EXAMPLE OF APPLICATION OF MECHANIZED DIGGING WORK METHOD FOR COLLECTOR WELL

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ABSTRACT

Conventionally, collector wells have been largely dug by manual labor and the workers have been likely to be exposed to breakdown of underground walls, generation of toxic gas, lack of oxygen, and the like. There has been another problem related to construction efficiency; since the tools such as breakers are used, a excavation speed drops extremely if a natural ground gets harder. Considering the above-mentioned background, this time, we have introduced a mechanized excavation method to dig the collector wells in order to realize labor-saving by mechanized construction and improvement of safety such as mechanized excavation by remote-control robot, carrying out of excavated muck by vacuum, releasing of workers from a deteriorated work environment. In this thesis, we would like to present the cases in which digging work robots were introduced in collector well construction which was one of anti-landslide construction work and report construction conditions, track record, improvements in the field, and future prospect.

1. INTRODUCTION

Compared with digging work employed for other applications such as foundation piles, excavation of the collector wells is more difficult to mechanize. One of factors is a difference in construction conditions. The collector wells are excavated in the mountains and scattered with spacing of 50 m or more. Generally, therefore, multiple collector wells are not excavated simultaneously and roads are not specially constructed to carry in large heavy machines.

The second factor is a structural difference. In addition to using reinforcing rings and vertical stiffeners as well as liner plates to prevent a landslide, elevation steps which will be used even after completion must be installed in parallel with excavation, unlike a temporary elevation facility used for foundation pile work, thus limiting the underground work spaces and preventing use of a large excavator.

Based on the construction data where the mechanized digging work method was applied to collector well construction whose mechanization had been considered difficult, we would like to mention in the following the requirements for mechanization of collector well construction and the effects which may be brought about by its introduction.

2. OUTLINE OF DIGGING WORK ROBOT

The digging work robot is a construction machine mainly designed for safety and labor-saving. A single operator remotely controls it on a step about 4 to 5 m above the work floor and can carry out excavation and earth-moving work which has been done by 4 workers(when a digging diameter is 3.5 m) so far.

One robot can handle a series of work ranging from excavation to carrying out of muck. Table 1 shows the specifications of the robot. The robot is light-weight and compact, weighing only 2 tons. It has a swiveling body on the crawler with sediment cutters and buckets(Fig. 1) or vacuums(Fig. 2) installed before and after the swiveling body. An applicable robot excavation range is 3.0 to 6 m in a digging diameter and 20 m in an excavation depth. The robot can excavate the ordinary ground to the soft rocks having unconfined compression strength of up to 10 MPa.

Table 1 Specification of the Robot

Main Dimensions	Overall Length 1,750mm Overall Width 1,190mm Overall Height 2,250mm	
excauation	Type	Cutter Drum (type)
	Motor	5.5kW 4P
Travel equipwont	Travel Type	crawler
	Travel Speed	0.17m/s
	Ground Pressure	0.04MPa
	motor	Hydraulic Motor
Loader	type	Bucket
	Bucket Capacity	0.025 m^3
Hydraulic Pump	Motor	7.5kW 4P
	Delivery Vol.	0.4×10^{-3} m^3/s
	Pressure	13.7~18.6MPa
Control Method	Sequencial Control	
	Out put	13kW
	Operating Weight	2,130kg

