

氏 名：張 帥 (チョウ シュアイ)

論 文 名：Effect of Overburden Depth and Curved Construction on Box Culvert in Rectangular Pipe Jacking and Its Countermeasures (矩形推進工法における土被り深度および曲線施工のボックスカルバートに及ぼす影響ならびにその対策)

区 分：甲

### 論 文 内 容 の 要 旨

In recent years, new pipe installation works in urban areas have been a concern due to their impact on existing lifelines and surrounding ground. One of the solutions of these problems is to apply the pipe-jacking method, which is one of the trenchless technologies. In addition, as a part of the life-related business in Japan, urban development in the social situation of the transition to an aging society requires universal design for pedestrian- and physically disabled-friendly city development. From the perspective of revitalizing local cities and improving convenience, there is also an increasing demand for advanced use of underground spaces and the expansion of underground passages. The rectangular pipe jacking method has been widely adopted in the development and use of urban underground spaces due to its excellent space utilization rate. In addition, as the scope of application of the rectangular pipe jacking method expands, it is increasingly being adopted for burials with a large overburden depth and curved construction. However, compared to circular pipes, box culverts have uneven earth pressure distribution, which makes them prone to stress concentration at corners and deformation at the roof and floor. In addition, it has been reported that in curved construction, cracks tend to occur easily because eccentric thrust acts on the box culvert during jacking pipe.

From the above points of view, this research discussed the outer surface forces acting on the box culvert, ground deformation, and box culvert behavior due to differences in soil covering depth and thrust force transmission axis in order to evaluate the effects of overburden depth and curved construction on a box culvert in the rectangular pipe jacking method. Then, a box culvert that can accommodate different overburden depths and curved construction was proposed and technical guidelines were established.

**Chapter One:** This chapter outlines the rectangular jacking method, its principles and characteristics, and a comparison with the circular jacking method, and the current status and characteristics were described. In addition, the classification and characteristics of tunneling machines used in the previous rectangular pipe jacking method were summarized, and problems related to the impact of the rectangular pipe jacking method on the surrounding ground were discussed. Furthermore, issues related to the rectangular pipe jacking method due to differences in overburden depth and thrust transmission axis were extracted, and the significance of this research was mentioned.

**Chapter Two:** This chapter discussed that the behavior of the box culvert due to the difference in the force acting on the outer periphery of the box culvert during jacking pipe and the difference in the thrust transmission axis center by means of three-dimensional numerical analysis. As a result, it was clarified that the force acting on the outer periphery of the box culvert increases with increasing overburden depth, and the stress distribution becomes uneven. On the other hand, when the overburden depth is small, the force acting on the outer periphery of the box culvert can be evaluated using the existing Terzhagi theory and the soil silo theory, but as the overburden depth increases, the existing theories cannot evaluate the internal stress generated in the box culvert, and it can be considered that the numerical analysis is useful. Furthermore, it was confirmed that

tensile stress acts on the roof and floor corners of the box culvert, but compressive stress gradually acts toward the center of the span of the roof. It was also pointed out that as the overburden depth increases, the tensile stress acting on the roof and floor corners and the compressive stress in the center of the span increase significantly, making the box culvert more susceptible to damage.

**Chapter Three:** This chapter discusses the effect of the thickness and shape of the box culvert on the strength of box culvert and the allowable jacking distance. The results showed that increasing the thickness of the box culvert improves the strength characteristics and increases the allowable jacking distance. It was also found that reducing frictional resistance during jacking of the box culvert makes it possible to increase the allowable jacking distance. From these results, it is considered necessary to determine the optimal box culvert shape by examining the required thickness based on the required box culvert scale such as dimensions, installation length, route conditions at each site.

**Chapter Four:** This chapter discussed the outer surface forces acting on a box culvert and the behavior of the box culvert due to differences in the thrust transmission axis when using the rectangular pipe jacking method for curved tunneling. It clarifies that the stress distribution on the box culvert, which acts uniformly during linear tunneling, changes from trapezoidal to triangular as the thrust transmission axis moves toward the corner. It also shows that the compressive stress acting on the center of the box culvert's span tends to increase significantly near the corner as the thrust transmission axis moves, and that if a large earth covering load is applied to this, the box culvert will be severely damaged. It also points out that effective countermeasures include increasing the thickness of the box culvert and installing haunches at the corners.

**Chapter Five:** As a result of investigating the site situation where the rectangular pipe jacking method is applied, it was found that the buried depth of the box culvert in Japan will be about 20m in 2020, and it will be necessary to increase the thickness of the concrete to increase the load-bearing capacity when applying it to large overburden depth. In addition, as a result of investigating and analyzing the Shanghai Jing'an Temple Station project in China, it became clear that the steel-concrete composite box culvert is an effective solution to high circumferential pressure and eccentric thrust. From this result, a composite box culvert with steel plates wrapped around the outer shell of the box culvert is proposed in order to increase the load-bearing capacity of the box culvert, secure the effective cross-sectional area, and reduce the thickness, and it is concluded that this is also advantageous for sites with a large overburden depth and curved construction.

**Chapter Six:** This chapter summarizes the overall research framework and structure of the thesis and synthesizes its key findings.