INSTALLATION OF DUAL 1000MM HDPE FORCE MAINS UNDER HONOLULU HARBOR BY HORIZONTAL DIRECTIONAL DRILLING

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Title: Microtunneling Under a River through Mixed Ground Conditions

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Abstract: This recently completed 440-meter river crossing in Korea advance through 65 meters of rock not exceeding UCS 1200 kgf/cm^2, 130 meters of soft clay, silt, and sand not exceeding N=30, and 220 meters in rock ranging between UCS 400 – 600 kgf/cm^2. The river crossing, utilizing 1778-mm OD x 19-mm Wall x 6000-mm steel casing pipe without intermediate jacking stations, was part of a 7 kilometer LNG transmission line.

The drive was completed without changing disk cutters or using the airlock. The airlock was incorporated into the machine design because of the long drive.

Microtunneling Under a River through Mixed Ground Conditions

This 7-kilometer long pipeline project was required to supply Liquefied Natural Gas (LNG) to a POSCO steel mill located in Korea. The general contractor, Samsung Corporation, and its subcontractor, Kyung Dong Co., completed the 440-meter (1443-foot) crossing of the Kwang Yang River. This paper will discuss only the Kwang Yang River crossing as seen in Picture 1.

Picture 1. The Kwang Yang River with the proposed crossing highlighted in red.

The jacking pipe used on this project was steel casing. The casing was 1778-mm (70-inch) OD x 19-mm (0.75-inch) wall x 6000-mm (19.7-foot) long steel casing pipe. The steel casing pipe was joined with full penetration butt welds. The drive was completed with out the installation of intermediate jacking stations. When completed, the final gas pipe was installed inside the jacked steel casing.

The project profile along the projected alignment is summarized in Figure 1. The first 65 meters (213 feet) of the drive was through rock ranging in strength up to UCS 1200 kgf/cm^2 (17,000

psi). The machine's speed of excavation ranged between 7 and 20-mm (0.27 and 0.79 inches) per minute. The machine then progressed though the soft ground for 135 meters (443 feet). This ground consisted of silt or clay and sand and full 17 meters (55 feet) of hydrostatic head from the river above. The machine progressed through this ground between 80 and 180-mm (3 and 7 inches) per minute. The last 240 meters (787 feet) was in rock with a strength ranging between UCS 400 and 600 kgf/cm^2 (5,700 and 8,500 psi). The machine progress ranged between 10 and 25-mm (0.4 and 1.0 inches) per minute.

