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Calculation of influence range of impact holing on the adjacent railway

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Abstract. In order to solve the impact of actual construction projects on the existing surrounding environment, the impact and vibration of the impact on the existing railway subgrade stability caused by the construction of the bridge foundation are analyzed. Based on the actual case of the construction project of No. 37 main pier across the Jiaoji Railway Main Bridge at Binlai expressway, the influence of the impact holing on the adjacent railway is analyzed. The influence range of the construction vibration is based on the Chinese Seismic Intensity Scale (GB/T 17742-2008) and Safety Regulations for Blasting (GB6722-2014), and taking the maximum velocity allowable value as criterion, the minimum safety range of impact drilling is obtained. Using the theory of small hole expansion to calculate the influence of the effect of soil compaction, the minimum allowable value of safe distance for the Construction technology of impact forming hole is considered 6.5m; in addition, based on the numerical simulation of nonlinear time history analysis, a reasonable exciting force parameter is given for practical engineering. The influence of impact amplitude A and impact frequency f on construction safety distance is analyzed. The results show that: The minimum safety distance of impact drilling is linear with the increase of impact amplitude A . When the impact frequency f is greater than 10Hz, the minimum safety distance tends to a fixed value as f increases. The results of this study guide the actual construction of the field, it guarantees the normal traffic of the Jiaoji Railway and provides a theoretical support for similar projects.

1. Research background

The impact of bridge pile foundation impact hole on the existing building structure has always been a hot issue in geotechnical engineering, and the structural disease caused by impact hole formation has become increasingly prominent^[1]. In the process of construction, the impact of vibration pile driving on the surrounding environment is divided into the following: 1) the vibration caused by impact hole reduces the strength of the soil around the pile and affects the bearing capacity of the bridge pile foundation; 2) the impact of the vibration load caused by impact on the adjacent structures, the influence degree of different construction technology is different; 3) impact hole formation squeezes the soil around the pile, resulting in plastic failure of the soil. Therefore, exploring the safe distance of impact hole formation on the surrounding environment and taking effective protective measures can effectively reduce the impact of impact hole formation on the surrounding environment^[2].

Shao Hongjie et al.^[3] used numerical analysis and combined with the field measurement results to estimate the pile side resistance in pile driving by using numerical analysis and combined with field test results in view of the weakening of the soil strength in pile driving. Dong Junfeng et al.^[4] analyzed the difference between pile-driving vibration damage and earthquake damage, enumerated the permissible limits of vibration in relevant current codes and standards, and evaluated the impact of pile-driving vibration. Li Sa et al.^[5] studied the influence of pile side friction on the sliding pile during pile driving. According to the different degree of influence, the soil around the pile was divided into three areas: full influence zone, partial influence zone and non-influence zone. And the calculation method of friction



resistance in different areas is given. CAVICCHI A et al.^[6] evaluated the drilling speed of rock percussion hole formation based on finite element simulation, and developed and verified a method for simulating dynamic indentation of percussion hole formation.

At present, there are few studies on the impact of percussion drilling on neighboring structures, especially on railway subgrades. Based on this, this paper combines actual engineering and uses small hole expansion theory calculations and numerical simulations to determine the minimum safe distance for percussion drilling. According to the actual situation of the Jiaoji Railway, the impact of the impact hole construction technology on the railway subgrade was analyzed, and the reasonable vibration frequency and amplitude were proposed. It provides an analysis method and judgment standard for the safe construction of similar bridge pile foundation impact-forming engineering, which has great theoretical reference value.

2. Project Overview

2.1 Bridge and railway position relationship

The overpass over Jiaoji Railway is the most difficult bridge in the reconstruction and expansion project of Shandong Binlai Expressway. The bridge design adopts 50m+85m+50m continuous box girder, the structure is orthogonal, the angle between the direction of the bridge and the downward line of the Jiaoji Railway is 104.47°, the cross-sectional width of the bridge is 26.5m, the starting point is K65+674.75, and the ending point is K65. +859.75. In order to minimize the impact of the construction of the bridge superstructure on the safe driving of existing railways, the overpass across the Jiao-Ji railway adopts the balanced rotation method.