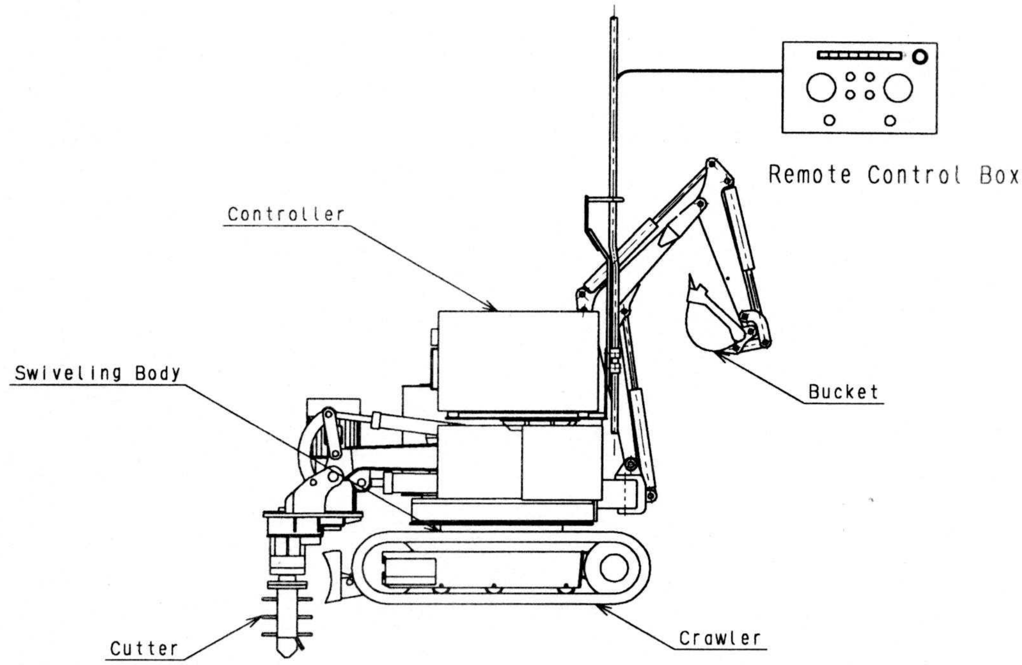

Fig.1 Digging Work Robot (Bucket Type)

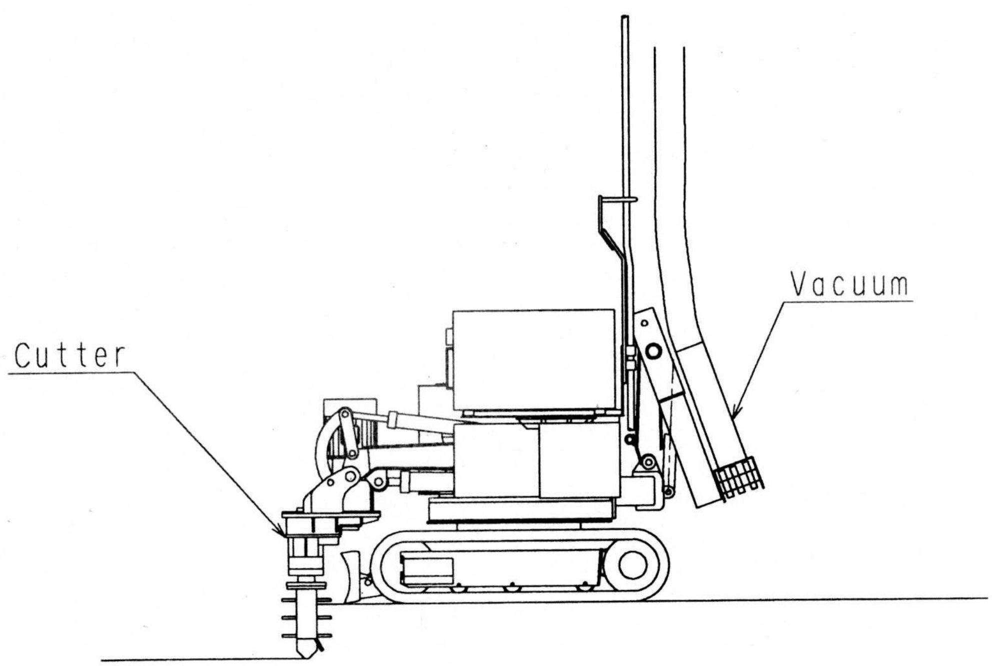

Fig.2 Digging Work Robot (Vacuum Type)

3. COLLECTOR WELL CONSTRUCTION

3.1 Current Circumstances of Collector Well Construction and Its Problems

Collector well construction is to excavate a well in order to get rid of underground water too deep to collect it by horizontal bowling work. Its construction method is similar to the digging work method. Because of conventional peculiarity of a landslide-apt zone, we have greatly depended on manual labor to prevent a landslide in the collector well. With four workers forming one group, they excavate the ground by about 0.7 m and load the excavated earth. Then they assemble 7 liner plates for each ring(0.5 m). They repeat these work processes. The workers are always forced to stay and work in a narrow pit for a long period of time. Furthermore, underground work is very dangerous, exposing them to a breakdown of pit walls at excavation time(generation of boiling), lack of oxygen due to generation of toxic gases, and the like. Nevertheless, the excavation work conditions have not been greatly improved, leaving the following problems desired to be solved.

