MONITORING THE IMPACT OF SOIL IMPROVEMENT FOR THE LARGE DIAMETER SHIELD TUNNEL PROJECT ON SURROUNDING STRUCTURES

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1. INTRODUCTION

Soil improvement was conducted in order to prevent the leakage of pressurized water and to ensure the stability of ground at launching shaft section of 13.5 m diameter Shield Tunneling project. Nevertheless, the stability of shaft and existing underground sewer pipe and water supply pipe had to take into account. In this paper, a series of measurements was carried out to ensure the stability of shaft and underground sewer and water supply pipe due to soil improvement by double-packer grouting method.

2. SOIL IMPROVEMENT

The target of soil improvement layers with maximum depth of GL-45 m were consist of Alluvial Clay (Ac) N_5, Alluvial Sand (As) N_{16}, Mudstone (Slm) N_{100}, and Alternation of Diluvial Sand (Sls) N_{100}. Therefore, jet grouting method was not applicable for soil with N_{100} and also double strainer grouting method was not applicable for soil deeper than GL-25 m. Double-packer grouting method was selected due to that reasons.

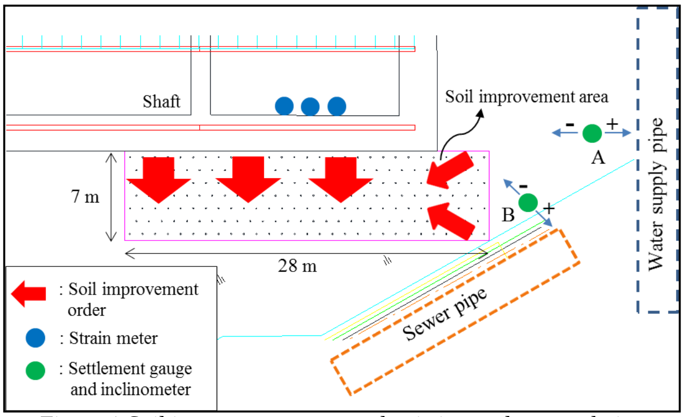

Figure 1 Soil improvement area and existing underground pipe

Figure 1 present soil improvement area and its surrounding underground water pipes. Total 7 m x 28 m range of soil improvement was conducted with injection rate about 6～10ℓ /min in order to maintain the stability of shaft and water pipes. Furthermore, soil improvement was conducted from injection hole in shaft side and water pipes side direction to secure its first. Soil improvement was conducted with three steps sleeve grout filling, primary grouting of cement-bentonite, and secondary grouting of modified liquid-phase silicate. Designed quantities of it were 108 m^3 of sleeve grout, 297 m^3 of primary grout, and 1397 m^3 of secondary grout. Furthermore, target coefficient of permeability $k=1x10^{-4}$ cm/s was determined. In order to ensure the effectiveness of soil improvement, designed quantity of grouting materials and coefficient of permeability has to be satisfied. Design quantity was used as parameter to ensure that grout materials displace the groundwater within soil grains. The target coefficient of permeability was used as parameter to measure the effectiveness of cut-off wall.

