Design of Earth Retaining Structures and Monitoring Results of Singapore MRT Project

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This paper introduces the design method of Earth Retaining Structures (ERS) of Singapore MRT project Contract 905. The analysis results by FEM are compared with the Japanese Subgrade Reaction Model (SRM) and measurement data.

１． Introduction

Contract 905 is a special part of Singapore MRT Downtown Line 1 which comprises the design and construction of two pairs of stacked bored tunnels and NATM across Marina Bay. Since there is no underground station in the contract, two launching shafts, receiving Shaft are necessary for bored tunnel construction. The project layout is shown in Fig. 1.

Fig. 1 Layout of C905 and Launching Shaft A

FEM is used in the design of ERS in Singapore and the design of MRT project must follow Civil Design Criteria (CDC) by Land Transportation Authority (LTA)[(1)], while in Japan, Japanese SRM is widely used for ERS design. In this study, the results by the two different analysis approaches are discussed and compared with the measurement data.

２． Design Methods for Earth Retaining Structures

FEM Software called “PLAXIS” is commonly used in underground structure design in Singapore. Soil is modeled by nonlinear 15-nodes anisotropic elements. D-wall and strut are modeled by plate and spring elements, respectively. In CDC-LTA, it is stated that except Marine clay and fluvial clay, both drained analysis considering separation of water from soil and undrained analysis considering soil and water together shall be carried out. The analysis model of Shaft A (2 RC struts, 2 steel struts and 3 RC slabs) is shown in Fig. 2 and the soil profile and parameters are indicated in Fig. 3.

For Japanese design method, the elasto-plastic spring is introduced for representing soil and classical theory of active and passive soil pressure is applied. The typical Japanese spring model software is such as “Kasetsu5x” and “RainPal”. In this study, RainPal with the design approach in Cut&Cover Tunnel Design, JSCE[(2)] is introduced. In order to compare with same order of spring model, Mohr-Coulomb criterion is used in Plaxis analysis.

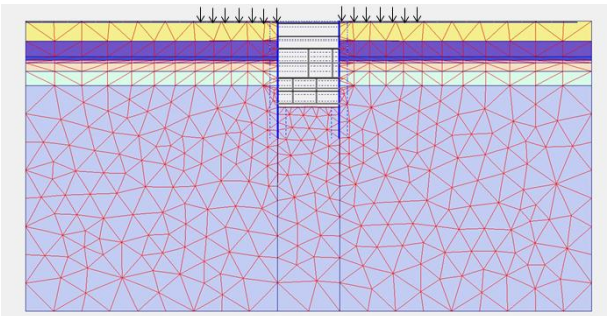

Fig.2 FEM Analysis by Plaxis

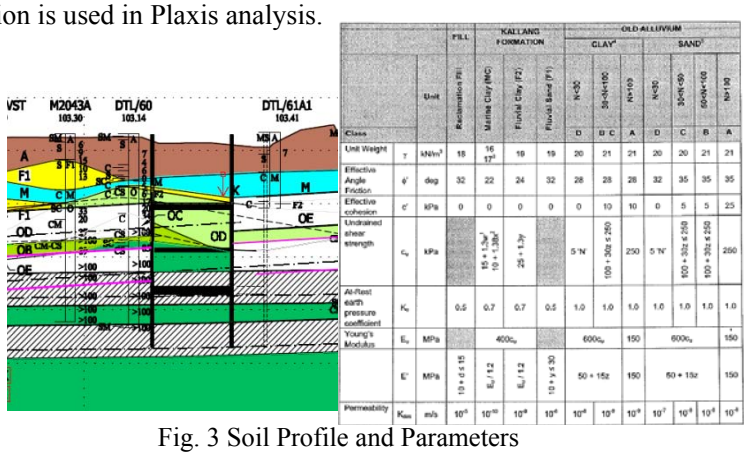

Fig. 3 Soil Profile and Parameters

Keyword: Singapore MRT, Subgrade Reaction Model, Plaxis, Monitoring Results, Earth Retaining Structures

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3. Analysis Results

The analysis results of drained and undrained analysis cases from Plaxis and from RainPal after remove S6 are compared in Fig. 4 and Fig. 5, respectively. The same sets of soil/structure parameters except Young's Modulus of soils are introduced in each approach. The Young Modulus's specified in Singapore LTA is used in Plaxis; whereas, the Young's Modulus and soil spring constant (k_h) from JSCE code is adopted in RainPal. It is shown that both methods provided similar results. The profile of deflection, bending moment and shear force agrees well. Some differences occur due to movement of ground at the toe of D-wall. This is because FEM is 2D approach and the effect of basal heave is included in the analysis, while in the spring model only behaviour from horizontal direction is taken into an account.

