Review on the difficult case of the pipe roof project to crossing National Highway no.1

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ABSTRACT

In order to solve the local traffic problem, Construction Office New Taipei City Government planned to build a new road. Extending from Fude 2nd Rd to the north to Kangning Street, and using the pipe roof method (width 20.6m, height 10m, length 52m) to cross National Highway no.1 underground. However, there are existing 60cm diameter piles which under the retaining wall of National Highway No. 1. Due to the construction limitations of the pipe roof method, the existing piles must be removed before the advancement operation.

The soil condition at the construction site is characterized by silty clay with intermittent sand layers, with SPT-N values ranging between 4 and 5, indicating soft cohesive soil. The groundwater level is approximately at G.L-7.1m(below the highway pavement). Considering the constraints of the limited construction site area and traffic maintenance, this project utilizes four elliptical steel liner plate (2.1m x 6.8m) as vertical working wells. And supplemented with steel horizontal bracing, to carry out the excavation work for soil barrier construction. And circular steel sheet piles are used as horizontal working wells to facilitate horizontal excavation work. The excavation depth reaches the elevation of the lower row of pipe-jacking steel pipes (G.L-13.5m). In summary, in order to enhance construction safety and feasibility, ground improvement is carried out before the excavation. Using TAM grouting and JSG method respectively to increase soil self-supportiveness and reduce soil permeability.

KEYWORDS: Ground improvement, TAM grouting, JSG method, Excavation

1. Introduction

Due to the Keelung River, National Highway No. 1 and National Highway No. 3, the north-south traffic in Xizhi District of New Taipei City is blocked by it. At present, only one road connects to the outer road as the main road. In order to solve the local traffic problem, Construction Office New Taipei City Government planned the improvement project of the overall surrounding traffic corridor. One of them is the construction of a new road to replace the beam bridge across the river. The road starts from Fude 2nd Road along TungHing Road and runs north to the end of the road at Kangning Street. This project adopts the pipe roof method (width 20.6m, height 10m, length 52m) to cross National highway no. 1, then excavate and construct the culvert (FIG. 1). Upon completion of the project, north-south transport links will be smoothly established to promote regional prosperity and development. To provide a safer and more convenient transportation environment for New Taipei City residents.

There are two major projects that need to be completed before the project can proceed: (1). Site improvement works; (2). The barrier of the retaining wall foundation pile is removed. The purpose of the ground improvement:

A. To increase the soil cohesion and reduce the soil permeability in response to the needs of the pipe roof engineering departure/arrival well.

B. The foundation pile of the existing retaining wall is broken by manual excavation, which has high construction risk and needs to increase the formation strength.

C. The soil covering depth from the national highway pavement to the top of the pipe roof is only about 1.5-4.0m, and the soil excavation of the pipe roof project may cause settlement and displacement of the retaining wall or highway.