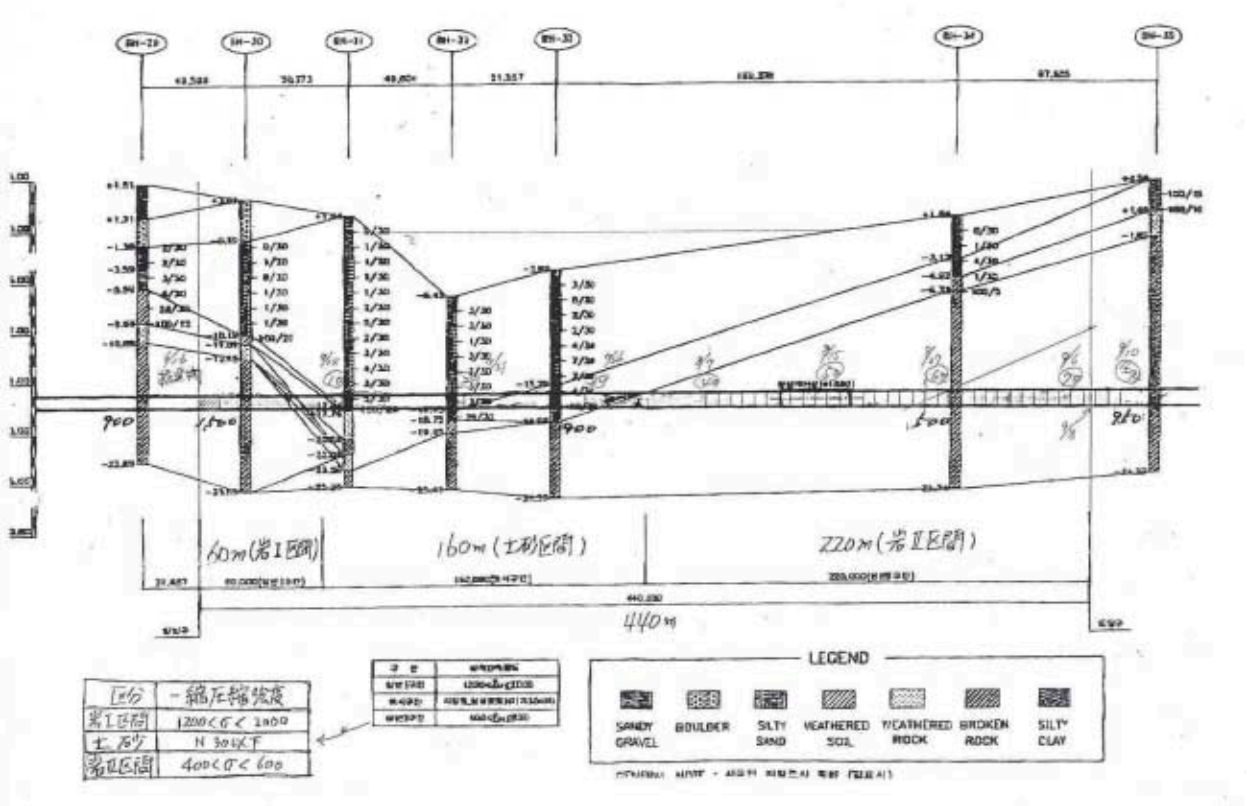


Figure 1. Project profile with production notes.

The first transition from the rock into the soft ground was a steeply dipping decline. The machine started to fall into the soft ground. Steering provided the required correction and the machine returned to near line and grade. The second transition was a slow rising incline. The soft ground was above the much harder rock formation. The machine was steered down and was below grade before hitting the incline.

The jacking forces remained low through the first two soil types. The jacking forces increased in the third soil type because the rock was degraded and was capable of blocking. The actual soils contained cobbles and boulders with a sand and clay matrix.

The actual jacking reports are summarized in Figures 2A and 2B which has three graphs included. On all graphs, the horizontal axis is the pipe joint number, or the distance jacked. The

top graph is the jacking force in metric tons. The middle graph is the steering direction and the pitch of the machine. The top of the graph is UP or LEFT and the bottom is DOWN or RIGHT. The vertical axis is measured in millimeters. Each line represents 10-mm, for a total steering of 40-mm. Zero is the middle line. The bottom graph scale is the actual line and grade of the machine as installed. The vertical axis in measured in millimeters and is of the same scale as the middle graph. The total on the graph ranges from 70-mm on the top to 150-mm on the bottom. Zero is the eighth line from the top.

Figure 2A. Actual jacking and steering record.

