Pavement deformation prediction and monitoring case analysis of jacking and underpass highway in Huairou District, Beijing

Ye Yuan¹, Yang Wang²*, Shuqing Zhao³, Mengda Ding⁴

¹,³,⁴China Urban Construction Design & Research Institute Corporation limited, Beijing, China
²Beijing Guodaotong Highway Design & Research Institute Corporation limited, Beijing, China

*Corresponding author e-mail: 158762116@qq.com

Abstract. In recent years, with the construction of municipal pipeline, the situation of pipeline crossing highway is increasing day by day, and the pipe jacking construction is often used at the crossing place. Pipe jacking construction will inevitably cause deformation of surrounding soil and ground settlement, which will affect the smoothness of the road and the comfort of driving. Taking Huairou District sewage pipe jacking project as an example, this paper uses numerical simulation method to simulate the construction process, predict the deformation of the road surface during the construction process of the road crossing, and verify the feasibility of the calculation of subgrade deformation caused by pipe jacking construction by analyzing the monitoring data.

1. Introduction

In recent years, more and more pipeline lines are laid underground, forming a large-scale underground pipe network in major cities of the country. The situation of pipeline crossing the highway is increasing. The traditional underground pipe network construction generally adopts the open excavation method, which has a great impact on the ground traffic. In order to solve this problem, the hidden excavation method is used to solve the problems such as damage to urban buildings and road traffic jams in the open construction of pipelines.

Pipe jacking is often used in the underground excavation of municipal pipelines. The factors of ground deformation caused by pipe jacking construction include soil loss, positive additional thrust, friction between roadheader and follow-up pipeline and soil, among which soil is a major factor. [1] at
present, the settlement calculation methods caused by soil loss mainly include empirical method [2], analytical method [3] and finite element method. In order to ensure the safety and comfort of the highway itself and driving, it is necessary to calculate and analyze the impact of pipe jacking construction on the existing expressway to ensure the safe and comfortable operation of the expressway. [4-7] In this paper, Midas GTS NX is used to simulate the ground settlement in pipe jacking construction [8-9], but the results of numerical calculation alone cannot be used as the basis for the three-level early warning control value of the monitoring unit. In this paper, the monitoring data of an example is used to verify the feasibility of calculation of subgrade deformation caused by pipe jacking construction.

2. Engineering survey

In this paper, the example of Huairou town sewage treatment market construction supporting pipe network project Pipe Jacking under the influence of long road pipe jacking construction.

The pipe jacking crosses section 1 of Huaichang road horizontally. The specific location is as follows: the pipeline W55×35-w56×35 well section (Qiaozi town) crosses at K6 + 550 of Huaichang road horizontally. The width of Huaichang road is 21.2m at present, and the pipe jacking method is adopted for construction.

3. Geological conditions at the crossing

In 1959, the highest diving water level of the site was close to the natural surface, and the buried depth of the highest water level in recent 3-5 years was considered as the natural surface. The buried depth of stable water level is 12.80m, the elevation is 44.54m, and the designed pipe bottom elevation is 45.43m. The influence of groundwater level is not considered in pipe jacking construction.

The soil layer for mechanical pipe jacking construction is mainly ② clayey silt and sandy silt.

4. Basic information of highway

The width of Huaichang Road in the crossing section is 21.2 meters, the width of subgrade is 23.2 meters, two road forms, each side has 7 meters lane, the central partition bandwidth is 7.2 meters, and each side has 1 meter soil shoulder. Huaichang road is a class III Highway with a design speed of 40 km / h.

Huaichang road structure:

Surface course: 4cm fine-grained plant mixed hot recycled asphalt concrete AC-13C;

Base course: 16cm lime fly ash stabilized macadam.

5. Analysis of the influence of Pipe Jacking under highway

Crossing Huaichang road section is from well W55 to well w56, crossing Huaichang road K6+550, with a total length of 71 meters. The pipe type is DN800mm reinforced concrete F-shaped steel socket pipe (Class III). One pipe jacking pit with a plane size of 8000x4500mm is located 23m away from the curb on the north side of Huaichang road; one receiving pit with a plane size of 4500x4500mm is 25m away from the curb on the south side of Huaichang road. The ground elevation is 62.041-63.121 m, and the buried depth is 6.1-7.2 M.
Figure 1. Location relationship of the proposed pipeline crossing Huaichang Road.

The pipe jacking well is located in the south of Huaichang Road, 23m away from the curb of Huaichang Road, and the receiving well is located in the south of Huaichang Road, 25m away from the curb of Huaichang road. Pipe jacking starts from jacking into the working pit and crosses Huaichang road. The influence of jacking construction on Huaichang road subgrade is analyzed by finite element method.