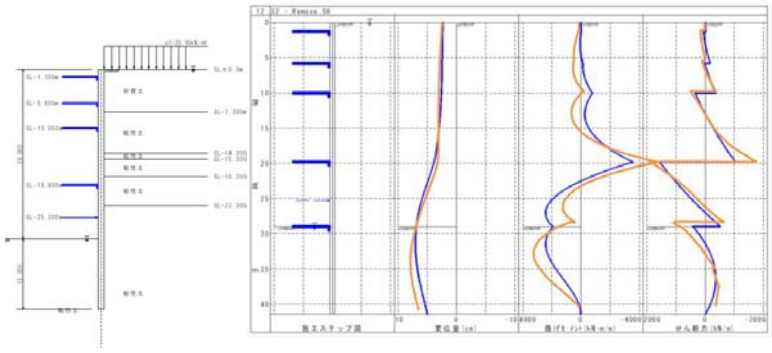


Fig. 4 Drained Analysis Result

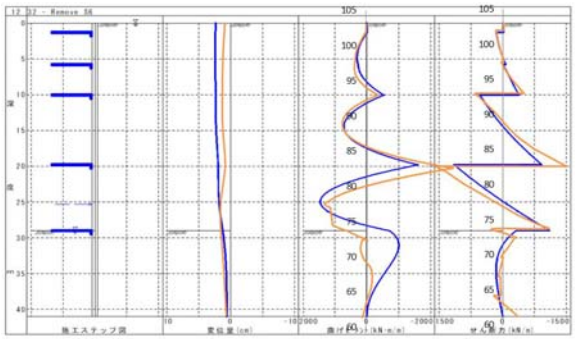
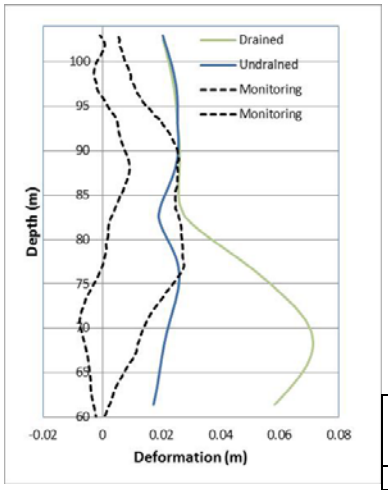
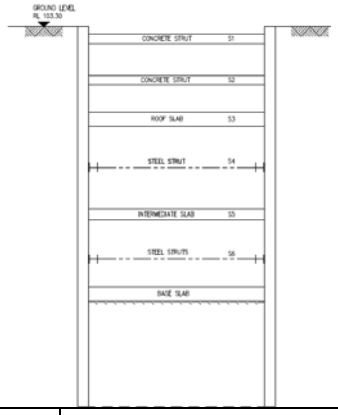


Fig. 5 Undrained Analysis Result

4. Comparison of Analysis Results with Monitoring Results.

The minimum requirement for monitoring points has been specified in CDC-LTA. Several instrumentation devices, such as ground settlement markers, inclinometers, piezometer/water standpipes, strut strain gauges and load cells were installed and the results had been discussed daily comparing with the design value.





Strut Level	Max. Strut Force (kN)				
	Actual Force	Undrained Analysis		Drained Analysis	
		Plaxis	RainPal	Plaxis	RainPal
S4	184	2422	2546	3280	2722
S6	259	1894	1558	3534	3010

Fig. 6 Monitoring Results

The wall deflection predicted by FEM analysis and in-wall inclinometer results are compared in Fig. 6. The result shows that the actual wall deflection is closer to undrained analysis result. This is because Old Alluvium layers have permeability of about 10^{-8} m/s or less; therefore, with in the excavation period, the behavior is most likely undrained. The drained analysis is considered as conservative design.

The comparison of strut force shows that the actual force from load cell is much smaller than the values predicted by Plaxis and RainPal.

4. Conclusion

The results from two different analysis approaches is compared and discussed in this paper. The results from both methods are similar when uses the same set of input parameters for both drained and undrained cases. For Young's Modulus of soil, when the recommended value proposed by JSCE is used in Japanese SRM and the value proposed by Singapore LTA is used in FEM, the prediction values agree well with measurement data.

References

1. Rail & Engineering Groups, LTA "Civil Design Criteria for Road and Rail Transit System" Rev A7, Jul 2009.
2. 2006 年度制定　トンネル標準示方書開削工法・同解説　土木学会