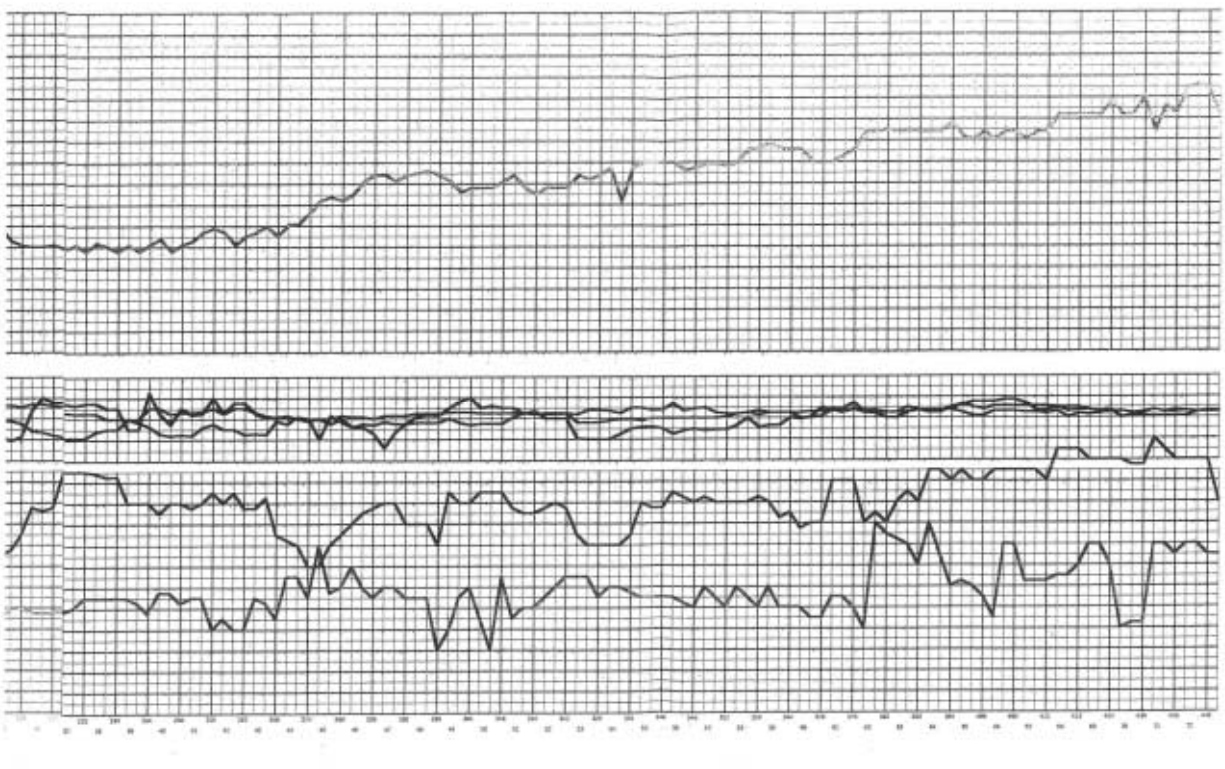


Figure 2B. Continued.

The TCS 1500 microtunneling machine, with specifications summarized in Table 1, was selected for this project. The microtunneling machine had several unique features, including;

Compressed airlock
Access door to the cutter wheel
Grippers
Retractable head
Data Recording
Small Unclemole Crusher

The most visible feature is that the machine had several trailing cans in order to accommodate the airlock. The airlock was required in case the back-loaded disk cutters required replacement during the river crossing. The airlock was never used and the cutters never replaced.

The access door to the cutter wheel is located at the 10 o'clock to 2 o'clock position above the center drive shaft. The disk cutters are back-loaded with lifting points pre-positioned to assist in lifting and replacing the cutters.

Table 1. TCS machine specification.

Crusher Head			**CRUSHER**			**STEERING JACKS**	
Crusher Torque	10,500	60 Hz	Crusher Type	Cone Crusher		Thrust Capacity	100 Tonf x 4 nos.
Revolution Speed (RPM)	10.0	60 Hz	Eccentric Rotation (RPM)	0~13.2	60 Hz	Reference	By Laser Beam
Button Bits Roller Bits	7 no. 2 no.		Power	440 V	Power	Steering Angle	UP or DOWN 1.8
				55 kW-4P-1 no.			LEFT or RIGHT 2.2
Power	440 V	60 Hz	Crushable Cobble Diameter (mm)	100		Hydraulic Power	Motor: 3.7 kW-4P-1no. Pump: Gear Type Pressure: 210 kgf/cm^2
	55 kW-4P-1 no.						
Allowable Earth Pressure	60	(tf/M^2)	Crushed Cobble Diameter (mm)	40 or Less			
Unclemole Super			UCS (kgf/cm^2)	2000		**GRIPPER JACKS**	
Model	TCS	1500				Capacity	37 Tonf x 2 nos.
Outside Diameter	1800	mm				Hydraulic Power	Motor: 3.7 kW-4P-1no. Pump: Gear Type Pressure: 100 kgf/cm^2
Length	5850	mm					
Weight	20	Tons					