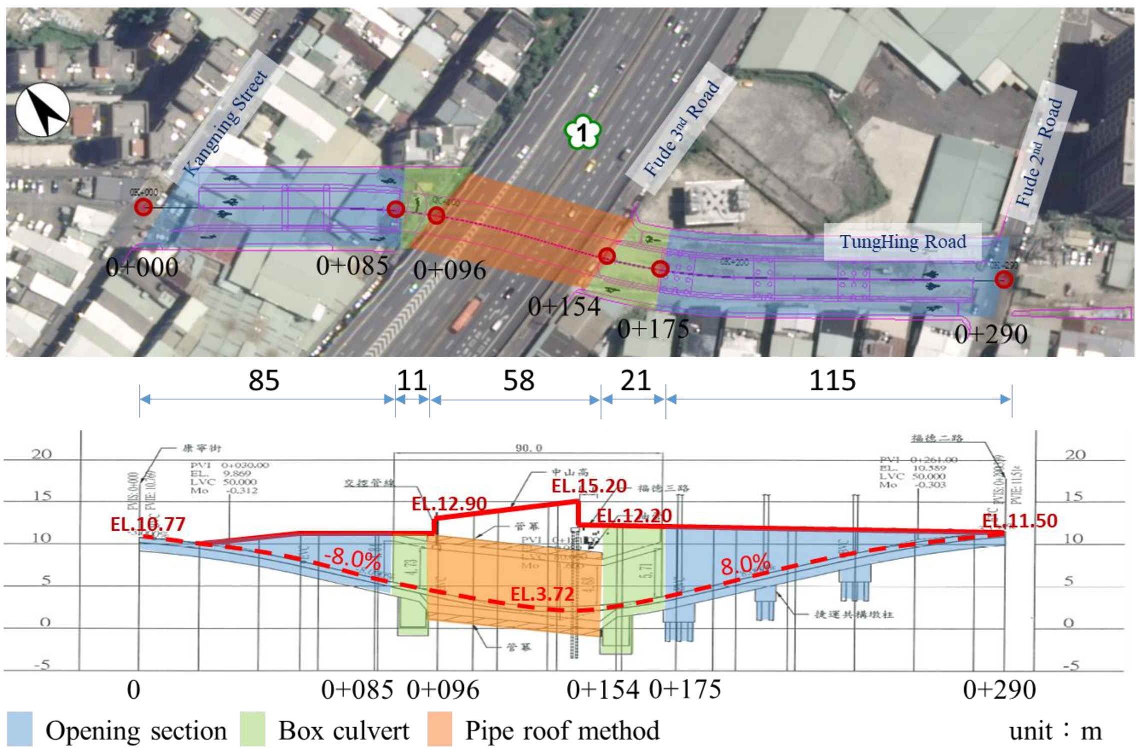

Figure 1. Project outline drawing

2. Ground improvement

The site is composed of silty clay with SPT-N value ranging from 1 to 5. Above the site is the gravel gradation material for the embankment of the national highway. The geology of the grouting range (G.L. -3.24m ~G.L. 20.8m) is mainly a soft clay layer coupled with fine sand, and the geological conditions are very poor. The water table is about 3.6 m below the Fude 3nd Rd ground surface(7.1m below the highway pavement). Because the backfill embankment is constructed in different periods, there is a new and old interface (weak surface) in the gravel gradation backfill layer of the embankment (FIG. 2).

The ground improvement method of this project is including jet grouting and the double packer method, in which the construction procedures of two are briefly described as follows:

(1) Jet grouting method adopts the double fluid system, and uses water knife to cut soil first (Pre cut) and then spray grouting.
(2) Double packer method is to drill holes and bury TAM pipe, then chemical grouting.

Limited by the size of highway construction space, it is necessary to set up additional construction steel structure platform for construction machinery and tools to walk. Since the Fude 3rd Road works area is also small, the mud pit (also known as decompression tank) required for high-pressure conversion can only be set in the road shoulder area. The construction machinery and tools are placed in the work area of TungHing Road, and the grouting pipe and water supply pipe of the two places have been connected through the road-buried pipe, as shown in FIG. 3 and FIG. 4.

