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Safety Analysis and Risk Control of Pipe Jacking Technology in Municipal Water Supply Pipeline River Crossing Construction

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Abstract Taking a municipal water supply pipeline river crossing construction project as an example, this paper explains the construction characteristics of pipe jacking technology, construction application, and gives the formula for calculating the mechanical parameters of each stage of municipal water supply pipeline river crossing construction. According to the relative position relationship between the new pipeline and the urban river, and to meet the requirements of certain boundary effects to determine, using finite element simulation software MIDAS-GTSNX to build a numerical model of municipal water supply pipeline river crossing construction, and at the same time to determine the parameters of the model in this paper and boundary conditions. Combined with the model and research data in this paper, the safety analysis in the construction of municipal water supply pipeline river crossing is explored, and the risk management and control strategy is proposed. The result of pipe settlement in municipal water supply pipeline river crossing construction is 1.237, which meets the safety standard requirements of pipe jacking technology. As long as the friction coefficient of pipe-soil is maintained less than 0.43, slight settlement occurs in front of the working surface, while the safety coefficient is much larger than the bearing capacity. In order to improve the construction risk control, three risk control strategies are proposed to accelerate the sustainable development step of urban planning, which greatly contributes to the economic and social effects.

Index Terms pipe jacking technology, urban planning, numerical modeling, river crossing construction, sustainable development, social effect

I. Introduction

Although the construction technology of pipe jacking method started late and developed slowly in China, some remarkable achievements have been made in the field of pipe jacking engineering through the unremitting efforts of Chinese researchers [1], [2]. From 1987 to 2010, China completed more than 20 pipe jacking projects with a length of more than 1000m, which is in the forefront of all countries, and the world record of single jacking length in pipe jacking project is held by the project located in Zhejiang, meanwhile, important progress has been made in the field of submarine pipeline jacking, such as the construction of Hong Kong-Zhuhai-Macao Bridge and other projects [3]-[5].

At present, the construction speed of Chinese cities is accelerated year by year, power pipelines, communication pipelines, drainage pipelines and other pipeline projects cross each other peer, and city roads also interact with each other, when faced with the pipeline project expansion and upgrading problems, in order not to exacerbate the contradiction between the urban construction construction and the existing urban main life, it is necessary to rely on the jacking method of pipeline engineering construction [6]-[8]. Pipe jacking engineering construction technology is characterized by its ability to be constructed in a specific location to complete the pipeline laying work, which can avoid as much as possible the impact on the structures along the pipeline, and it has become an important means of construction of urban underground pipeline under the river, buildings (structures), etc [9], [10]. The parallel jacking construction with multiple rows of pipe jacking can improve the construction efficiency and shorten the construction period [11], [12]. However, the pipe jacking construction can disturb the adjacent soil, and improper control of construction and protection measures can lead to damage to the surrounding environment as well as safety and stability problems for the neighboring buildings. Top pipe jacking will bring higher construction difficulty and risks, requiring more complex coordination and control measures to ensure the safety and quality of construction [13]-[15].

Resources such as water and electricity are the basic resources for cities to maintain normal operation, and it is necessary to maintain a stable supply of water and electricity resources [16]. Taking water resources as an example, long-distance water transfer needs to spend high engineering construction costs, and the subsequent maintenance also needs to invest more resources, and needs to adopt a highly efficient and low-investment construction technology to meet the demand for the supply of water resources [17], [18]. As a mature construction technology, jacking pipe down through the river can meet the demand for long-distance water resources deployment in most cases, and it is necessary to make a detailed analysis of the construction safety risk control of jacking pipe down through the river [19], [20].

Compared with the traditional research on the safety and risk control of municipal water pipeline river crossing construction, this paper adopts the finite element simulation software MIDAS-GTS NX to quantitatively assess the safety of water pipeline river crossing construction, and puts forward a few targeted strategies to enhance the safety and risk control awareness of construction personnel. Taking a municipal water pipeline river crossing construction project as the research background, we discuss the construction characteristics and application of pipe jacking technology, and determine the parameters and mechanical structure of the main control points in the construction process. Considering the boundary conditions and irregular structure shape of the water supply pipe river crossing construction, accordingly, the finite element simulation software MIDAS-GTS NX is used to establish a numerical model including geotechnical, water supply pipe, pipe jacking, working well and receiving well structure. Based on the step-by-step simulation according to the actual construction program, the safety and risk control in the construction of municipal water supply pipeline river crossing is explored in all aspects.