Grippers were located on the machine to prevent rolling while the machine tunneled through a full face of rock. The over cut on a rock machine prevents skin friction. On a typical microtunneling machine, the ground squeeze provides sufficient friction to prevent the machine from rolling. If the machine were to roll, the momentum caused by the RPM of the cutter wheel could cause the machine to rotate several times before the power could be shut off. This would cause all of the trailing utilities to twist together and possibly break.

Before the disk cutters can be removed, the cutter wheel must be withdrawn a distance sufficient enough that new cutters can be installed. New cutters have a larger outside diameter than worn cutters; there fore the cutter wheel must be retracted from the face to allow new cutters to be installed. The grippers are extended and the steering jacks fully extended while cutting. When the steering cylinders are fully extended, the head is then retrieved with the steering cylinders. The head can be jacked free of the trailing pipe string if more room is required. This entire procedure is for safe conditions only and is not to be performed in highly permeable ground in the presence of ground water.

The machine was equipped with automatic data recording. The data-recording target is vertically at the centerline of the machine. The horizontal axis of the data-recording target is to the right of the machine centerline. The conventional laser target is at the vertical and horizontal centerline of the tunnel. The machine controls included steering using the conventional laser, TV camera, and TV monitor.

A small Unclemole microtunneling machine is installed behind the cutter wheel and at the slurry intake. The Unclemole is set to crush all the material that is oversized for transportation through the slurry lines. Oversized material typically causes premature slurry pump failure, slurry line wear out or plugs the slurry lines.

The project was completed successfully without use of the airlock, without replacement of the cutters, and any machine delays. The microtunneling machine, following completion of the project, is shown in Picture 2. The tunnel was installed very close to line and grade, 10-mm low and 10-mm left of the designed tunnel centerline.