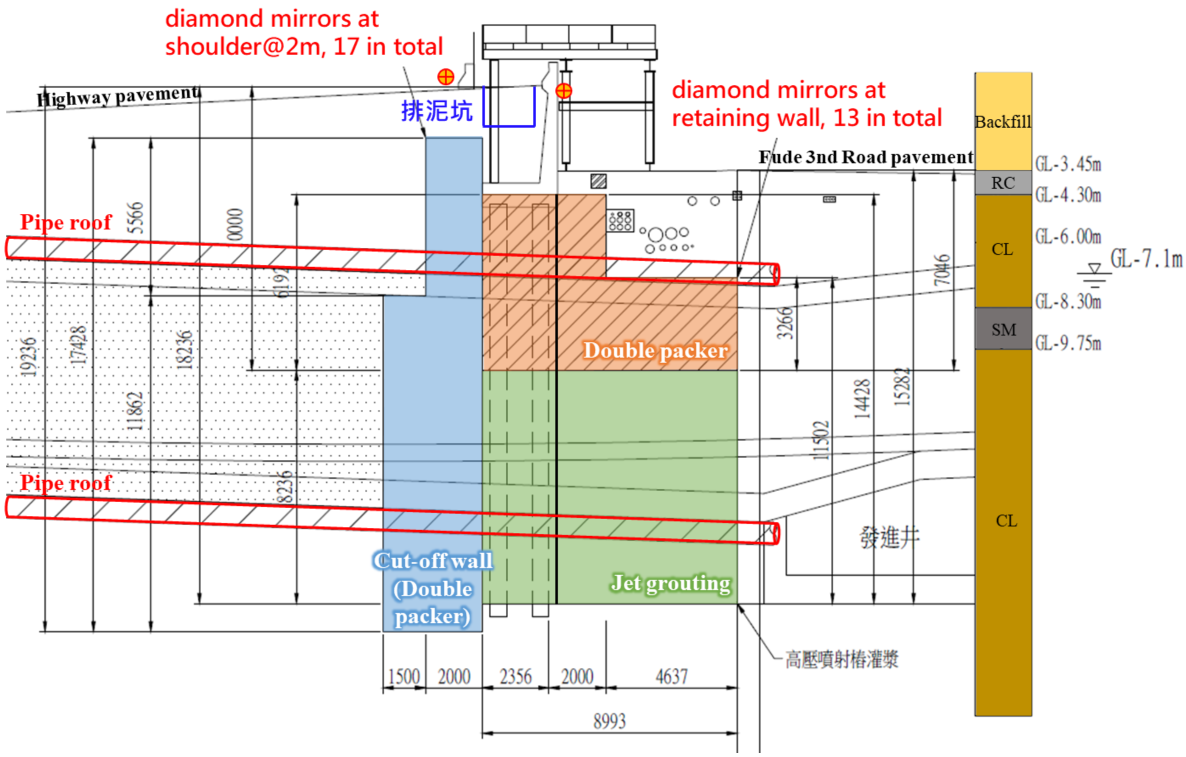

Figure 2. The profile of ground improvement

Figure 3. The Construction arrangement of ground improvement (1)

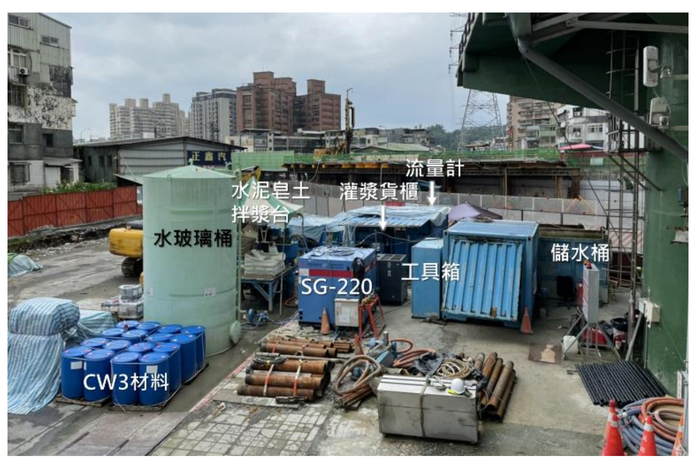

Figure 4. The Construction arrangement of ground improvement (2)

2.1 Quality control

(1) Before construction

According to the requirements of the construction code, jet grouting should be tested before construction. The pile diameters designed for jet grouting were 2m(below the highway shoulder) and 3.2m(below Fude 3nd Road), and 3 test piles were carried out for each diameter, totaling 6 test piles. The purpose of the test is to verify whether the proposed operating parameters meet the requirements of the design pile diameter, the design permeability coefficient, the design strength, and the design spacing of each grouting pile.

Ground improvement results generally require an in-situ falling head permeability test (k ≦10-5cm/sec), core sampling, and uniaxial compression strength test. (qu: clay ≧10 kgf/cm2, sand≧20 kgf/cm2). In order to strengthen the verification that the grouting pile can meet the design requirements, the test carried out the drilling verticality detection (SAA), the Pain bar test to measure the cut mark of steel pipe and the JWM pile diameter to measure the sound test simultaneously during the grouting construction process, so as to effectively grasp the construction results.

(2) During construction

The construction plan for jet grouting is arranged to add two decompression holes next to the grouting hole (main hole) to increase the mud discharge path when the grouting is returned. In order to control the smoothness of mud discharge in the process of grouting and reduce the construction accidents caused by bad mud discharge. The double packer method has only grout holes.

