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A study of double-deck tunnel depending on types of intermediate slab with beam-spring model

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ABSTRACT

Intermediate slab of double-deck tunnel has an effect on stability of segment lining. Types of intermediate slab could be categorized by support methods at the end of the slabs and the methods cause a difference in degree of integration with the segment lining. In this study, a beam-spring model of the double-deck tunnel is built to analyze distribution of bending moment depending on types of the intermediate slab. The structural element of the slab is determined as simple support beam and fixed end beam whose reaction forces are different at the end of the beams. The result of the study shows that the type of the intermediate slab is one of the important parameter for double-deck tunnel to evaluate the stability

1. INTRODUCTION

Intermediate slab functions as an element for dividing inner space of double-deck tunnel and supporting traffic load. Unlike bridge slab, the intermediate slab is supported at the ends connecting with segment lining. Therefore, influence of the intermediate slab on the segment lining should be considered. As an initial study for the development of a double-deck tunnel stability evaluation program, behavior of segment lining depending on types of intermediate slab is analyzed with beam-spring model built in EXCEL VBA. ‘no slab’, ‘simple support beam’ and ‘fixed end beam’ cases are considered and influence of each case on segment lining is analyzed.

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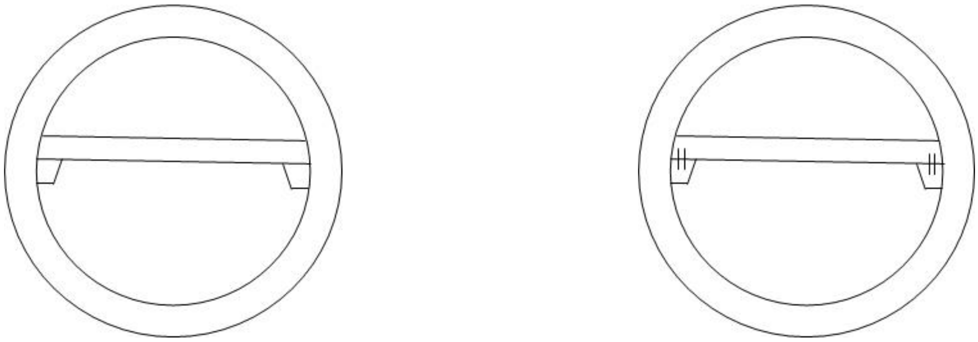
2. SUPPORTING TYPES OF INTERMEDIATE SLAB

The intermediate slab is a structural element crossing inside the tunnel and supports the traffic load. Figure 1 shows kinds of intermediate slab depending on connecting type. The difference in the supporting method affects the behavior of the intermediate slab and segment lining. In the case of simple support intermediate slab, it is just placed on the bracket installed on the segment lining. However, in the case of fixed end intermediate slab, the intermediate slab is combined with the segment lining and bracket, thereby influencing all movement (Lee and Moon 2016).



(a) Simple support intermediate slab (b) Fixed end intermediate slab

Fig. 1 Supporting type of intermediate slab

3. STRUCTURAL ANALYSIS OF DOUBLE-DECK TUNNEL

According to ITA (2000), the method of structural analysis for tunnel could be classified into analytical method and numerical analysis method and each method has advantages and disadvantages. The analytical method is relatively easy to calculate objects compared to other methods. However the numerical analysis method could analyze complicated shaped objects. Beam-spring model, one of the most popular numerical analysis methods, has benn studied over a long period of time (Klar et al. 2008; Lee et al. 2015, Nikkak et al. 2016). In this study, beam-spring model is used to simulate the intermediate slab of the double-deck tunnel and the model is built with EXCEL VBA.

3.1 *Beam-Spring model*

The beam-spring model is shown in Figure 2. The model could be defined by depending on simulation of segment joint in transversal direction or ring joint in longitudinal direction. I - IV models are in 2D that does not take into account the longitudinal direction. They represent stiffness degradation due to segment joints by hinge or spring elements. The Ⅴ and Ⅵ models are in 3D which can consider the ring joints in the longitudinal direction with rigid elements or shear spring. In this study, as an initial stage of the development of a double-deck tunnel stability evaluation program, a model of a double-deck tunnel structural analysis solver is constructed by adopting a relatively simple type II model.