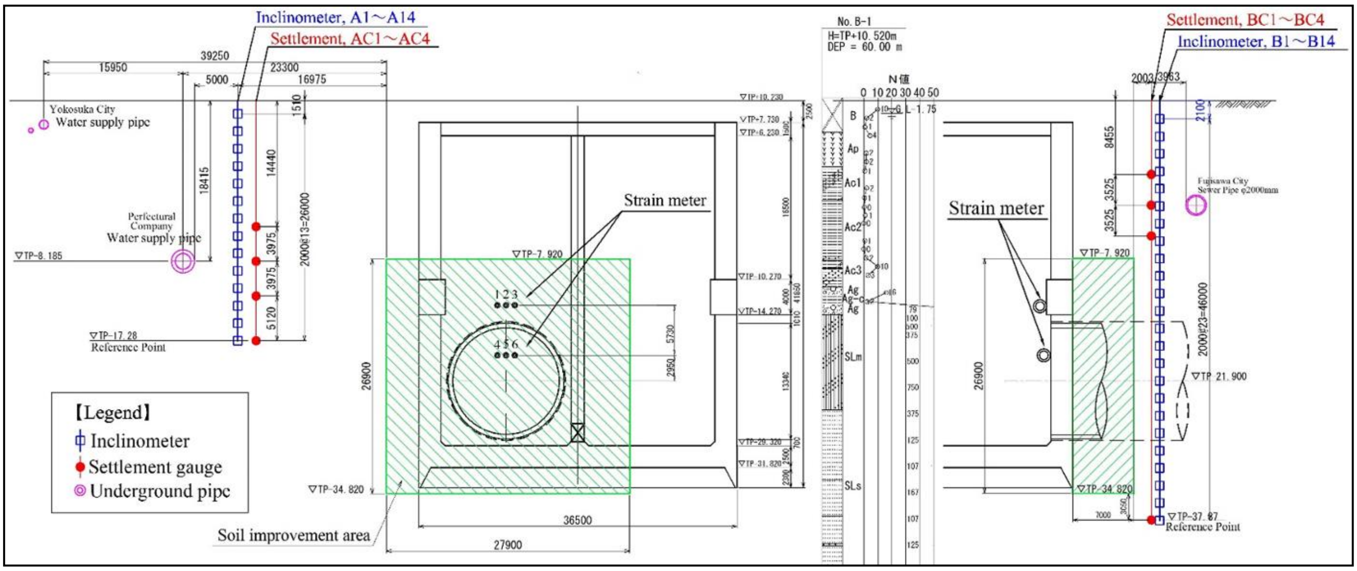

Figure 2 Measurement point and underground pipe location

3. MEASUREMENT

The injection of grout materials generate force into shaft and produce tensile strain on the inner wall of the shaft. It predicted that the largest tensile strain is located in the center of the framing beam. Moreover, the replacement of void within soil grain into grout material was expected to trigger ground displacement surrounding grouting area. This

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behaviors have to be monitored to overcome the occurrence of deformation on shaft and installation pipes. Figure 2 present the details of installed measurements inside shaft and existing underground pipes. Total 6 sets of strain meter were installed in entrance wall, 2 sets of settlement gauge and 2 sets of inclinometer were installed nearby underground water pipes. These measurements were performed automatically every 5 minute to monitor the effects of soil improvement by double-packer grouting method. Measurement was conducted alongside the soil improvement process.

4. RESULT AND DISCUSSION

Table 1 shows control value of each measurement that used as judgement criteria to monitor the wall displacement. Strain increment were kept bellow 5 μ st per 5 minute in order to suppress strain under the control value. Displacement increment also kept bellow 0.3 mm per 5 minute in order to restrain the damage of water pipe. Furthermore, in order to control not only strain increment but also horizontal and vertical displacement, the adjustment of discharge rate and number of injection was applied.

Table 1 Control value of measurement

Measurement Point	First control value	Second control value	Limit control value
Strain 1-3 (TP-13.27)	217.8 μ st	290.4 μ st	363.0 μ st
Strain 4-6 (TP-19.00)	231.0 μ st	308.0 μ st	385.0 μ st
Displacement	10 mm	16 mm	20 mm

Figure 3 shows the relationship between strain and date of measurement. About 300 m^3 of grout materials was injected at the primary grouting and strain increase about 80 μ st. The strain graph showed that regardless of injection time, strain value keep increasing in general. It indicated that elastic region of soil was exceeded and cause soil deforms permanently. The outcome behavior of primary grout has to take into account and enhanced caution of secondary grout is necessary.