The construction process can be divided into the drilling stage and the grouting stage. In the drilling stage, whether it is the main hole or the decompression hole, the construction inspection must be carried out according to the hole coordinates, the bore diameter, the drill pipe Angle and the drilling depth. In the grouting stage, there are different inspection items and standards according to the Jet grouting methods and Double packer method, as detailed in Table 1 and Table 2. Refer to FIG. 5-8 for of on-site construction inspection photos.

Table1. Jet grouting method Inspection item and standard

Inspection item			Inspection Standard
During construction	Pressure gauge、Flow meter	Calibration qualified or not	Calibration report
	Grout material	★Specific gravity	1.40 ± 0.05
	Rod rotation	rotation speed	φ=2.0 m，7~9rpm φ=3.2 m，5~7rpm
	Rod lift	lift speed	φ=2.0 m，10 min/m up φ=3.2 m，12 min/m up
	Grout flow rate	★flow rate value	φ=2.0 m，180 L/min±10% φ=3.2 m，360 L/min±10%
	Grout pressure	★pressure value	φ=2.0 m，320 kg/cm^2±10% φ=3.2 m，340 kg/cm^2±10%
	Compressed air	★Pressure value	10 kg/cm2 ±10%

Table2. Double packer method Inspection item and standard

Inspection item			Inspection Standard
During construction	Pressure gauge、Flow meter	Calibration qualified or not	Calibration report
	Grout material	CB liquid	Specific gravity 1.40 ± 0.05
		CW-3 liquid	Setting time < 5min
	First Grouting (CB liquid)	Grout pressure	2.0~30 kg/cm^2
		Grout flow rate	4-15 L/min
		Grouting work step by step	Each step is raised by 33cm, the number of total steps is ___.

Inspection item			Inspection Standard
	Second Grouting (CW-3 liquid)	Grout pressure	2.0~30 kg/cm^2
		Grout flow rate	4-12 L/min
		Grouting work step by step	Each step is raised by 33cm, the number of total steps is ___.

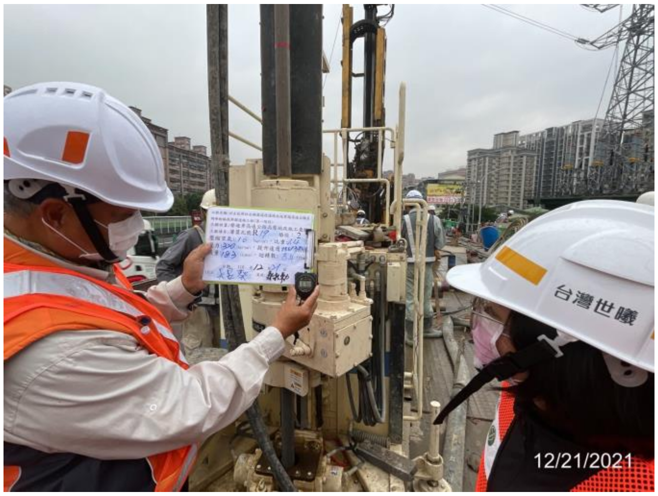

Figure 5. The Inspection of rod lift (Jet grouting method)

Figure 6. The Inspection of grout flow rate and pressure (Double packer method)

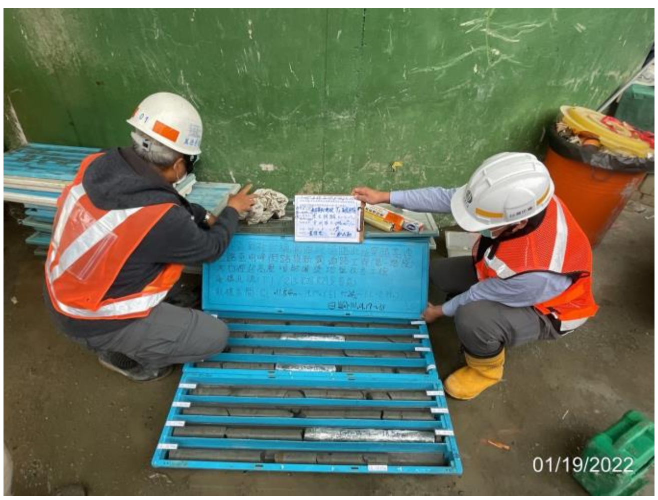

Figure 7. The take core of jet grouting


Figure 8. The in-situ falling head permeability test

2.2 Construction safety monitoring

During grouting, automatic monitoring is the main control item. The subject matter of monitoring is the change of highway pavement and embankment retaining wall on both sides of expressway. Install the reflective diamond mirrors on the shoulder of the highway and the side of the retaining wall (FIG. 2), and set up the total station at the visible position. The monitoring frequency is about 1.5 hours to return the monitoring data. The 3D-LiDAR scan was performed once or twice a month for cross-comparison of highway elevation.

