ANALYSIS OF EMBANKMENT ON SOFT CLAY IMPROVED BY VERTICAL DRAIN

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1. INTRODUCTION

In order to maintain the ground stability during and after embankment construction, the soft ground is improved by using such kind of improvement methods as DJM, CCP and vertical drain etc. This paper is to analyze the improvement effect of vertical drain taking into consideration of a practical construction stage of embankment on Ariake clay ground. Fig.1 shows the geological profile and soil properties at Shiraishi(right bank of Rokkaku river) for analyzing. The top layer, the Ariake clay, is about 18m thick. Below the clay layer is a sand layer with N values of 5 to 31. The improvement area and the distribution of the vertical drain are also shown in Fig.1. The load-time relationship is plotted in Fig.2(a). The soil properties during different stages were investigated from the check bores(as shown in Fig.3). This paper mainly describes the mobilized shear strength and stability of improved soft clay.

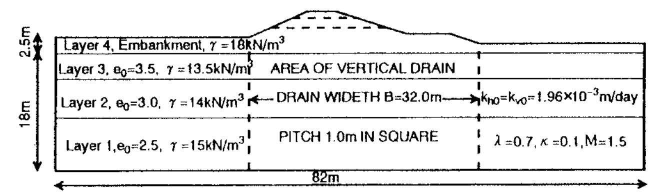

Fig.1. Embankment section and geological profile

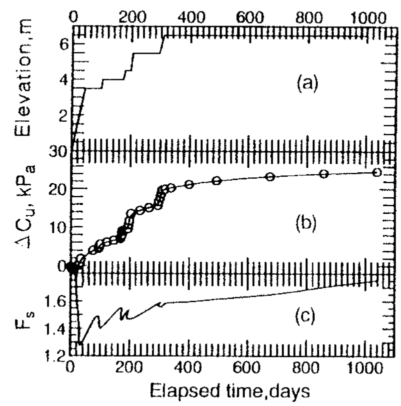

Fig.2. Loading stages, increment of strength and factor of safety

2. FEM ANALYSIS

The constitutive model of soft clay used in the analysis is the Modified Cam-clay. The model of the embankment material is linear elastic. The FEM analytical pattern of the ground with 18m height and 82m width is shown in Fig.1. The soil properties of soft ground are divided into 3 layers. The initial permeability of improved soft ground is considered to be 2~4 times of unimproved ground. The permeability is also considered to vary with the void ratio. In the analysis, a practical construction stage was simulated, in which the loading was imposed in 59 steps and the consolidation was considered 25 time steps.

Excess pore pressure: Fig.4 shows the calculated excess pore pressure under embankment centerline at depth 2m with different permeability. At the first stage of loading(H≤3.5m), due to rapid loading, excess pore pressures are little greater than vertical stress increments. After two month consolidation, excess pore pressures of improved ground dissipate gradually. However, the excess pore pressures of unimproved ground go down slowly. Without vertical

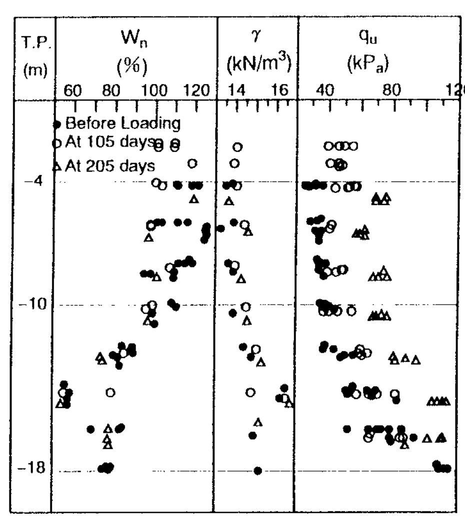

Fig.3. The change of soil properties during construction

drain, the excess pore pressure exceeds the overburden pressure. With the increasing of embankment height, excess pore pressure increases very rapidly and when the height of embankment reaches to 4 meters, the soft ground below the embankment yields. It is manifested that 2 or 3 months consolidation time for each stage load on unimproved ground is inadequate. With the vertical drain, the highest excess pore pressure is 55kP$_a$ which is about 90% of vertical consolidation pressure. After two years, only about 4% of excess pore pressure remains. Therefore, it is confirmed that the vertical drain is very effective.

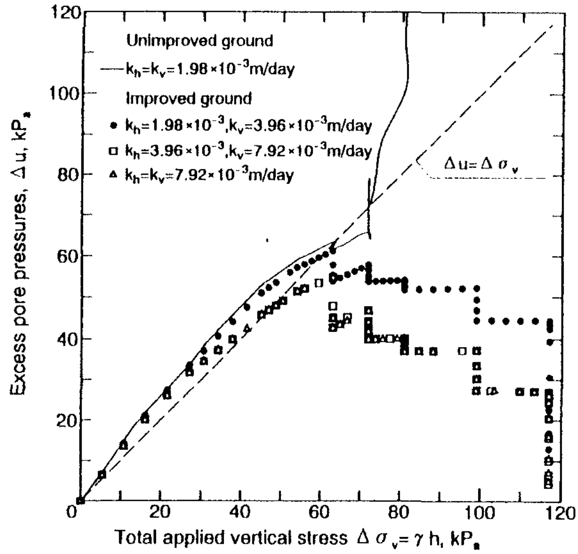

Fig.4 Pore pressures under the centerline of embankment during stage-construction

Stability during and after staged construction: The mobilized undrained shear strength is calculated by the empirical equation (Ladd,1991): $\Delta C_u=\sigma'_{vc}S(OCR)^m$. Fig.2(b) shows the computed increment of undrained shear strength under centerline at depth of 2m. Due to the improvement by vertical drain, the consolidation progresses fast and shear strength is increasing rapidly. By the end of construction, about 80% of ΔC_u is obtained. The other 20% of ΔC_u is gained within 2 years after construction. Fig. 5 shows the variation of uniaxial compression strength under centerline of embankment. During construction, at the top and bottom, the increase of strength is faster than in the middle point of clay layer and the strength of middle layer increases gradually.

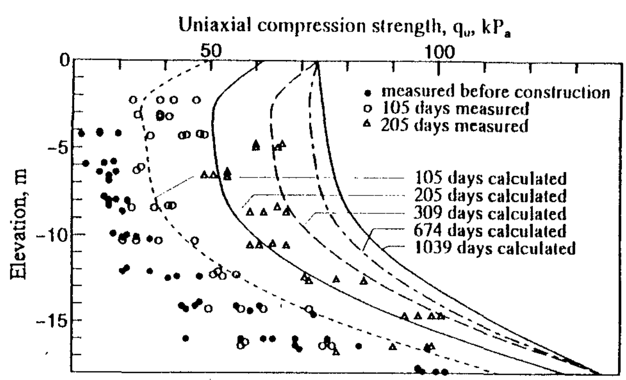

Fig.5 Compression strength of clay during construction

Fig.2(c) shows the factor of safety. F_s decreases during loading and increases with consolidation. Within two years after the construction, F_s can increase about 0.2.

3. CONCLUSIONS

This study discussed the increase of undrained shear strength of Ariake clay improved by vertical drain under the embankment constructed stage by stage. By the FEM analysis and in-situ measured data, it is confirmed that the vertical drain used to improve the clay ground under embankment is very effective. Within 2 years after construction, the increment of shear strength is about 20% of the total increment of shear strength and the factor of safety increases about 0.2.

REFERENCES Ladd, C.C.(1991):Stability evaluation during staged construction, Journal of Geotechnical Engineering, ASCE, Vol,117,No.4, pp.541-615.