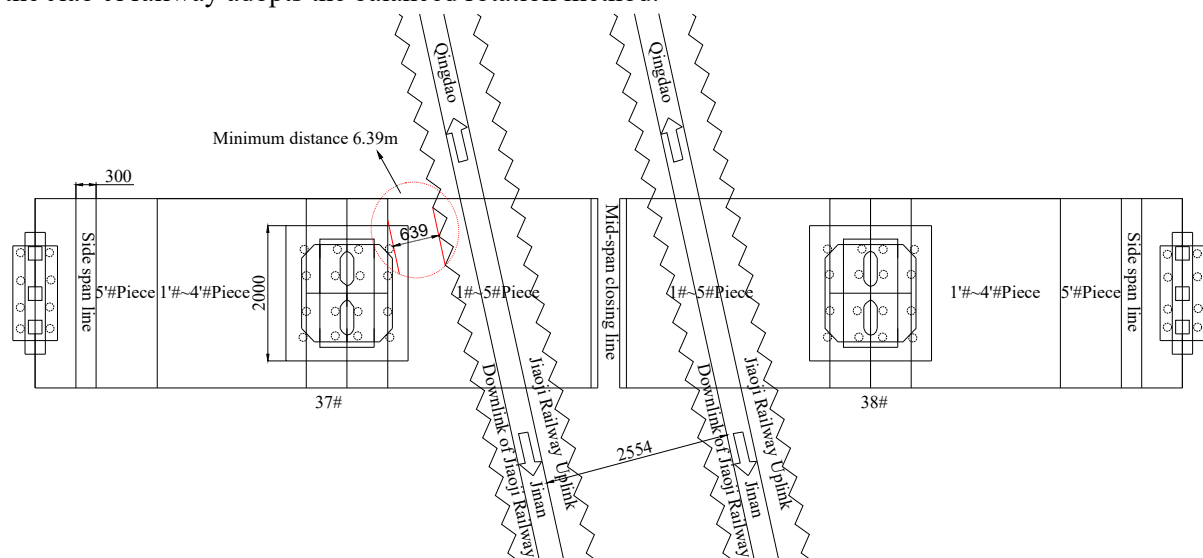


Figure 1. Plane map of bridge position

2.2 Physical and mechanical parameters of soil layer

The topography and geomorphology of the bridge site area are more complex, with many types of rock and soil, large changes in properties, large undulations in the bedrock surface, and complex lithology. The overburden is mainly Quaternary deposits; the underlying bedrock is mainly Yanshanian diorite, diorite porphyry, and gabbro porphyry.

3. Numerical simulation analysis

Vibration is generated during the impact hole construction, and vibration elastic waves are generated in the soil around the pile foundation and spread to the soil layer around the pile. The vibration caused by impact hole construction includes the following five vibration parameters: amplitude A, particle

velocity V , particle acceleration a , frequency f , and wave propagation velocity v . The vibration of the foundation soil caused by the impact hole is generally propagated to the surroundings in the form of a parabola proportional to the attenuation of the vibration amplitude and the square root of the distance^[2]. And the vibration attenuation is related to the state of the foundation soil, the elastic modulus of the soil and the frequency of drill bit impact. In engineering practice, it is difficult to accurately obtain the dynamic response parameters of the foundation soil under impact. Therefore, the MIDAS-GTS finite element software is used to establish the space mechanics model of the pile-soil interaction, and the vibration load is applied to the infinite space to simulate the actual vibration and impact construction of the hole, and analyze the impact and scope of the impact of the vibration on the surrounding environment.

3.1 Model building

In this analysis, the pile diameter is taken as 1.8m, and the calculation range is 45m outside the pile circumference. The calculation model is approximately regarded as a semi-infinite space body. For the boundary conditions of the calculation model, the X, Y direction displacement constraints are imposed on the side of the model, and the X, Y, Z direction displacement constraints are imposed on the model bottom surface. The vibration load generated during the construction process is applied to the rigid pile head in the center of the model to accurately simulate the actual working conditions. The three-dimensional meshing of the calculation model is shown in Figure 2.

