Modeling of Opening at Side Walls of Cut-and-cover Tunnels

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1. Introduction

We have developed a proposed method for modeling the openings in the side walls of cut-and-cover tunnels. Such openings are often needed in construction projects such as the renewal of underground stations with cut-and-cover tunnels. This proposed method enables evaluation of the complicated three-dimensional behavior of a cut-and-cover tunnel with a large-scale opening by using a simplified two-dimensional frame analysis. The applicability of the proposed modeling method has been verified through comparison with a two-dimensional frame analysis using the previous modeling method and a three-dimensional finite element analysis ("FEA"). The method has also been validated through a soil test simulation analysis.

2. Opening modeling method

The proposed method for modeling an opening is shown in Figure 1. The method defines the stiffness of a pseudo beam so that the deformation of the opening's center may be expressed by modeling the top wall at the opening (area immediately above the side wall) as a double-end fixed beam and causing the amount of deflection at the center of the opening span to agree with the amount of shrinkage at the opening in the two-dimensional frame analysis. As a comparison, the previous method modeled the opening in the same way as the method modeled the center pillars. It defined the stiffness of the pseudo beam by considering the average deformation near the opening.

3. Validation of proposed method

First, the result of validation through analysis is shown in Figure 2. When the opening width is small, the results of the three-dimensional FEA, proposed method and previous method (two-dimensional frame analysis) indicate similar values at the focus point. As the opening width increases, the bending moment tends to increase as shown by the result of the three-dimensional FEA, and the proposed method was able to follow that tendency.

Next, the soil test simulation result is shown in Figure 3. In the soil test, an acrylic model of a cut-and-cover tunnel with a one-layer and two-span structure, having an opening equivalent to approximately 10 meters in actual size, was placed in the simulated ground made of the Toyoura sand and loaded with uniformly-distributed load from the top wall. The values calculated in the proposed method repeated or included the test values at the top wall near the opening. Besides, the bending moment (inward tension) was generated at the ends of the top wall, which showed the same tendency as the three-dimensional FEA.

From the comparison between the analytical and test results, we were able to verify the applicability of the proposed method to a renewal construction with a large-scale opening in the side wall.

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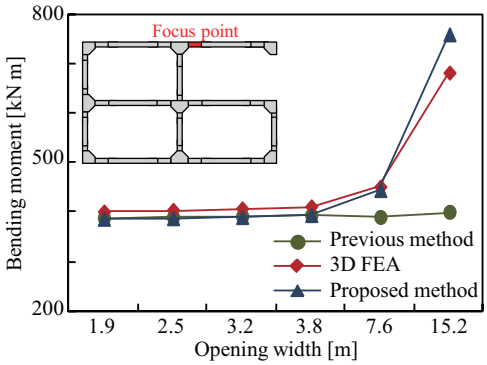
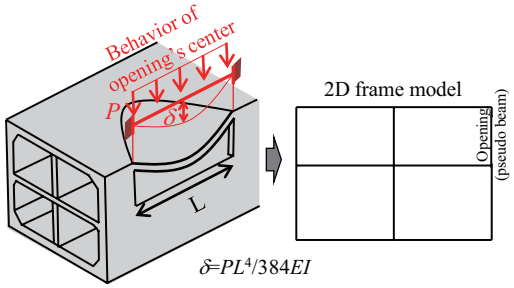


Fig. 2 Relation between opening widths and bending moments



=> Determine the stiffness reduction rate of the pseudo beam so that the calculated amount of shrinkage at the opening in the 2D frame analysis agrees with the above amount of deflection.

Fig. 1 Method for modeling side-wall opening

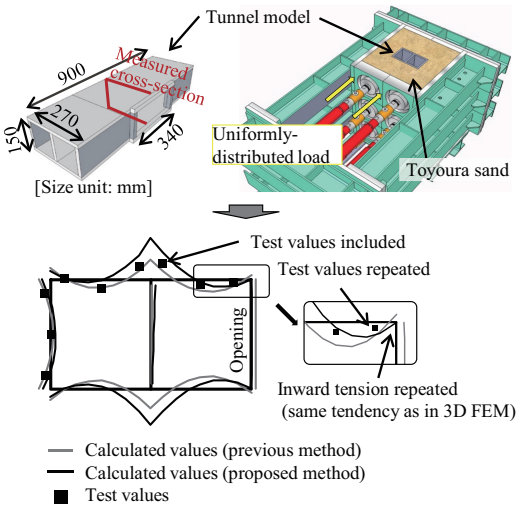


Fig. 3 Test result and analytical result by proposed method