(1) Releasing of the workers from the deteriorated work environment

(2) Technical development to improve safety and construction capabilities

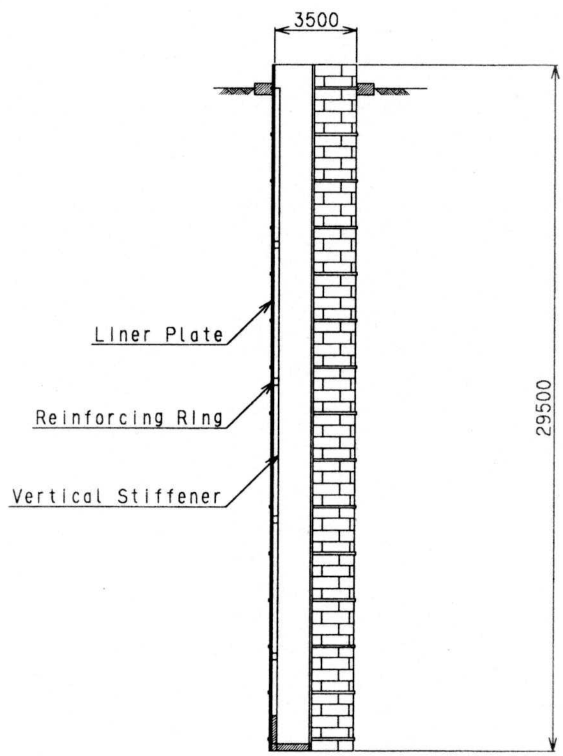

Fig.3 Structure of the Collector Well

3.2 Outline of Construction

Fig. 3 shows structure of the collector well, Fig.4 shows robot excavation system configuration. Photo 1 shows an entire view of temporary construction, and Photo 2 shows excavation circumstances, respectively. The collector well was 3.5 m in its diameter and 29.5 m deep. The liner plates, reinforcing rings, and vertical stiffeners were used to prevent a landslide. A vacuum system was employed to move the excavated earth.

The robot was moved to an excavating position by a crane and excavated two layers(60 cm), 30 cm deep each, through remote control. The excavated muck was sucked and carried through an earth moving hose(150 mm in a diameter) by an air current generated by the Root's blower vacuum pump on the ground. Mixed sediment was separated into an air current and sediment in the earth moving machine on the ground, drops automatically by gravity, and accumulate in a hopper. Then, it was loaded onto a dump truck by a belt conveyor and carried out of the field. After excavation was completed, the robot was lifted by the crane, and the liner plates, reinforcing rings, vertical stiffeners, elevation steps, and the like were assembled. These processes were repeated every time the earth was excavated by 50 cm, which was one excavation cycle.