Through the monitoring results, it was found that during the initial drilling period, the shoulder of the highway had settled(FIG. 9(a)). After five days of drilling, the road settlement was 5.0mm. In the end, drilling caused the pavement to continue sinking, with a settlement of up to 16mm (FIG. 9(a)&9(b)).

There is no significant displacement of the retaining wall during drilling. After the grouting operation began, the subsidence rate of the road surface was relatively gentle. However, the grouting pressure causes lateral deformation of the retaining wall, with a maximum value of about 8mm.

In general, local road settlement caused by drilling can be controlled by subsequent low-pressure grouting lift. However, the displacement of retaining wall affects the recovery of pavement subsidence by low-pressure grouting. Moreover, the grouting pressure estimation will cause the continuous displacement of the retaining wall, so the displacement of the retaining wall is suppressed by increasing the support.(FIG.10)

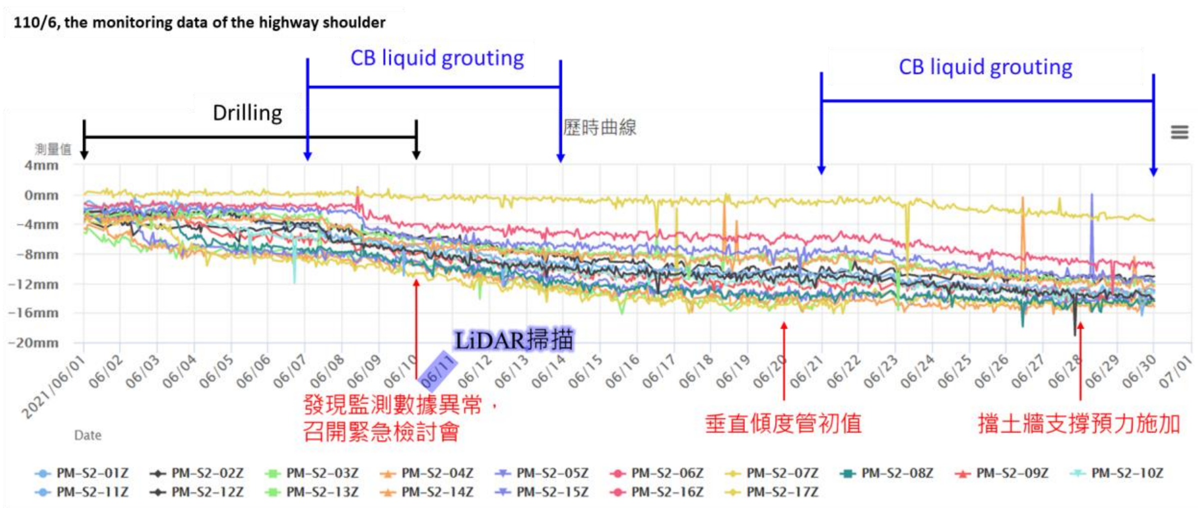