II. Construction of river crossings for water pipelines based on pipe jacking technology

II. A. Project Overview and Construction Characteristics of Pipe Jacking Technology

II. A. 1) Summary of works

This project is a construction project for municipal water supply pipelines crossing rivers. The construction technology for steel pipe jacking inside reinforced concrete pipes includes D2600 × 260mm reinforced concrete pipes and D2220 × 26mm welded steel pipes with straight seams; This section involves two top pipe construction measures wells, namely the working well H1 # (13.6m × 8.8m) and the receiving well H2 # (22.6m × 13.6m). The designed bottom elevation of the top pipe in H1-H2 section is 387.445-388.433m, and the designed ground elevation of the construction site is 396.691-407.543m. The maximum burial depth of the pipe bottom is 22.159m, the shallowest burial depth is 10.253m, and the total length of the pipeline is 440m. This pipeline crosses the Xiling section of the Fenghe River in Xi'an, Shaanxi Province, China. The underground geological conditions are complex, and this section of the pipeline is part of the drinking water work of the Southwest Suburban Water Plant, involving the daily water use of urban users, which is of great significance.

II. A. 2) Construction characteristics of pipe jacking technology

The cross river construction of municipal water supply pipelines based on pipe jacking technology is a non excavation pipeline laying method based on the principle of pipe jacking construction. Set up receiving and working wells on the pipeline laying path, and use hydraulic jacks to control the pipe jacking. The use of non excavation technology can achieve the goal of renovating underground pipelines without excavating channels, greatly reducing engineering costs and expenses, saving engineering time, and improving work efficiency. It is widely used in the construction of municipal water supply pipelines. The use of top-down construction will not have a significant impact or damage to the surrounding environment, and only requires local construction with fences, without the need to excavate a large area [21], [22]. Before construction, the technical plan for pipe jacking should be strictly demonstrated on the terrain, and a reasonable construction plan should be formulated based on the actual geological conditions. With the continuous advancement of technology and the expansion of its application scope, pipe jacking technology will play an important role in more complex environments.

II. B. Construction application of pipe jacking technology

II. B. 1) Preparation for pipe jacking construction

River crossing pipe jacking projects usually use C50 reinforced concrete steel pipes due to the deep thickness of the soil cover, and paint to prevent corrosion of the steel pipes. Construction standards should be strictly followed. The adoption of short pipe can effectively avoid the problem of route deviation, with strong maneuverability, but obviously increase the frequency of pipe loading. Pipe jacking equipment includes top iron, jacks, high pressure oil pumps, earth moving equipment, etc., which should be fully prepared before construction.

II. B. 2) Pipe jacking construction process

The pipe jacking method is to put the structure into the base to form the channel needed for the operation. Before the pipe jacking construction, the receiving and working wells are dug in advance, and the construction work is carried out in the wells that have already been formed. Since the working space of pipe jacking construction is assumed by the pipe jacking well, the construction of the pipe jacking well should be planned in detail. The spacing and arrangement of working wells and receiving wells should be set reasonably, usually, the spacing of working wells is set the same as the spacing of inspection wells. Working wells can also be divided into single-row hole wells and single hole two kinds of single-hole working wells are mostly circular in cross-section, the strongest bearing capacity, single-row hole wells are mostly square in cross-section, the bearing capacity is weaker, so according to the different geological conditions and the demand for the bearing capacity to choose the appropriate working wells, reduce the cost of construction and maximize the benefits.

II. B. 3) Pipe jacking construction procedure

(1) Pipe jacking design

The maximum length of the pipe is 440m, and it crosses the lying river. Mechanical pipe jacking is selected, and appropriate hydraulic jacking system is used to ensure that the jacking force meets the needs of the TBM. When crossing the valley river, use the special head to break, and slow down the digging speed to ensure safety. The subsidence observation point is set at the road axis, and then the vibration monitoring is carried out to grasp the driving dynamics at any time.

(2) Back design

The back of this project adopts reinforced concrete to lean against the wall. After the concrete pouring at the bottom of the working pit is completed, the reinforcement lashing and support mold are carried out. The back height is 4000mm, the width is 5000mm, and the thickness is 500mm. The minimum strength of the backseat wall should ensure that it is not destroyed under the action of the design jacking force, and leave a large degree of safety. In order to give full play to the jacking efficiency of the main top workstation, the compression rebound is required to be minimal.