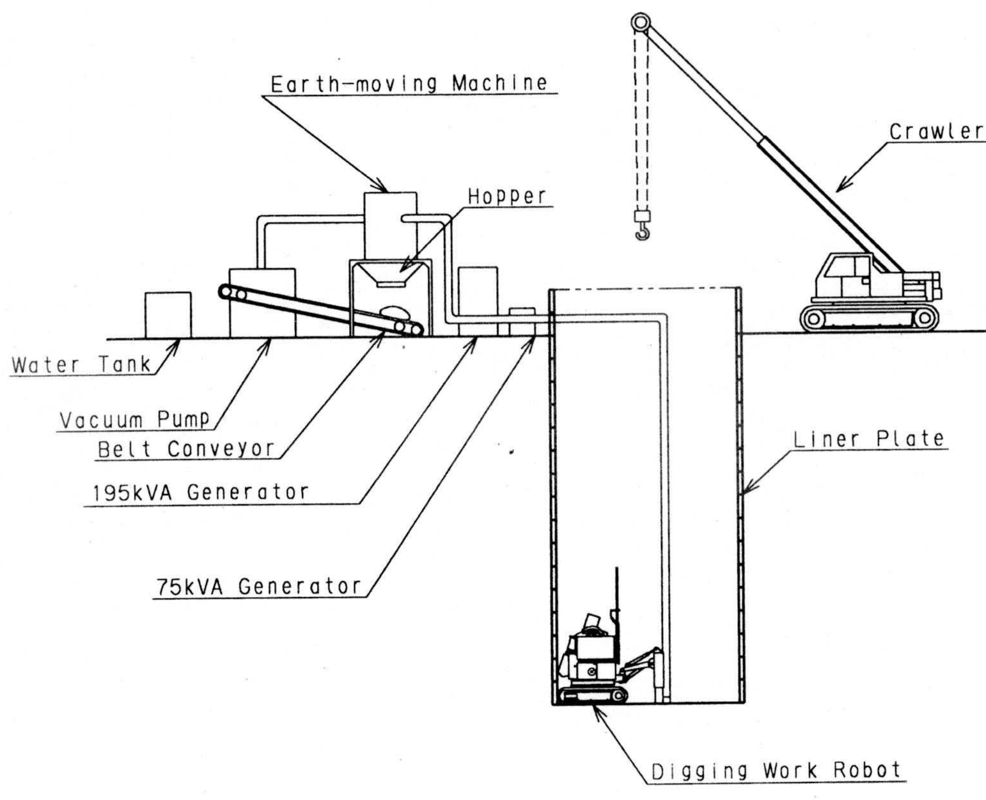

Fig.4 Robot Excavation System Configration

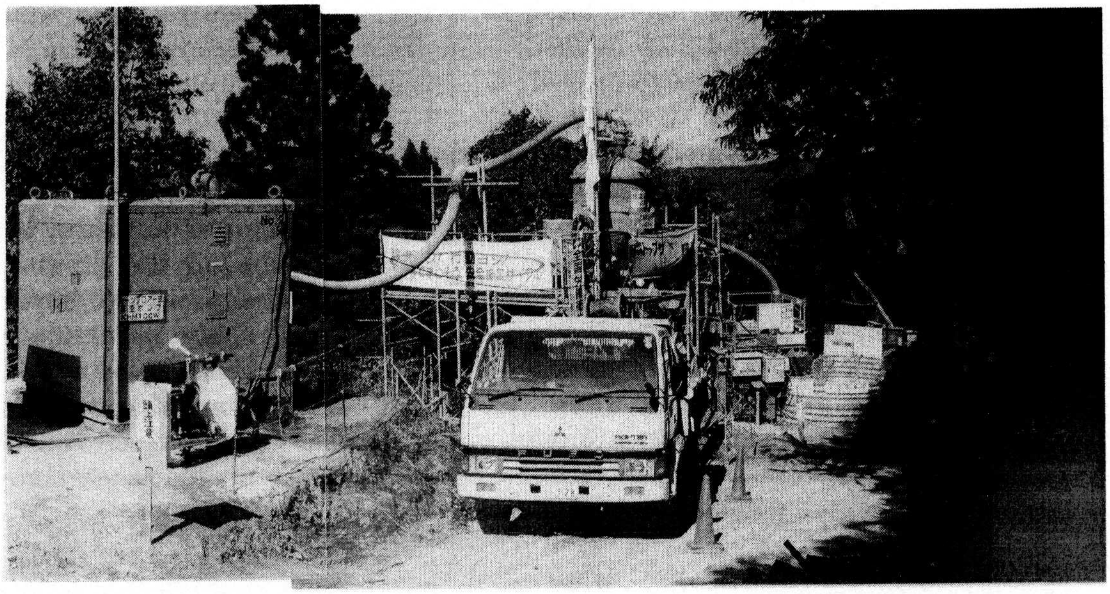

Photo 1　Entire View of Temporary Construction

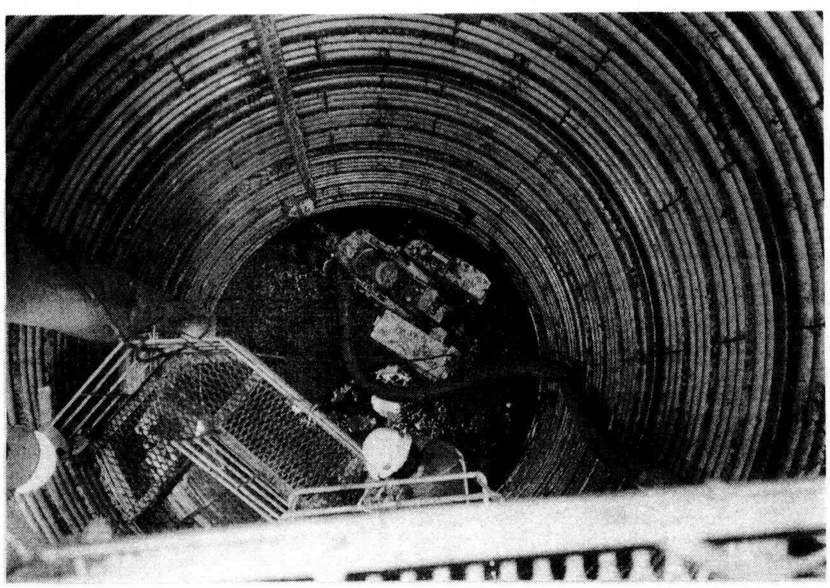

Photo 2　Excavation Circumstances

3.3 Soil Requirements

The soil of the excavated collector well consists of high-wind sandstone 13.8 m deep from the ground level. Deeper than 13.8 m, it was a sandstone layer. Table 2 shows the results of a soil investigations at each depth.

4. OUTLINE OF CONSTRUCTION INVESTIGATION

4.1 Investigation Report

This investigation was conducted emphasizing the following points.

1) Labor-saving Whether it is possible for a single operator to excavate.
2) Constructibility Construction capabilities of the digging work robot and earth-moving capabilities of the vacuum(excavation applicable depth).
3) Safety Whether safety of the workers has been improved.

Table 2 Result of Soil Investigations

	W – 21 GL – 5.0	W – 21 GL – 12.0	W – 21 GL – 19.0	W – 21 GL – 23.5
unit weight of soil constituents ρs g/c㎥	2.650	2.574	2.642	2.606
natural water content in per cent of dry weight ωn%	38.6	34.9	25.8	20.7
gravel	0.5	60.1	31.1	0
sand	90.1	20.2	42.8	66.3
silt	5.9	13.9	10.6	20.7
clayey soil	3.5	5.8	15.5	13
uniformity coefficient Uc	3.58	189.5		68.18
curvature coefficient Uc'	1.16	0.585		13.60
maximum grain dimater	1.76	19.1	19.1	2.00
grouping	sand	gravel	sandysoil	sandy soil
symbol	S	GF	SF	SF

4.2 Results of Construction

(1) Operation of the robot does not require any special legal qualification. The operator could master it after about 2-day training and one robot could excavate all the sections. Compared with the conventional construction method, it required less labor.

(2) Unconfined compression strength of the sandstone layer was 3 to 5 MPa and it could be excavated by the cutter without any problem.