Figure 9(a). the monitoring data of the highway shoulder at 110/6

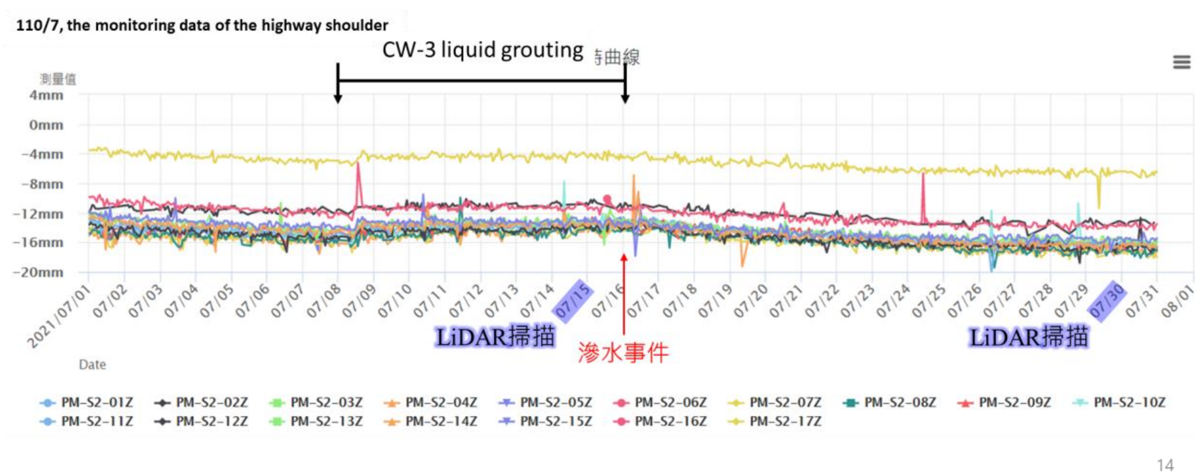

Figure 9(b). the monitoring data of the highway shoulder at 110/7

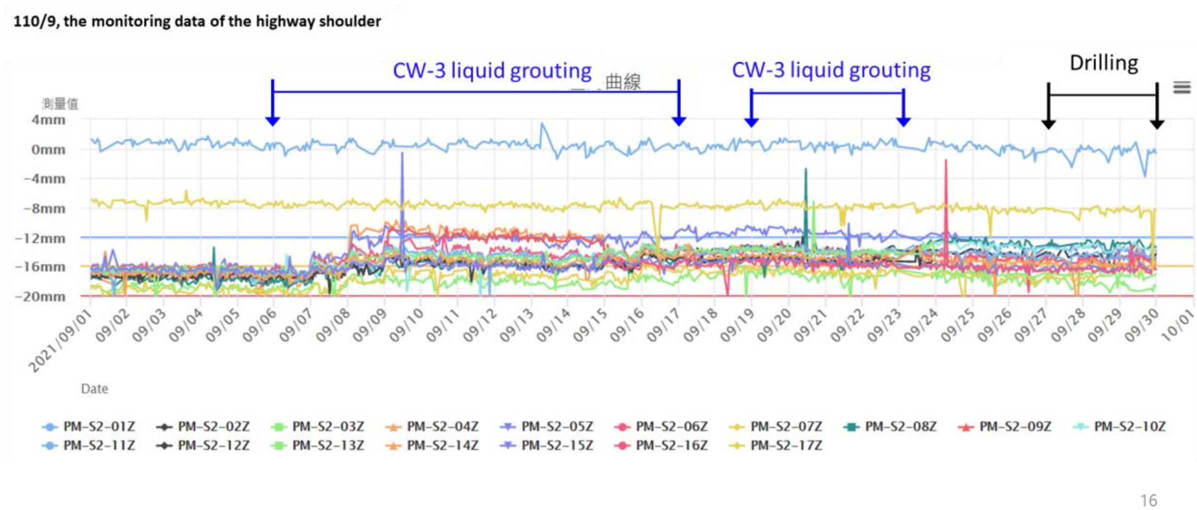

Figure 9(c). the monitoring data of the highway shoulder at 110/9

Figure 10. Retaining wall with added lateral support to control displacement

3. Foundation pile removed

After the ground improvement, the next step will remove the foundation pile of the retaining wall. The retaining wall is reinforced by ground improvement at the bottom, adding a self-drilling rock bolt and reinforcing beam on the bottom plate. The foundation piles of the retaining wall are arranged as flower-shaped pattern, and the farthest distance between the center of the demolished piles and the vertical working wells is still approximately 1.5m. A total of 17 piles need to be removed, each foundation pile also needs to cut the upper and lower rows, a total of 34 places(show in FIG.11-13). The cutting elevation of the pile in the bottom row is 13.5m below the surface, that is the elevation of the bottom pipe roof.

