博士論文内容の要旨

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氏　名　　HUYNH NGOC THI

Due to limited underground space in the 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 an 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.

The characteristics of H&V shield method, compared with other type shields, are as follows: 1) Tunnel shape and alignment: H&V shield can construct a separate tunnel and a spiral tunnel. In the case of a separate tunnel, H&V shield forms a tunnel with a multi-circular cross section at first, and two ordinary tunnels with a circular cross section after a specified point along the tunnel alignment by separating the H&V shield to two ordinary shields. On the other hand, in the case of a spiral tunnel, H&V shield constructs a tunnel with a multi-circular cross section, which is changed continuously from horizontal multi-circular shape to vertical one, or vice versa; 2) Construction period: H&V shield can shorten a construction period because H&V shield can omit an intermediate vertical shaft to separate the body in the case of a separate tunnel, and can construct multiple tunnels at once in the case of a spiral tunnel; and 3) Construction cost: H&V shield can save a construction cost because H&V shield body can separate without an intermediate vertical shaft and a ground improvment in the case of a separate tunnel, and can reduce the adjacent distance between two circular tunnels in the case of a spiral tunnel.

Shield is operated for excavation, steering shield, filling up in the tail void, and segment installation mainly. As for steering shield, the shield is controlled by jack, copy cutter and articulation mechanism in practice. The jack generates thrust and horizontal and vertical moment, which can be determined by jack pattern and shield jack pressure. The copy cutter can carry out overcutting with a specified depth and a specified range along the circumference of cutter face. The overcutting by copy cutter defines excavation area and reduces ground reaction force at the overcutting range, which makes the shield rotate toward the overcutting range easier. The articulation mechanism for articulated shield can crease shield with a specified direction and a specified angle. The crease of the shield can reduce ground reaction force at curves by fitting the shield for its excavation area, which makes the shield rotate easily.

H&V shield for a spiral tunnel can be controlled by spiral jacks, copy cutter and articulation system. The shield jack system including spiral jacks, causes the eccentric forces to generate torque to twist an H&V shield around its axis. The copy cutter can reduce the ground reaction

force at a specified area by overcutting the ground, and the articulation system also can reduce the ground reaction force by articulating the front body from the rear body of each shield. Using these functions, H&V shield can rotate around its axis and can advance, thus, H&V shield can construct a spiral tunnel.

Recently, a construction project has been planned using H&V shield method. Because of the limitation of land use, such as, narrow river and existing structures over the planned route of the tunnel, only the spiral excavation mode of this method can construct the tunnel, of which the cross section enables the required amount to be discharged. However, this is the first application in practice except for the test execution. Therefore, this study aims to examine the H&V shield control method before the construction.

At first, the shield steering parameters, such as, copy cutter operation (length and range) and articulation operation (direction and angle), were determined, based on the geometric conditions for both bodies of H&V shield independently. After that the jack operation (jack thrust force, horizontal moment and vertical moment) were determined, using the kinematic shield model for H&V shield. Next, the H&V shield behavior was simulated using the kinematic shield model for H&V shield, which has been developed from the one for the single circular shield to simulate H&V shield behavior during excavation theoretically based on equilibrium conditions. In the simulation process, the ground displacement around the shield was taken into account, and the shield operational parameters obtained from the above were also used. In this process in order to validate the model performance, the calculated shield behavior was examined from the viewpoint of theory, and the H&V shield control method was confirmed by comparing the calculated shield behavior with the plan data. Besides, the force acting at the connection point between the left body and the right body was calculated for shield design. This paper describes the H&V shield behavior at the a curve.

As a result, the followings were found: 1) The calculated H&V shield behavior is reasonable from the viewpoint of the theory and site experience. 2) The calculated shield behavior has an overall good agreement with the planned one; 3) The ground displacement is a predominant factor affecting shield behavior; and 4) The proposed model can simulate the H&V shield behavior reasonably.
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