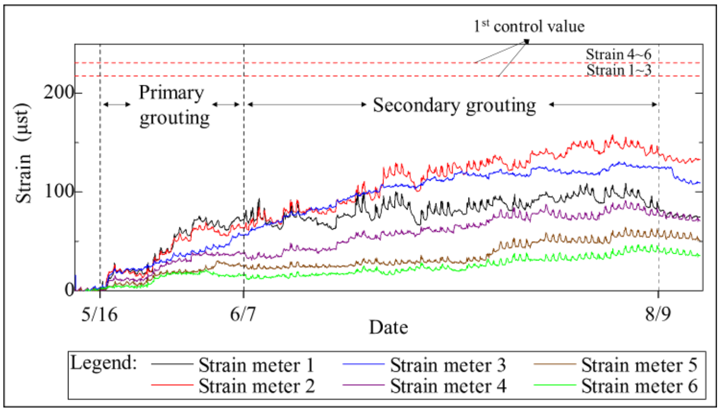

Figure 3 Strain of the shaft

Horizontal displacement in A point (Figure 4) of soil kept around 1 mm at the primary grouting. Although, B point (Figure 5) that located adjacent to injection area were more fluctuate than A point, displacement of soil also kept around 1~2 mm at the primary grouting. Horizontal displacements of both measurements begin to increase at the secondary grouting after about 700 m^3 of grout materials was injected. It indicated that grout materials start to displace the groundwater within soil grains away from shaft and generate force towards the underground sewer and water supply pipes.

Vertical displacement at A and B point were not increasing about 1 mm in second grouting after about 700 m^3 of grout materials was injected. It indicated that grout materials slightly affect the uplift of soil near the construction area.

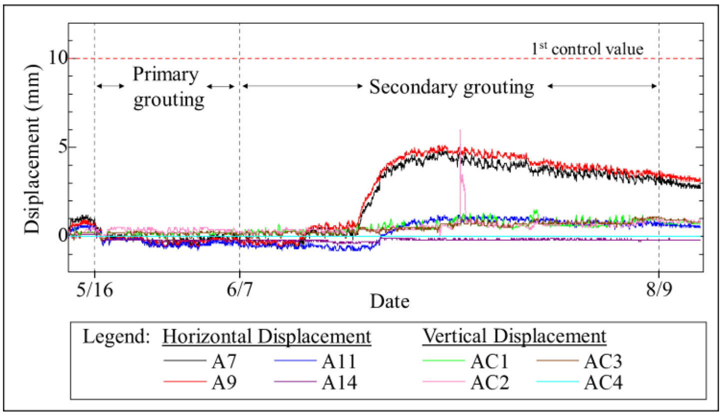

Figure 4 Displacement in A

5. CONCLUSSIONS

There are several features that have to take into account in order to ensure the effectiveness of soil improvement while maintain the stability of existing underground pipes. The amount of designed grout materials were about 1800 m^3 and about 1850 m^3 of grout materials were injected. In-situ permeability test were conducted in 3 different layer of soil. In-situ permeability coefficient of Alluvial Sand (As) was 7.84×10^{-6} cm/s, Mudstone (Slm) was 3.77×10^{-5} cm/s, and Alternation of Diluvial Sand (Sls) was 2.51×10^{-5} cm/s that smaller than initial target of permeability coefficient. The results were indicated that the effectiveness of soil improvement was obtainable.

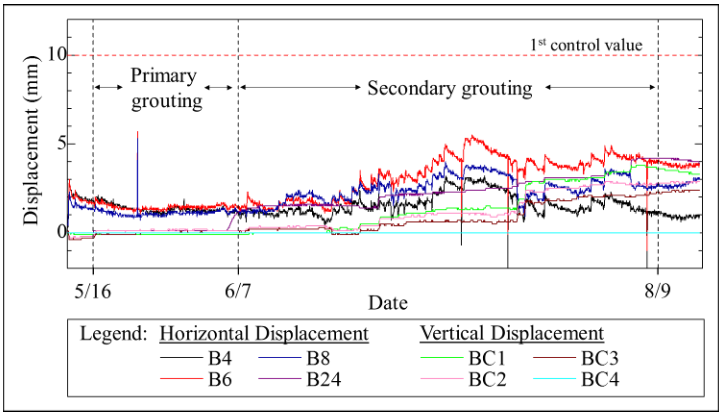

Figure 5 Displacement in B

The analysis of measurements shown that strain in the center of shaft (strain meter 2) had the largest strain value due to large tensile stress applied in center of framing beam. Horizontal displacements of soil reach to 5 mm due to the force of grout materials that displace void material within soil. Although, the measurement during construction shown the soil movements, it was prevent the ground deformation that cause the damage of shaft and existing pipes.