Due to the limitation of the construction site, only small machines and tools can be used to support the manual work. In vertical excavation, four 2.1m*6.8m elliptical steel lining plate is used as working wells. And supplemented with steel horizontal bracing, to carry out the excavation work for soil barrier construction. Lateral horizontal manual excavation with ∮1.2m circular steel lining plate as temporary protection. Considering that the ground improvement after excavation has been confirmed to be effective, the soil's self-supporting capacity is high. Therefore, the excavation of the vertical working well is canceled and replaced by oblique excavation. The adjacent foundation piles are broken by unsupported excavation. The construction photos show in FIG 13.

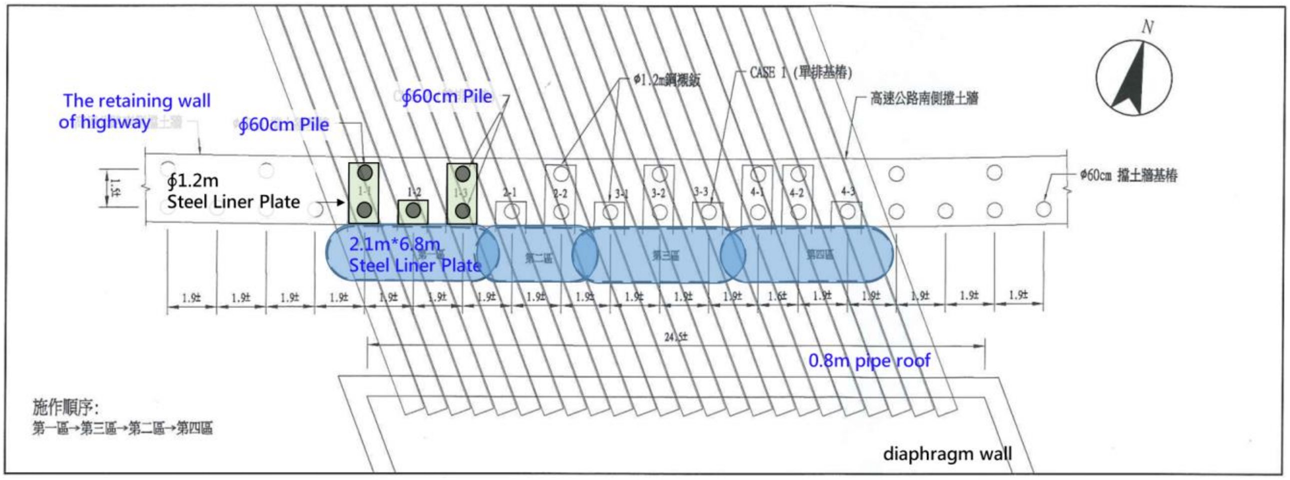

Figure 11. The plan of the retaining wall foundation pile is removed

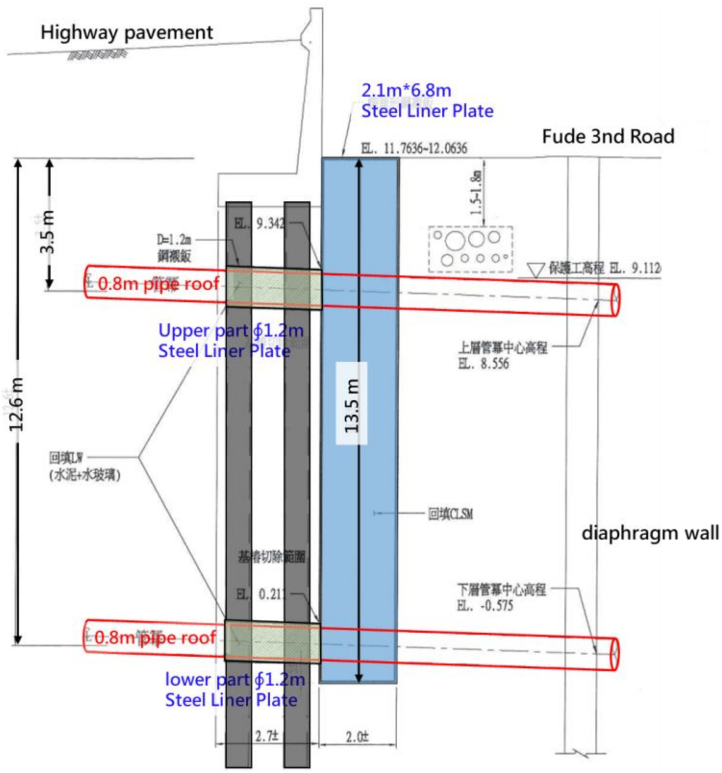

Figure 12. The section of the retaining wall foundation pile is removed

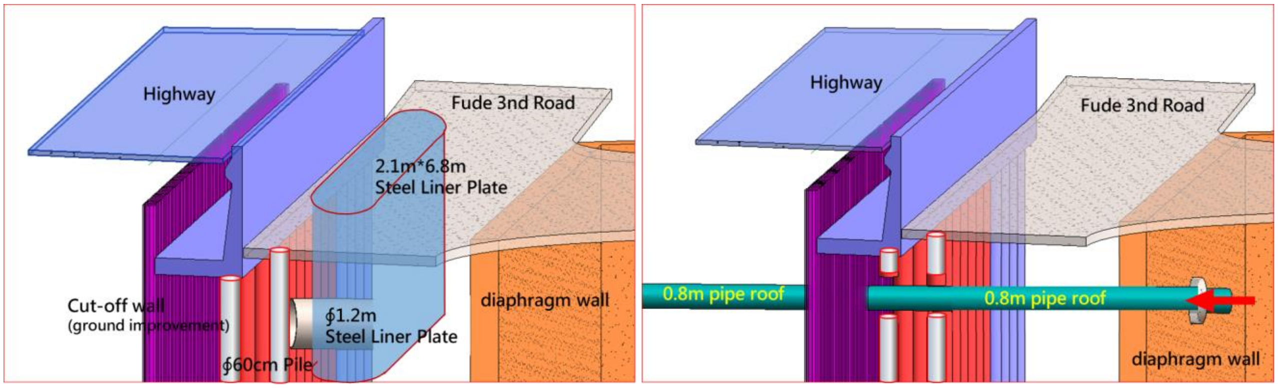

Figure 12. The 3D schematic of the retaining wall foundation pile is removed

Figure 13. The photo of the foundation pile removed

4. Risk management

Although the above-mentioned construction projects are hypothetical projects, due to the proximity to the highway and the existence of weak strata, there are non-negligible construction risks. In this case, there are not only weak ground surface, but also difficult construction problems of road seepage and road bulge after grouting. In order to effectively control the construction risk, to ensure the highway traffic safety. The following points are the improvement methods of the construction process.

(1) Countermeasure 1: The waterway is blocked. The weak surface is blocked by instantaneous grouting in the shallow double packer method ground improvement range (within 7 meters below the road surface). The controllable setting time of the grout material is adjusted to 3~5 minutes to overcome the waterway formed by low soil pressure and weak surface of the formation.