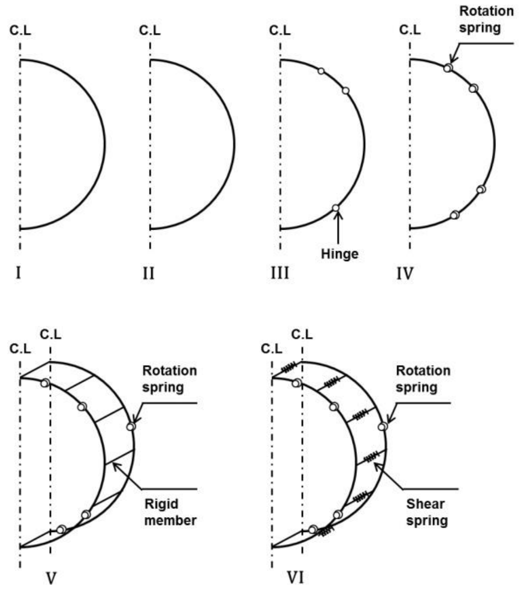


Fig. 2 Beam-spring model for TBM segmental linings (JSCE, 1996)

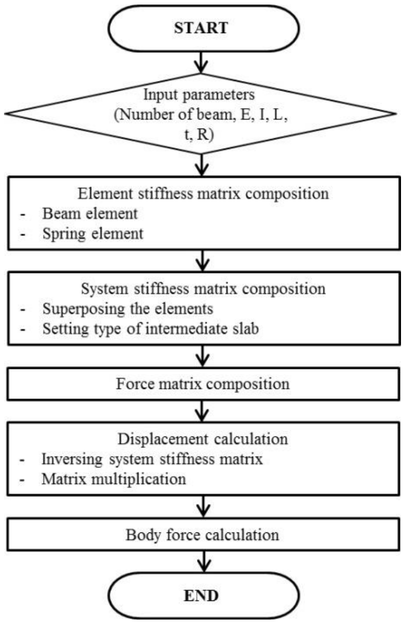


Fig. 3 Flow chart of beam-spring model calculation

The model consists of beam elements for concrete segment lining and spring elements for subgrade reaction between earth and segment lining. The reaction is caused by deflection of segment lining. Because of this, the reaction is expressed only as compressive force directed toward the inside of the tunnel. The intermediate slab is presented as simple support beam and fixed end beam for simple support intermediate slab and fixed support intermediate slab .

(a) Simple support beam (b) Fixed end beam

Fig.4 Structural elements of intermediate slab

3.2 *Beam-Spring model for double-deck tunnel*

Numerical analysis procedure of the double-deck tunnel is shown at figure 3. Tunnel specification, properties, load condition and boundary condition of intermediate slab are as figure 5, 6 and table 1, 2. DB-13.5 is applied as vehicle load model for the traffic load on the intermediate slab.

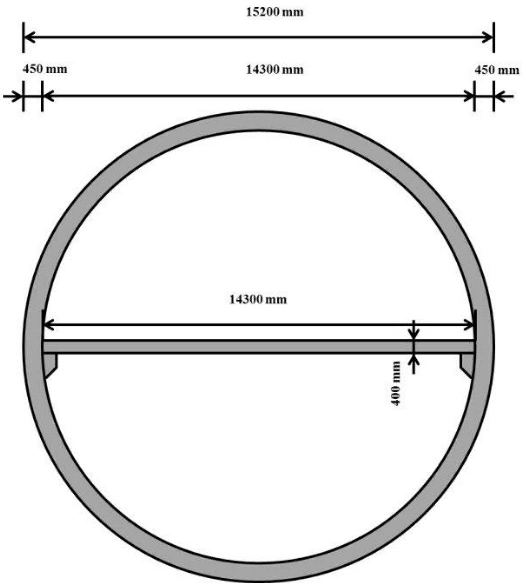


Fig. 5 Cross-section of double-deck tunnel

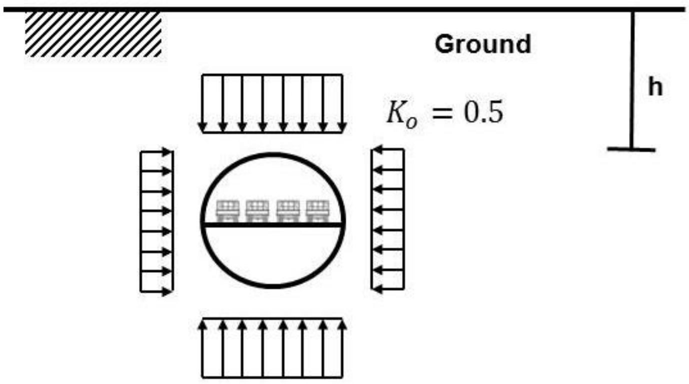


Fig. 6 Load condition of beam-spring model for double-deck tunnel

Table. 1 Properties of segment lining and intermediate slab

	Properties
γ_{CONC} (unit weight)	26 kN/m^3
E_{CONC} (elastic modulus)	38.82 GPa
N (number of joints)	6 EA
I (moment inertia)	1.519 $\times 10^{-2} m^4$
I_e (moment of inertia of force transmission zone)	1.059 $\times 10^{-2} m^4$

