Study on Evaluation of Friction Force and Applicability to Rectangular Pipe Jacking

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1. Introduction

In recent years, Japan has been promoting the construction of cities that make effective use of underground space. That is why underground and barrier-free underground passage ways are being constructed in urban areas. In the past, open trench cut or shield tunneling methods were mainly used to install pipes under the ground. However, these existing methods are difficult to apply in urban areas because they require the occupation of a wide construction area, and a long construction period at high cost. Therefore, the pipe jacking method, which is a non-disruptive excavation technology, has been developed as an effective construction method in urban areas and has been implemented in recent years. Currently, not only circular pipe jacking but also rectangular pipe jacking is commonly applied, and rectangular one is expected to be applied increasingly in the future due to its high space utilization. However, there is no friction force prediction model based on rectangular pipe jacking, if this rectangular one is designed. Therefore, this study proposes a new friction force prediction model for rectangular pipe jacking and investigates its applicability using 3D-σ.

2. New model for predicting frictional force

Before constructing the new model, six existing prediction models based on circular pipe jacking were examined. It was found that applying the existing model directly to rectangular pipe jacking tends to predict frictional forces excessively. This was thought to be due to the fact that the lubricant between the pipe and the ground was not taken into accounts. Therefore, a prediction model was developed that included a factor for the distribution of the lubricant. As shown in Fig. 1, the vertical earth pressure was considered to be the effect of arching, and Terzaghi's loose earth pressure was adopted. As a result, the new model constructed by resolving the vertical and horizontal earth pressures based on the JSTT model was shown in Fig.1.

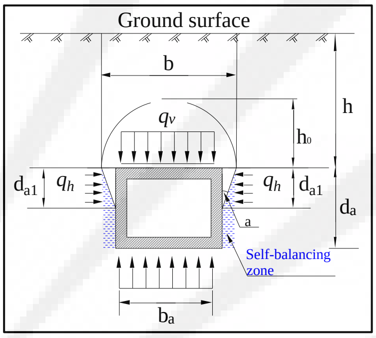

Fig.1 Pipe-soil contact model

The new model is as follows;

$$F_{fric} = \mu L(q_v(2b_a + K_0\lambda d_a) + W) + 2L(1-\lambda)d_a\tau$$

where λ is as a parameter that shows the distribution of the lubricant.

3. Results and discussions

In this study, data from three field sites (Case-A, B, and C) were used to confirm the accuracy of each of the six existing models and the new model. Table 1 and Table 2 show the errors between the predicted and measured values from the existing and new models. For the new model, the comparison was made by changing the situation of lubricant distribution (λ). Among the existing models, the Weber model was found to be the most accurate in rectangular pipe jacking. In all cases, however, the new model was more accurate than the existing model's, confirming the applicability of the new model in rectangular pipe jacking.

In addition, it was considered that there was the relationship between the pipe geometry and λ. Therefore, to clarify this relationship, a numerical analysis was conducted as a case study. The results show that the distribution of lubricant in the sidewalls becomes discontinuous as the vertical to horizontal ratio of the pipe increases.

Table 1 Error between existing models and actual measurements

model	error(%)		
	Case-A	Case-B	Case-C
JSTT	-100.8	-38.0	-71.9
CSTT	-70.4	-12.3	-49.2
Chapman	34.2	63.2	62.6
Weber	-8.6	9.6	-30.2

Table 2 Error between new model and actual measurements

model	error(%)		
	Case-A	Case-B	Case-C
λ=1	-5.0	7.0	8.9
λ=0.5	-4.3	5.9	-13.9
λ=0	-3.73	4.9	-24.4
Weber	-8.6	9.6	-30.2