(3) Guide rail installation

The guide rail is composed of rail, beam and pad welding, and the rail uses 50# heavy steel rail. Before installing the guide rail, check the position of the center line of the pipeline. The guide rail installation must meet the requirements of the middle line and elevation of the pipe jacking. The position deviation of the guide rail axis should not exceed 3mm, the height deviation of the top surface should not exceed 3mm, and the deviation of the inner distance between the two rails should not exceed 2mm. The two guide rails should be straight, parallel and equal in height. There is no longitudinal slope of the pipe jacking here, so there is no need to set longitudinal slope of the guide rail.

(4) Main top equipment installation

The main top jack needs to be fixed on the combination jack stand. When jack arrangement is jacked in, the number of catties is adjusted according to the change of the jacking force during the jacking process. Usually, 2, 4, 6 and 8 are selected only according to the even combination. After installation, the axis of the top iron shall be parallel and symmetrical with the axis of the pipeline, and the contact surface between the top iron and the guide rail and the top iron shall not have dirt and oil. Cushion material should be used between the top iron and the pipe mouth. When the top force is close to the allowable compressive strength of the pipe joint material, U-shaped or annular top iron should be added to the pipe end. When jacking in, the staff shall not stay above and on the side of the top iron, and should observe the top iron at any time for abnormal signs.

(5) Water seal ring installation

The water seal ring is composed of embedded steel plate ring, rubber ring, steel press plate, steel press ring and bolt. The structure adopts steel flange and press plate, and the middle is sandwiched with 2 layers of 20mm thick rubber water seal ring. After the installation is fixed, cement mortar is used to seal the joint at the contact surface between the embedded steel ring plate and the concrete wall.

(6) Mud treatment system installation and debugging

Before the pipe jacking machine is pushed in, the mud treatment system should be installed and adjusted. The pipe jacking operation can only be carried out after the installation and debugging of the mud treatment system. Grouting should be carried out from the grouting hole every 6 meters.

II. C.Main control points for river crossing construction of water supply pipelines

II. C. 1) Friction-reducing grouting

Thixotropic slurry system consists of three parts: slurry mixing, slurry injection and piping. Slurry mixing is to mix the grouting material with water and then stir it into the required slurry (the slurry should be left to stand for 24 hours before use). Grouting is carried out through the grouting pump, according to the pressure gauge and flow meter, it can control the pressure of grouting (pressure control in the water depth of 1.1-1.2 times) and the amount of grouting (metering bucket control). The pipe is divided into a main pipe and a branch pipe, the main pipe is installed on one side of the pipe, and the branch pipe transports the slurry from the main pipe to each grouting hole. Concrete pipe grouting holes are arranged as follows: starting from the head of the machine, four grouting holes are placed at intervals of 5.0m, and each grouting hole is fitted with a small 1-inch ball valve, which is connected to the main grouting pipe by a rubber hose. The slurry main pipe is a 2-inch galvanized iron pipe connected to the slurry pump. The thixotropic slurry is mixed with water in a certain proportion in the mixing cylinder and then stored for 24 hours before use.

II. C. 2) Trunking arrangements

When the river crossing construction of municipal water supply pipeline is based on pipe jacking technology, the jacking force is limited by the permissible jacking force of the backseat of the working well or pipe, and cannot be increased infinitely. According to experience, generally for a jacking length of more than 100m jacking pipe should be considered to set up relay relay room, relay room according to the jacking force calculation to layout.

II. C. 3) Top force calculation

Pipe jacking process is a complex mechanical process, which involves many disciplines such as material mechanics, geotechnics, fluid mechanics, elastic-plastic mechanics and so on. Small pressure, a large amount of mud and sand influx, will cause damage to the road surface, surface facilities damaged; pressure is too large, will increase the main jack load, serious may produce the phenomenon of topping, curve pipe jacking jacking force can be divided into axial force and lateral force two parts.