Table. 2 Properties of ground

	Properties
γ_{ground} (unit weight)	19 kN/m^3
E_{ground} (elastic modulus)	7.04 MPa
ν(Poisson's ration)	0.33
K_0 (coefficient of lateral earth pressure)	0.5
h (height of overburden)	20m

3.3 *Result of analysis*

Numerical analysis of the beam-spring model for the double-deck tunnel is conducted in 3 cases (no intermediate slab, simple support intermediate slab and fixed end intermediate slab) and result is shown as figure 7. The supporting type effects on bending moment distribution of segment lining. No intermediate slab type shows maximum bending moment at crown and bottom of double-deck tunnel. On the other hand, both simple support intermediate slab type and fixed end intermediate slab type present different distribution of bending moment. Especially, fixed end intermediate slab type shows more changes at spring line of tunnel segment lining. It is caused by degree of integration between segment lining and intermediate slab.

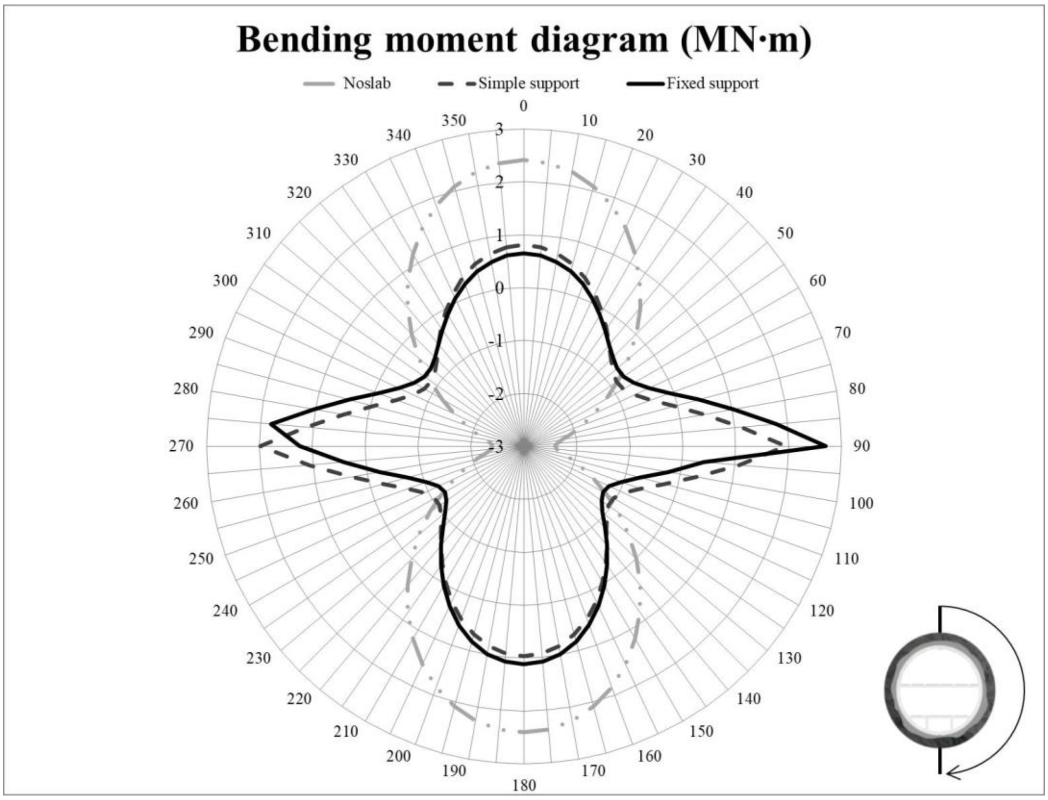


Fig. 7 Bending moment diagram of segment lining depending on intermediate slab supporting type

4. CONCLUSIONS

In this study, numerical analysis model of double-deck tunnel is built with beam-spring model and bending moment distribution is calculated depending on support method, ‘no intermediate slab type’, ‘simple support intermediate slab type’ and ‘fixed end intermediate slab type’. The distribution is influenced by support method which has different degree of integration. To evaluate stability of double-deck tunnel, it needs to emphasis on connection area between segment lining and intermediate slab.

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