(2) Countermeasure 2: Adjust the double packer method. The daily amount of single-hole grouting is reduced, and the grouting is performed by jumping steps. Each hole jumps 1~2 steps, from the bottom up to raise the grout. This method requires six grout breaks per hole to complete.

(3) Countermeasure 3: Add to horizontal drainage holes. Provision of horizontal drainage holes under highway pavement. Through forced decompression, the pore water in the formation is eliminated, and the doubt of pavement seepage is reduced.

(4) Countermeasure 4: Night construction. The outermost part of the grouting range and the part near the surface shall be constructed at night. Two lanes outside the road shoulder are closed to traffic. To ensure that if construction problems arise, there will be minimal disruption to the traffic of the national highway. The case ended with approximately 4 weeks of night-time construction.

5. Conclusion

In the process of grouting, the porosity of the old and new interfaces and the water under the backfill layer greatly increase the difficulty of construction. It is easy to have water seepage on the pavement during construction. By adjusting the construction method, we found the most suitable mode for this site conditions by jumping steps and jumping holes, small amount and multiple times, and night construction. Finally, with appropriate quality management and risk monitoring, the highway shoulder ground improvement is completed.

As a result of excellent ground improvement, soil strength has been significantly improved. The removal of foundation piles can reduce the excavation of vertical working Wells. The adjacent foundation piles are knocked out by lateral excavation. The excavation of one working well was reduced, and the removal of foundation piles was completed within 7 months.

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