(3) Since earth-moving efficiency by the vacuum dropped extremely at an excavation depth of about 25 m, it seems that the maximum excavation depth is about 20 m.

(4) Table 3 shows the results of the construction investigation. In conventional collector well construction, a standard excavation rate by machine(clamshell or mini-backhoe) combined with manual labor is about 0.4 m/day (when a digging diameter is 3.5 m) for geological condition like soft rocks. Similar excavation capabilities were exhibited in this construction as well.

Table 3 Result of Investigation

Soil Type		high − wide sandstone	Sand Stone
Length (m)		8.3	15.2
excavation	Preparation	880	2102
	Excavation	4760	12515
	Travel		200
	put in ordor	440	485
	Subtotal	6080	15302
Assemble	Preparation	150	407
	Linor Plate	660	757
	Reinforcing Ring	60	154
	Ladder, Landing	300	600
	Setting of Vertical Stiffener	280	531
	put in order	60	222
	Subtotal	1510	2671
Others		1540	1943
Total		9130	19916
Days of Work		19.0	41.5
Average (m/day)		0.44	0.37

(5) With the vacuum earth-moving system, sediment sticks inside a vacuum hose and cause a blockade, if the soil of the excavated earth is clayey and silty earth with high water content.

(6) Typical accidents in collector well construction usually take place during underground excavation work such as an injury of the worker by a flying or dropping object, generation of toxic gas, lack of oxygen. Therefore, we may say that this unmanned digging method has improved safety greatly.

4.3 Countermeasure for Blockade of Vacuum System

In the initial stages of construction work, the vacuum hose was often blocked due to adhesion of the excavated earth inside it. As it is clear from the soil investigation results of the excavated muck, the soil at a point of the ground level minus 5.0 m was 90.1 % sand, classified as sand soil, 5.9 % silt, 3.5 % clay, and natural water content was as high as 38.6 %, showing that the major cause was a soil condition with high viscosity.