(1) Pipe axial force

The back is made of C30 reinforced concrete, 5m long x 4m wide, 018@200 the upper layer of steel mesh is arranged bidirectional. Ignoring the influence of the steel backseat, it is assumed that the jacking force exerted by the main top jack is uniformly acted on the soil behind the working pit through the backseat wall. In order to ensure the safety of the backseat in the process of project loading, the reaction force or soil resistance R of the backseat should be 1.2~1.6 times of the total jacking force P, and the reaction force R can be calculated by the following formula:

R=a*B*(γ*H2*Kp/2+2c*H* √Kp+γ*h*H*Kp)

where: R- reaction force of total thrust, kN, a-- coefficient, a-1.5~2.5, the value is 2, B -- the width of the backseat wall, the value is 5m, γ-- bulk density of soil, kN/mm³, value 19 kN/mm³, H-- Height of backseat wall, value 4m, Kp -- passive earth pressure coefficient, value 3, Cohesiveness of soil, kPa, 40kPa, h -- Height from the ground to the top of the rear seat wall, value 15.

Backseat reaction:

R=47647.44KN> Design maximum total pushing force 23266.387KN*1.6-37226.22KN.

Therefore, the structure of the back wall meets the design requirements.

(2) Pipe lateral force

Figure 1 shows a schematic diagram of the jacking force of the straight pipe, and the turning Angle δ of the broken line is the supplementary Angle of $\angle \mathrm{ABC}$.

Because $\angle ABC = 2\beta$ shown:

$$\delta = 180 - 2\beta \tag{1}$$

$$\alpha = 180 - 2\beta \tag{2}$$

$$\delta = \alpha \tag{3}$$

Assuming that the pipe wall friction force is neglected, and assuming that the axial jacking force in pipe section AB is P_1, the axial jacking force and lateral component force in pipe section BC are:

$$F_{Axis} = P_2 = P_1 ctg\alpha \tag{4}$$

$$F_{Lateral} = P'_2 = P_1 tg\alpha \tag{5}$$

where P_2 - axial jacking force of the next pipe section, P_2' - lateral force of the next pipe section.

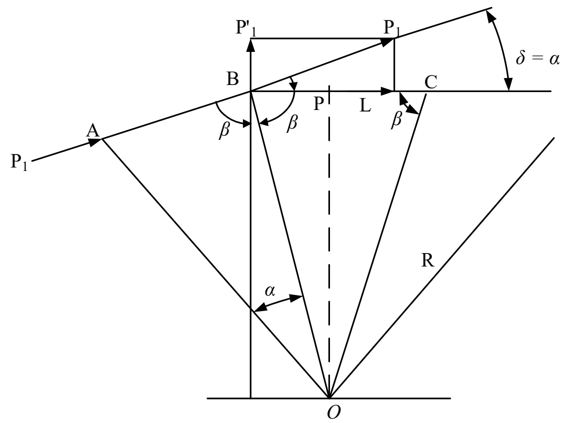

Figure 1: Curve pipe jacking force diagram

(3) Total pipe jacking force: (3) Total pipe jacking force: 1

II. C. 4) Accounting for back wall reactions

Figure 2 for the back wall force analysis schematic diagram, disappear, compression deformation disappears with it. This elastic deformation that is like a normal, pipe jacking, the back should not be destroyed to produce impermissible compression deformation.

The back is not allowed to appear up and down or left and right uneven compression. Otherwise, the jack in the remaining surface back, resulting in jacking deviation. In order to ensure the quality of jacking and construction safety, the strength and stiffness of the backrest should be calculated during construction. Backrest force calculation formula:

$$Ep = \left(0.5\gamma H2kp + \gamma Hhkp + 2CHKp^{1/2}\right)B/K \tag{6}$$

where

Ep - Allowable resistance of the backseat wall (Kn).

B - Width of the backing wall (m).

γ - Capacity of the soil (KN/m^3), take $18KN/m^3$.

H - Height of the recoil wall (m).

Kp - Passive earth pressure system.

c - Cohesion of the soil (kPa).

h - Height of soil from the ground to the top of the recoil wall (m).

K - Factor of safety B/H when not greater than 1.5, take $K=1.5$.

B/H When greater than 1.5, take $K=2$.

F - Top force on the backrest.

R - Soil reaction force.