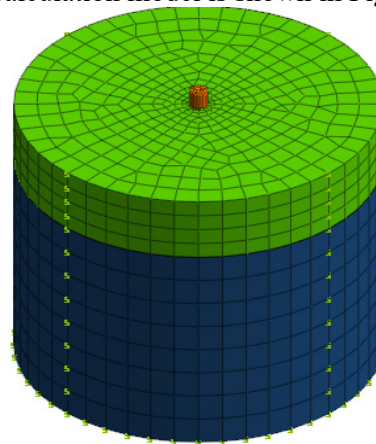


Figure 2. Grid partition diagram of impact holing construction model

Concrete and harder brittle rocks are mainly shear failure or tension failure. The rigid pile adopts the elastic constitutive model, and the rock and soil mass beside the pile adopts the Mohr-Coulomb constitutive model.

3.2 Parameter selection

The loading path of the impact force in the model is simplified to the downward maximum and zero point, the impact force amplitude A is 150kN, the vibration frequency f is 3Hz, and the loading path of the load is shown in Figure 3.

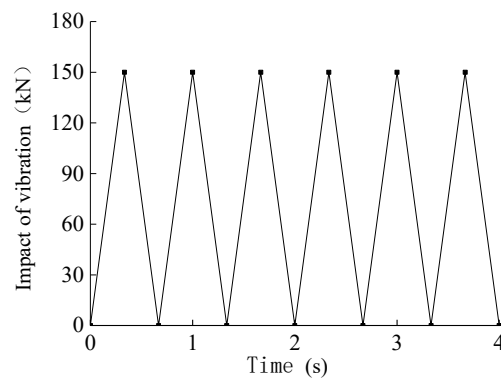


Figure 3. Impact loading path

According to on-site geological survey data, the foundation soil layer is simplified into two layers, the upper layer is silty clay, and the lower layer is medium weathered diorite. The physical and mechanical parameters are shown in Table 1.

3.3 Result analysis

By imposing a vibration and impact load ($f=2\text{Hz}$, $A=150\text{kN}$) on the foundation soil for 5s, taking into account the actual situation of the impact hole, 13 data points along the radial direction of the foundation soil model surface under the action of the vibration load. The vibration velocity response curve is shown in Figure 4.

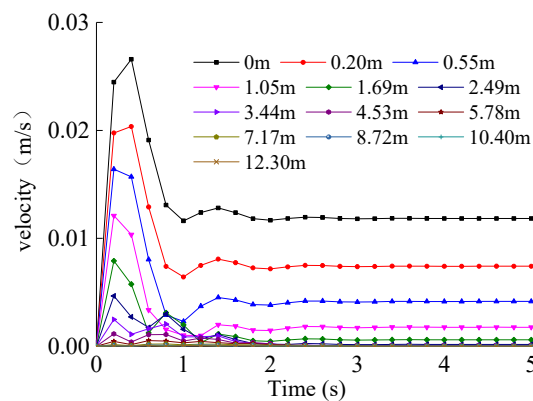


Figure 4. Response speed of ground vibration

It can be seen from Figure 4 that the surface vibration response speed curve at different points first rapidly increases to the maximum value as time increases, then rapidly decreases and maintains a fixed value fluctuates up and down, and the vibration speed tends to a stable value as time increases. And it can be seen that as the distance from the pile foundation increases, the maximum surface vibration response speed gradually decreases.

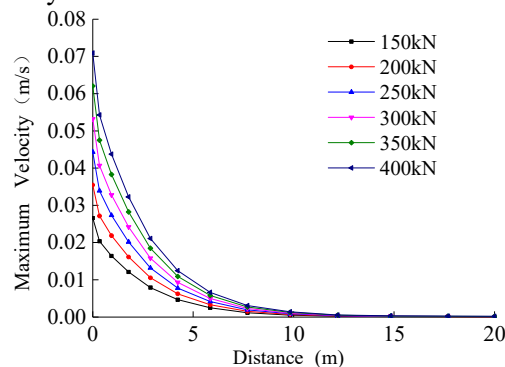


Figure 5. Surface maximum response velocity under different impacting force

It can be seen from FIG. 5 that, under the action of different impact forces, as the distance d from the pile foundation increases, the maximum value of the surface vibration response velocity decreases as an "inverse proportion function curve". At the same time, it can be seen that with the increase of the amplitude A of the impact force, the maximum velocity at different positions on the ground surface also increases. According to the provisions of the Blasting Safety Regulations (GB 6722-2003) and the Code for Seismic Design of Structures (GB 50011-2001) on the impact control on the surrounding environment, the particle vibration velocity of 0.01m/s is taken as the safety control standard, and the minimum safety distance under the action of different impact force amplitude A is calculated by interpolation, as shown in FIG. 5.

