Study on H&V shield control during spiral section

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1. Introduction

Due to limited underground space in urban area and for saving construction cost, multi circular face shield (MF shield) had been innovated to construct a twin tunnel at once. Furthermore, according to the more severe restriction of underground space use, horizontal and vertical variation shield method (H&V shield) was innovated, so that the cross section of a MF shield tunnel is changed from horizontal multi circular shape to vertical one, or vice versa. The H&V shield is manufactured by connecting two articulated shields at their rear bodies, and is steered by articulation mechanism and copy cutter, which can be operated individually at each body. These steering options can generate rotating force around the shield axis, which can realize the construction of a spiral tunnel. Recently the first spiral tunnel using H&V shield method has been planned. Therefore, the method to steer the H&V shield was studied. This paper introduces H&V shield method and describes the steering method of H&V shield along a planned alignment by articulation mechanism and copy cutter. Furthermore, the validity of the obtained results on articulation angle and copy cutter length and range is discussed from the viewpoints of geometric conditions and practical experience.

2. Characteristics of H&V shield

The characteristics of H&V shield method are as follows:

1) H&V shield can construct separate tunnels and spiral tunnels. The separate tunnel can be constructed by separating H&V shield to two ordinary shields. On the other hand, the spiral tunnel can be constructed by rotating H&V shield around its axis; and

2) H&V shield can shorten construction period and save construction cost. These are because H&V shield can omit an intermediate vertical shaft and a ground improving work for the separate tunnel, and H&V shield can construct a multiple tunnel at once and reduce the adjacent distance between two circular tunnels for the spiral tunnel.

3. Results and Conclusions

In this study, the following tunnel are assumed: 1) Tunnel A constructed by the left body of H&V shield is on a straight and horizontal alignment; and 2) Tunnel B constructed by the right body of H&V shield rotates around Tunnel A from the rightward transverse direction to the upward vertical one. The right body of H&V shield are considered to have two steering methods: 1) Case 1: the axis direction of the right rear body follows the alignment of Tunnel B and is free from that of the left body; and 2) Case 2: the shield axis direction of the right rear body is parallel to that of the left rear body since the both bodies are fixed at the rear body. Here, the constraint conditions of the right body for Case 1 and Case 2 are set to determine the articulation angle and the copy cutter length and range, based on site experience. To study the steering method of H&V shield, a 3-D compound alignment as shown in Fig. 1 is assumed as the alignment of tunnel B. In Fig. 1, BVC is the beginning point of vertical curve and EVC is the end point of vertical curve.

The calculated articulation angle in horizontal and vertical direction, θ_{CH} and θ_{CV}, of Case 1 and Case 2 are shown in Fig. 2 and Fig. 3 respectively. The contour maps of the copy cutter length distribution around the circumference of the tunnel in both cases are shown in Fig. 4 and Fig. 5 respectively. From these figures, the followings were found:

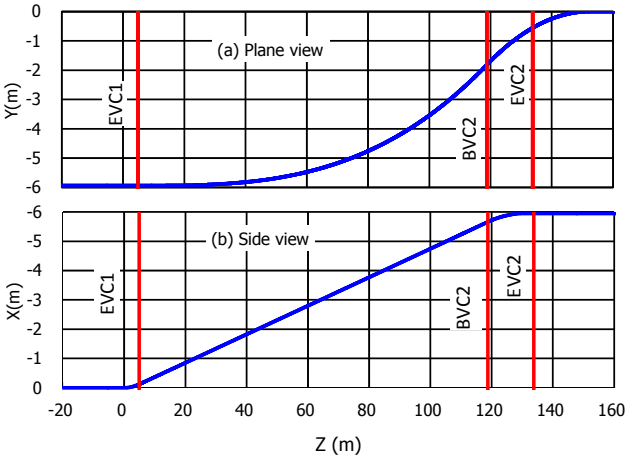

Fig. 1 *Tunnel alignment*

1) the analysis results demonstrate that the proposed steering method of H&V shield can provide articulation angle and copy cutter length and range reasonably from the view point of geometric conditions;

2) the articulation angle and the copy cutter distribution depend on shield dimension, tunnel

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alignment and operation rules of shield rotation; and