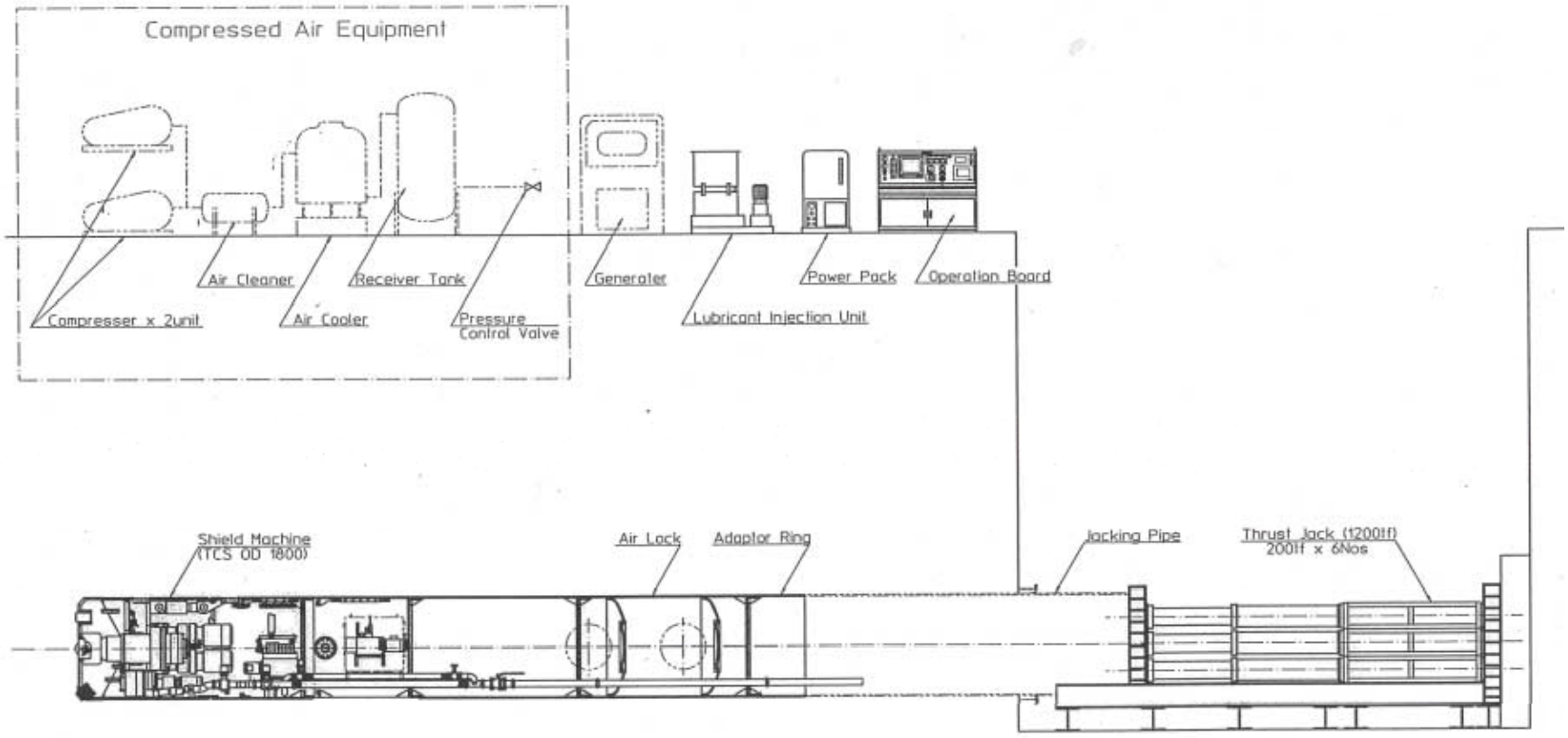
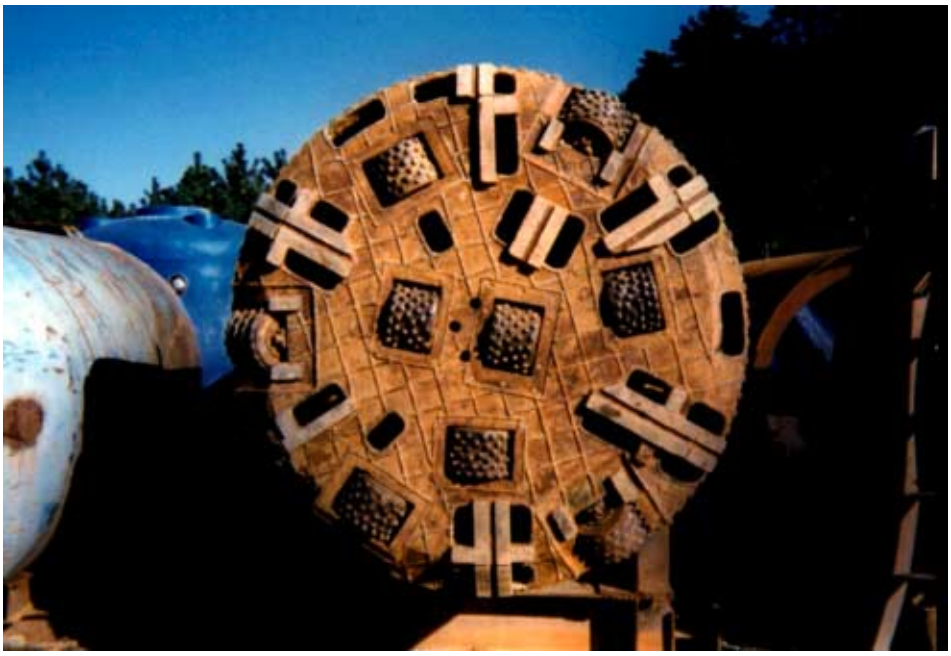


Figure 3. TCS machine and operating system profile.



Picture 2. TCS machine following drive.