As shown in FIG. 5, under different impact frequencies, the variation curves of maximum response velocity value of data points cross each other without obvious rules. Select 0.01m/s as the maximum allowable vibration velocity of the ground, and obtain the minimum safety distance with different impact frequencies through linear interpolation, as shown in FIG. 4. It can be seen from FIG. 4 that with the increase of impact frequency to the maximum value of 3.2m, the minimum safety distance gradually decreases and tends to a stable value when it exceeds 10Hz.

To sum up, the impact force is the key factor affecting the minimum safety distance. When the impact frequency exceeds 10Hz, the impact on the minimum safety distance can be ignored. Considering that the impact frequency generally fluctuates in a small range in practical engineering, the impact of impact frequency on the minimum safety distance can be ignored. The bit impact force for on-site drilling is about 200kN, and the analysis in FIG. 5 shows that the minimum safe distance is 4.2m.

4. Comparative analysis and engineering application

The pore expansion theory mainly uses the elastic theory to solve the range of the elastic zone, and defines the safe distance by the boundary conditions of the plastic zone; Finite element simulation analysis is mainly used to establish a finite element model through numerical software to simulate the impact of percussion drilling to form holes on the surrounding environment, and to determine the safe distance through the maximum response speed limit specified in the code. Due to different influencing factors considered by different calculation methods, the safety distance obtained by the corresponding calculation method is different. The calculation results obtained by the two calculation methods are shown in Table 3.

Table 1. Comparative analysis Table of calculated results

Analysis method	Purpose	Calculated safe distance /m
The numerical simulation	The finite element calculation model is established to analyze the influence range of percussion drilling	4.2m
Pore expansion theory analysis	The elastic zone is solved by elastic theory to define the safe distance	7m

It can be seen from Table 3 that the range of safety distance calculated by numerical simulation analysis and theoretical analysis is between 4.2m and 7m. Considering the actual hole forming characteristics on site, impact rate, pile driving technology and other factors, 6.5m is selected as the minimum safety distance. As mentioned above, the closest distance between the railway and pile foundation is 6.39m, which is within the range of the minimum safe distance. Therefore, corresponding measures should be taken in the construction process to reduce the impact of construction on the railway.

In September 2018, when the Kuajiaoji railway trunk line bridge was being constructed on site, the design unit changed the original design plan by referring to the above analysis results. Two rows of 16 pile foundations of No.37 main pier were constructed by manual digging, and two rows of pile

foundations of far railway line were constructed by percussive hole formation. After the change of the scheme, the construction of the main pier of the bridge not only ensures the normal operation of the railway trunk line, but also ensures the construction progress, which indicates that the safety range proposed in this paper is scientific and reasonable.

5. Conclusions and recommendations

(1) Finite element numerical simulation analysis and pore expansion theory are used to calculate and analyze the influence range of impact hole formation construction on No. 37 main pier of binlai high-speed Kuajiaoji Railway viaduct. Considering the actual construction geological characteristics and pore formation construction technology and other factors, the minimum safety distance is determined to be 6.5m.

(2) In the process of pore forming, the impact amplitude A has a great impact on the minimum safety distance. With the increase of the impact amplitude A , the minimum safety distance increases approximately linearly. When the impact frequency f is less than 10Hz, it has a great influence on the minimum safety distance. When the impact frequency exceeds 10Hz, the minimum safety distance tends to be stable with the increase of the impact frequency.

(3) In the process of site construction, it is suggested to strengthen the monitoring of the impact range of percussion drilling construction to ensure the running safety of existing railway lines in the construction process, and compare and analyze the measured value and calculated value to ensure its effectiveness, thus providing effective reference for similar projects..

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