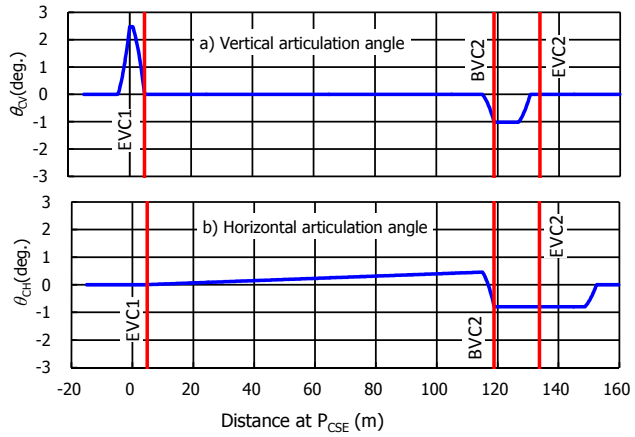

Fig. 2 *Articulation angle of Case 1*

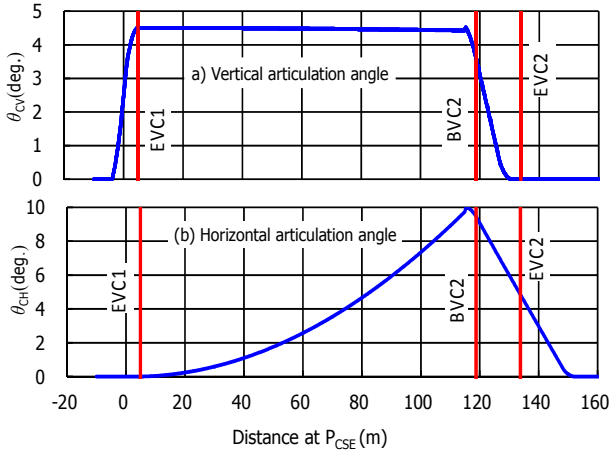

Fig. 3 *Articulation angle of Case 2*

3) Case 1 has an advantage from the viewpoint of ground stability around the shield since Case 1 can reduce the θ_{CV} and θ_{CH}, and the copy cutter length drastically, compared with Case 2. But since Case 1 has a possibility to appear more stress concentration at the connecting point at the rear bodies than Case 2, further examination is required from the viewpoint of mechanical engineering.

References

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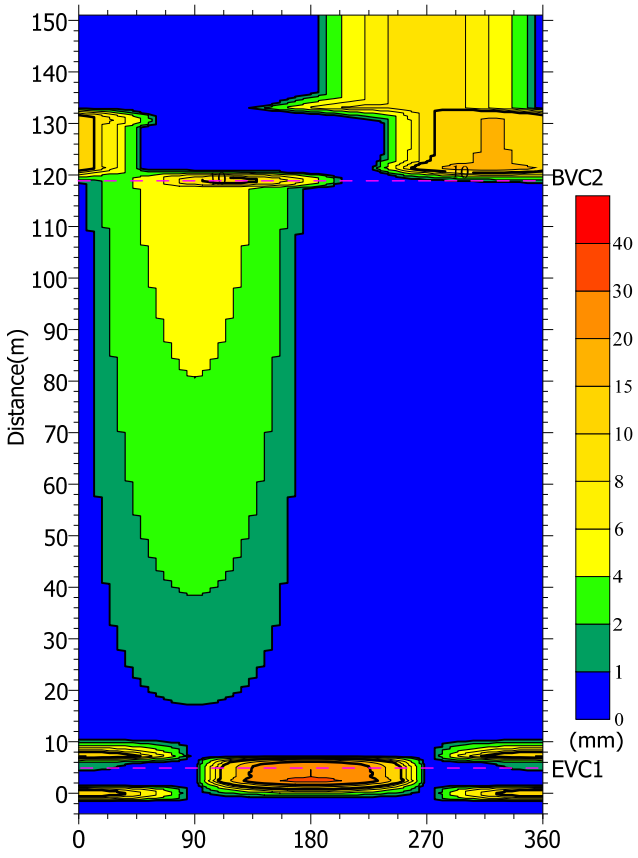

Fig. 4 *Contour map of copy cutter length in Case 1*

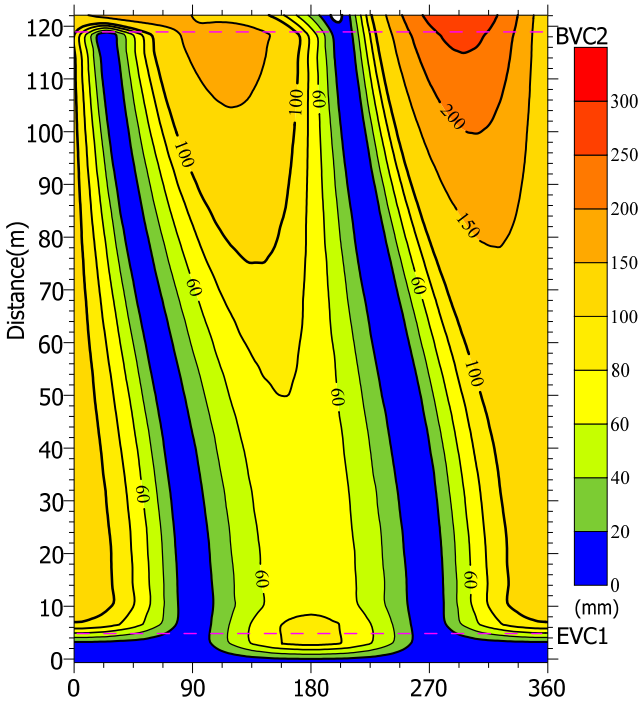

Fig. 5 *Contour map of copy cutter length in Case 2*