Full-scale testing of reinforced embankment on jet-grouted soil-cement piles

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1. Introduction

In the study, a full-scale testing embankment/wall using hexagonal wire mesh reinforcement with precast concrete facing was built on Bangkok soft clay ground, which was improved with soil-cement piles (DMM). The completed embankment was height of 6.0 m, 6.0 m long at the top, top width of 6.0 m and base width 18.0 m. The facing of the wall was vertical, the side and back slope was 1:1. The overall objective of this research is to present, evaluate and analyze the performance of the full-scale embankment during and after construction. Finite element method (FEM) also applied to simulate and predict the long-term behavior of the embankment/wall.

2. Testing procedures

The general properties of subsoil are listed in Table 1. Based on field vane shear testing, the top 2.0 m is weathered clay, under which is soft clay about 6.0 m depth, below 9.0 m depth is medium to stiff clay. Firstly, the soft clay was improved with soil-cement pile (9.0 length) by jet-grouting method (DMM), and then the settlement plates and piezometers were installed. After two months, the embankment was built up in 15 days by stage construction method. The backfill sand was reinforced with hexagonal wire mesh every 0.75 m thickness.

3. Results and discussion

Figures 1 to 3 show the observed settlement of ground surface, 3.0 m depth and 6.0 m depth. Comparing the curves, the primary part of settlement was developed in soft clay layer, below 6.0 m depth, the settlement is very small. Fig. 4 and Fig. 5 show the observed excess pore pressure of 3.0 m depth and 6.0 m depth respectively. All the piezometers demonstrate the build up of excess pore pressure during loading and subsequent dissipation afterwards. The maximum pore pressure occurred at 2 to 3 days after construction, the average maximum excess pore pressure was 24.5 kPa and 22.3 kPa corresponding 3.0 m depth and 6.0 m depth respectively. The dissipation of excess pore pressure seemed occur at a very quick rate, which means that the soil-cement column increased the permeability of the subsoil foundation.

Finite Element Method (FEM 2D) was applied to simulate and predict the long-term behavior of the testing embankment. The Soft soil model was used to simulate the behavior of the soft clay. The compressibility parameter used in the simulation was based on laboratory consolidation testing. One have to be mentioned is that the simulation wok was carried out one month after construction. Five sets of soil-cement elastic modulus, E_{col}, are used to investigate and predict its effect to the long-term behavior, the simulated results was plotted in all the Figures. Fig.6 shows the comparison of long-term settlement between FEM prediction and calculated results. Broms' method was used for long-term settlement prediction, the final settlement of 279 mm was obtained, which agree well with the settlement from FEM method, Ecol = 30000 kPa (100 Ccol). For untreated ground, the calculated settlement by 1-D consolidation method was 1017 mm and corresponding FEM prediction was 1238 mm.

4. Conclusion and recommendation

1) The combination of MSE and DMM is effective for building embankment/wall on soft ground.

2) FEM can reasonably capture the foundation behavior (settlement and excess pore pressure) through good agreement between the filed measurements and the prediction.

3) Three-dimensional finite element analysis should be performed to capture the overall behavior of the test embankment, for example, lateral deformation.

References

Bergado D.T., Long P.V., Loke K.H. (1994), "Performance of Reinforced Embankment on Soft Bangkok Clay with High-Strength Geotextile Reinforcement", Geotextile and Geomembrane, V. 13, pp. 403-420.

Table 1: General properties of subsoil at testing embankment

Depth (m)	γ_t kN/m^3	w_n %	Gs	PL %	LL %	PI %	Su kpa
1.5-2.0	17.2	38.34	2.65	28.99	69.08	40.11	37.5
2.0-2.5	16.6	47.95	2.64	37.8	76.58	38.78	8
3.0-3.5	16.7	66.13	2.65	31.96	83.19	51.23	6.3
4.0-4.5	14.8	85.29	2.69	34.22	96.99	62.77	
6.0-6.5	14.8	90.10	2.64	38	101	63	
7.0-7.5	14.9	95.07	2.65	38.88	99.36	60.48	6.0
8.0-8.5	15.5	78.04	2.68	37.54	98.8	61.26	10.9

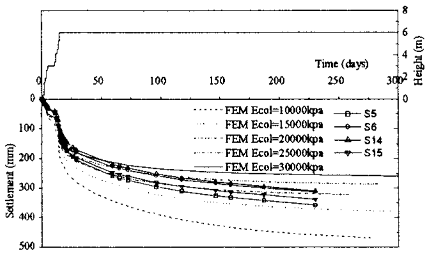

Fig.1 Settlement of ground surface

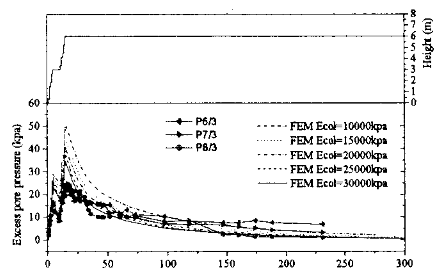

Fig.4 Excess pore pressure of 3.0m depths

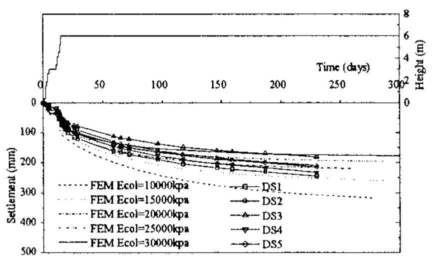

Fig.2 Settlement of 3.0 m depth

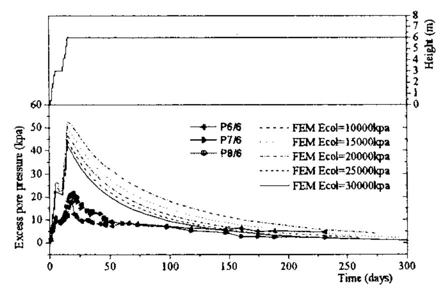

Fig.5 Excess pore pressure of 6.0m depths

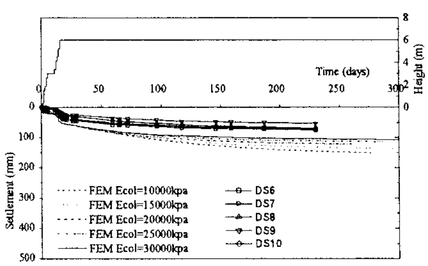

Fig.3 Settlement of 6.0 m depth

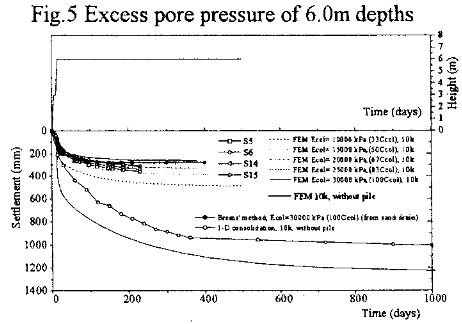

Fig.6 Comparison of different methods for surface settlement