Blocked areas were the rotary feeder of the robot which sucked in the excavated earth, bent part and joint of the vacuum hose, and inside the tank of the earth-moving machine. The following actions were taken to troubleshoot in the construction field.

1) Improvement of the soil of the carried earth by using the high-molecular moisture absorbent

A high-molecular moisture absorbent was used to troubleshoot a blockade of the earth-carrying route. A mixture of sodium acrylate was selected as an additive, because it had high gel strength, was expected to have a bearing effect between soil particles, flowed easily, did not lose moisture due to a reduced pressure even if it is hardened, and was harmless to the environment. It was sprinkled 0.7 kg/m^3 based on an used amount and the field test results on the blockade inside the vacuum hose. It was directly sprinkled over the natural ground and stirred with the earth by the cutter during excavation.

2) Improvement of the suction nozzle

The rotary feeder was also blocked because the excavated earth was viscous. Prior to improvement, the digging work robot had the rotary feeder installed opposed to the excavating cutter drum as shown in Fig. 5. To solve the blockade of the feeder and other sections, however, it was necessary to carry the earth improved by the high-molecular moisture absorbent in a short time. The nozzle feeder shown in Photo 3 was attached expansible to the side of the cutter drum so that the excavated earth could be immediately carried and discharged after excavation.

As a result of the above-mentioned actions, a blockade of the earth-carrying route has been reduced and a complete blockade can be now avoided by periodic cleaning.

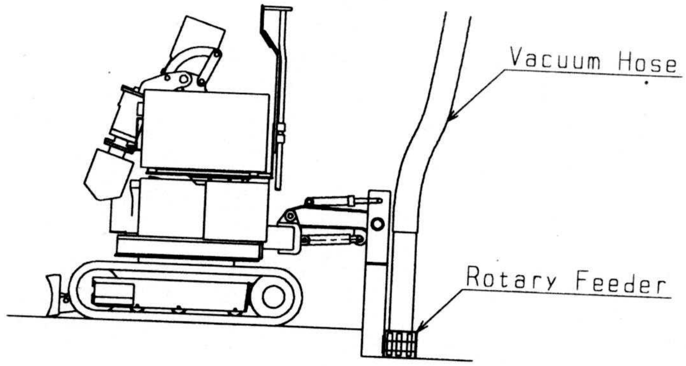

Fig.5 Rotary Feeder

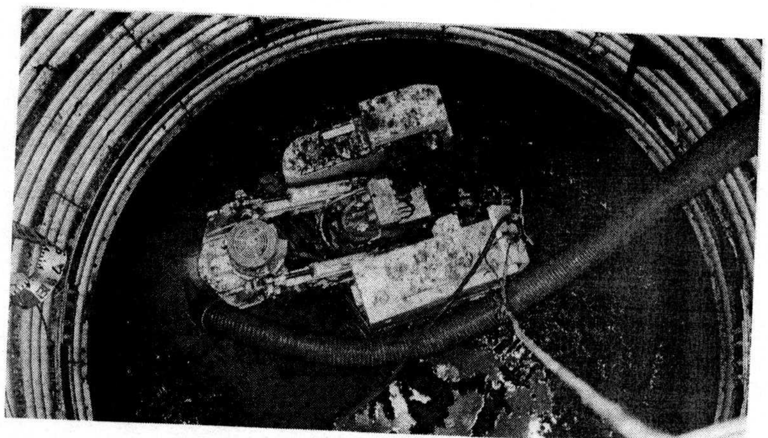

Photo 3 Nozzle Feeder

5. CONCLUSION

As a result of applying the mechanized digging work technologies to the anti-landslide collector well construction, we could verify that they were consecutively available for in the processes ranging from excavation to carry-out. However, the well frame still had to be assembled manually, 7 liner plates were used for each ring, and as many as 140 assembly bolts were used for every 1 m depth, leaving efficient assembly of the well frame in the pit to be desired. That is, improvement of the well frame material is one of the problems to be reviewed in the future.

In this test construction, it was found out that we had to take an action to prevent a blockade of the vacuum hose when the soil of the excavated ground was viscous. Furthermore, we believe that this construction method would be more widely used, if we develop the excavation technologies of the digging work robot available for soft rocks(5MPa) to medium hard rocks, and the full automation technologies for excavation to landslide preventive assembly work.