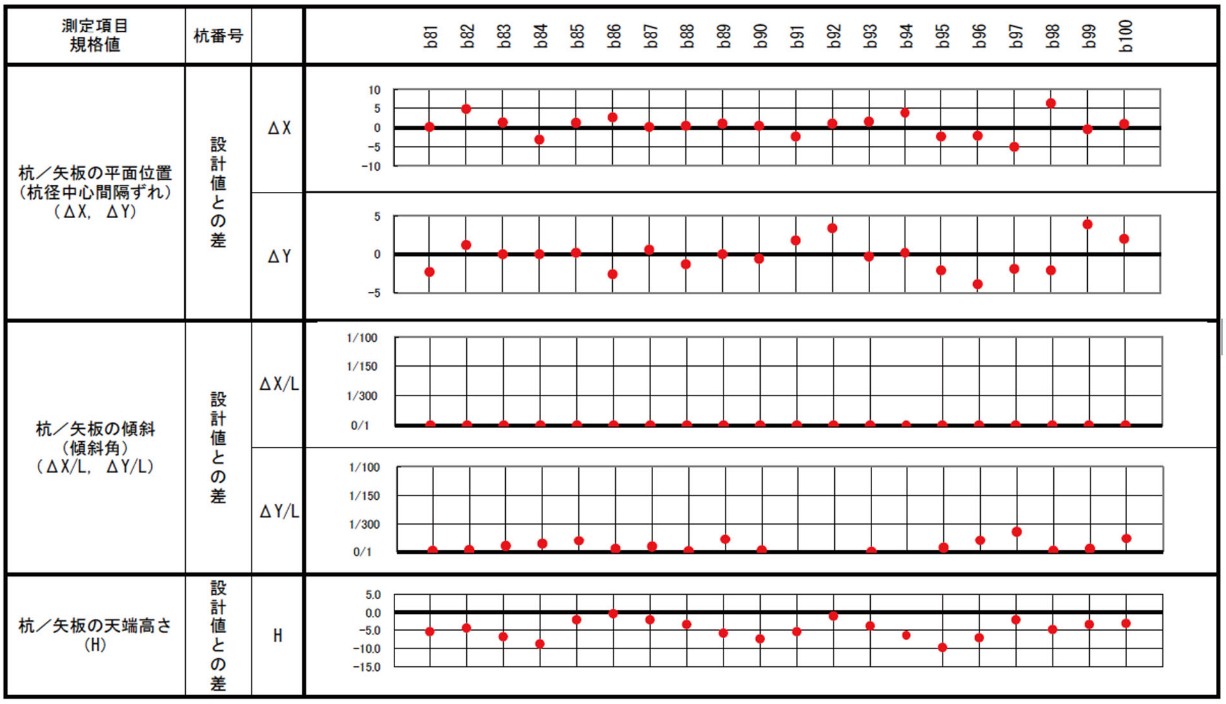

Fig. 10　As-built drawings using Implant NAVI.

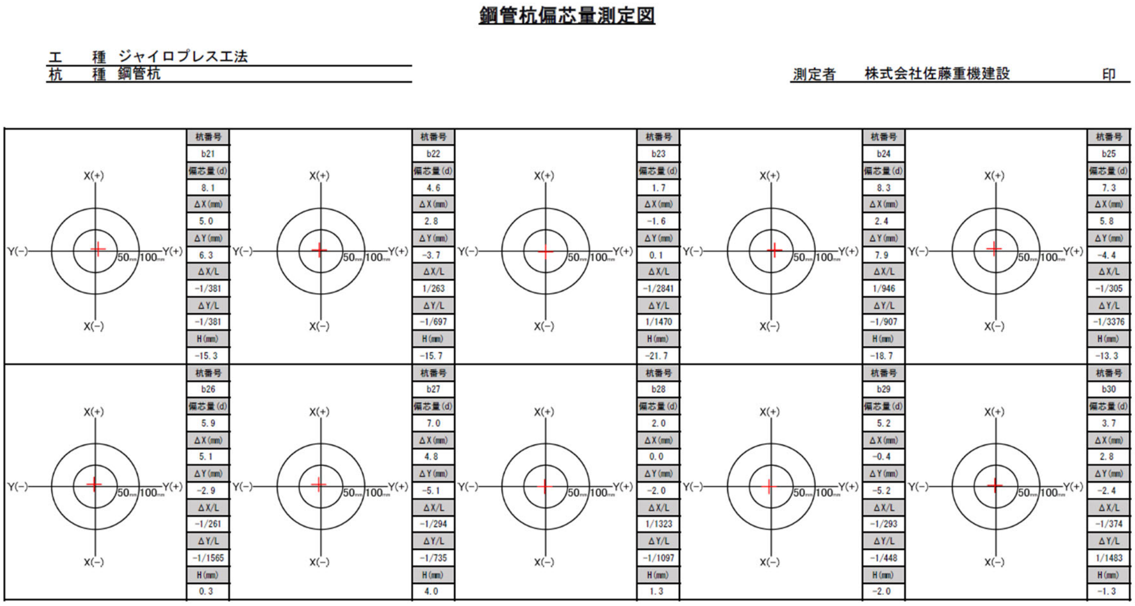

Fig. 11 Steel pipe pile eccentricity measurement diagram, Implant NAVI.

5. Concluding remarks

The Gyropress Method was employed to install steel pipe pile retaining walls on a steep slope.

The construction of all 274 piles was completed in 7 months, including the time spent on ancillary tasks.

The use of the GRB System enabled construction in areas where securing a work area was not possible.

By utilizing the Implant NAVI system, high-precision quality control and the visualization of results were achieved, enhancing the overall efficiency and reliability of the project.

Fig. 13 Material delivery

Fig. 12 Pile conveyed by Pile Runner

Fig. 14 Completion of piling of B-Line

6. Acknowledgements

The authors express gratitude to the individuals engaged in this project, who recognized the contribution of this paper.

We also extend our appreciation to all those who cooperated with this construction work.

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Fig. 15 Completion of access road