5.1 Model building

Midas GTS NX, a finite element software, is used to build a three-dimensional model including soil, highway subgrade, working well, receiving well and pipe jacking, and analyze the impact of pipe jacking construction on highway subgrade. Mohr Coulomb constitutive model is used for soil, plate element is used for working well and receiving well structure, and elastic solid element is used for pipe jacking material. The dimensions of the model along the X, y and Z directions are respectively 144m, 64.5m and 24.4m, where x is the jacking direction, y is vertical to the jacking direction, and Z is vertical. See Figure 2 and Figure 3 for the model overview.

5.2 Construction process simulation

According to the design scheme and construction experience of similar projects, and considering the most adverse impact of construction on highway subgrade, the construction process is divided into the following three working conditions.

(1) Working condition 1: pipe jacking to the curb on the north side of Huaichang Road;
(2) Condition 2: pipe jacking to the curb on the south side of Huaichang Road;
(3) Working condition 3: jacking completed.
5.3 Result analysis

For the construction of pipe jacking and passing through the existing highway, the influence of construction on pavement deformation is mainly analyzed. Condition 1, 2 and final condition (condition 3) are extracted when analyzing the influence on highway subgrade.

Through numerical simulation, the vertical displacement of the center of the highway subgrade, the top of the slope on the west side of the highway, and the top of the slope on the east side of the highway under various construction conditions (the abscissa is the distance along the longitudinal distance of the line from the model boundary /m, and the ordinate is the vertical displacement /mm) is obtained. The vertical settlement distribution curve of the subgrade is summarized and drawn as shown in the figure.

**Figure 4.** Distribution curve of longitudinal vertical displacement along the line at the center of Highway Subgrade.

It can be seen from the settlement curve that the maximum settlement at the center of highway subgrade during pipe jacking construction is 5.7mm, which does not exceed the control requirement of 15mm. The maximum settlement occurs at the completion of pipe jacking (condition 3).

It can be seen from the figure that the longitudinal influence range along the highway route is 18m, which is about twice the buried depth (7.2m) of the pipe jacking plus the outer diameter (1.02M) of the pipe jacking.

Through numerical simulation, the vertical displacement along the pipe jacking direction under various construction conditions (the horizontal coordinate is the distance along the longitudinal distance of the line from the model boundary / m, and the vertical coordinate is the vertical displacement / mm) is obtained. The vertical settlement distribution curve of subgrade is summarized and drawn as shown in the figure.

**Figure 5.** Vertical displacement distribution curve along jacking direction under various construction conditions.

It can be seen from the settlement curve that in the jacking process, the maximum displacement of the settlement tank moves forward to the jacking direction for each jacking section, and the maximum
settlement in the construction process is 5.5mm, which is 3M from the slope top on the south side of the road.

6. Monitoring data

The project was monitored on June 28, 2018, and jacking construction was completed on July 2, 2018. According to the monitoring data, 19 settlement measurement points of pavement, 6 settlement measurement points of side slope and 4 settlement measurement points of pipeline are monitored. See Figure 6 for layout of measuring points.

In this paper, the three points SX05, DL02 and DL04 with the largest deformation of the road surface are sorted out, and the vertical displacement curve of the road surface with time is shown in Figure 7. The vertical deformation and cumulative lateral deformation data of BG04, BG05 and BG06, the three monitoring points with large deformation, are sorted out, as shown in Figure 9.

The maximum value of pavement settlement is 5.7mm, the maximum value of slope displacement deformation is 4.66mm, and the maximum cumulative lateral displacement is 2.5mm.

7. Conclusion

Through the above deformation prediction and deformation monitoring analysis, the following conclusions can be drawn:

(1) The settlement value of numerical simulation is 5.7mm, and the settlement value after the monitoring deformation tends to be stable is 5.43mm. The calculation value of numerical simulation is feasible, and the settlement value can be predicted by numerical simulation, so as to provide basis for the three-level early warning value of monitoring unit.
(2) In Huairou area of Beijing, the width of the influence range of ground deformation caused by
the construction of pipe jacking and underpass is about twice of the buried depth of pipe jacking.

(3) After jacking, the settlement has been completed by 60%. The settlement tends to be stable
about two months after the completion of jacking.

(4) In the process of pipe jacking construction, grouting causes the road surface to swell and
deform. During the construction, a test section shall be set up, and the construction parameters shall be
adjusted in the test section to ensure the construction safety.

(5) The maximum displacement of the slope is 4.66mm, which is smaller than that of the pavement.
The slope has the cause of free face, and there is accumulated lateral displacement, and the maximum
accumulated lateral displacement is 2.5mm. From the deformation value, the pipe jacking construction
has obvious effect on the vertical deformation of the pavement, but has little effect on the vertical and
horizontal displacement of the side slope.

Through the analysis of the deformation prediction and deformation monitoring data of the
pavement, the settlement prediction results are basically consistent with the monitoring data. The
parameters used in the numerical simulation can be used as the basis for similar projects in Huairou
District of Beijing.

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