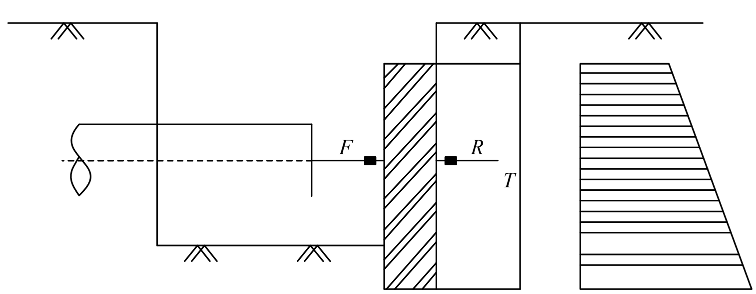

Figure 2: Schematic diagram of force analysis on back wall

II. C. 5) Measurement of straight pipe jacking

Measurement of straight pipe jacking is the key technical problem of straight pipe jacking. Because the inside and outside of the pipe can not be visualized during the straight jacking, the conventional construction measurement method must be changed, and the latitude and longitude instrument must enter the pipe. However, the pipe is constantly moving forward in the construction process, so the coordinates of the measuring station are also constantly changing. To point out the forward direction of the pipe at any time in the case of constantly changing station coordinates, which is the central problem to be solved by pipe directional measurement in straight pipe jacking. There are 2 solutions:

(1) Arrange many total stations in the pipeline, relying on the advantages of the total station, determine the direction of each station's latitude and longitude through the computer in a short time, and point out the direction of pipe jacking. This method is essentially the method of latitude and longitude guide line, which is feasible but costly.

(2) An ordinary latitude and longitude instrument is set up in the pipeline and a spotter, both of which are arranged at the back of the tool pipe. Tool pipe on the ruler, latitude and longitude instrument, rear-view surveyor between the three to maintain a certain distance, and fixed with the pipe, with the top of the pipe and then follow up. The latitude and longitude instrument, the center coordinates of the rear surveyor's beacon is based on the actual pipe axis calculated in advance, the tool pipe on the coordinates of the measurement point to check the design axis can be obtained.

II. C. 6) Straight pipe jacking line control

In the process of pipe jacking, the axial control measuring instrument mainly adopts J2 laser latitude and longitude instrument.

(1) Straight line jacking

When jacking in straight section, the deviation of jacking axis has great relationship with pipe jacking resistance, ground settlement, water tightness of pipe interface and hydraulic condition of pipe, so the following control and measurement methods are essential. Set up a firm measuring platform at the back of the working shaft leaning forward. The height of the platform matches the axis elevation, the laser latitude and longitude instrument is set on the platform, the infrared laser direction is adjusted, the height is the same as the design axis, there is a laser target at the center of the shell circle after the head, the light spot position reading on the light target is the actual deviation of the tail of the head. The reading of the light spot on the light target is the actual deviation of the tail of the machine. When combining with the folding angle between the front and rear shells of the machine head, the rolling angle of the machine head, and the reading of the tilt meter during the on-site construction, we can calculate the on-site deviation and development trend of the machine head. Thus the direction size and timing of corrective action can be determined.

(2) Straight section jacking

For steel pipe: the main use of inter-relay adjustment angle. For concrete pipe: the pipe must be forced to form a straight when jacking. Generally in the first 20 meters of the pipe formed after the straight, the back of the pipe section to follow up the basic along the original “straight track” forward. In order to ensure that the interface of each pipe section open evenly to ensure that the straight of the line quality, hydraulic jacks must be used to adjust the interface opening amount. When the interface is open, with padded thick wooden pads embedded in the opening and make the interface opening amount to maintain a constant.

The back is compressed under the action of the jacking force, and the direction of compression is consistent with the direction of the jacking force. When the jacking is stopped, the jacking force. That is:

$$tg\alpha = L/R \tag{7}$$

$$X = DL/R \tag{8}$$

$$X_0 = D_0 L/R \tag{9}$$

where, L - length of the pipe section (m). R - radius of curvature (m). D - outer diameter of the pipe section (m). D_0 - inner diameter of the pipe section Inner diameter of the pipe section (m)

Calculated as: pipe section corner α.

Pipe outer seam difference X.

Pipe outer seam difference X_0.

II. C. 7) Overexcavation for straight pipe jacking

Straight pipe jacking, which requires the linearly shaped pipe section to move along the circular arc, is shown in Fig. 3 as a schematic diagram of over-excavation for straight pipe jacking. Therefore it is inevitable to over-excavate.

The size of overexcavation is related to the bending radius, pipe diameter and pipe section length. The amount of over-excavation can be calculated according to the following formula:

$$m=\left[R-\frac{D}{2}\right]\left[1-\cos\frac{l}{2R}\right) \tag{10}$$

where m - amount of overdigging in the radius direction (m), R - Bending radius (m), D - Pipe outer diameter (m), l - length of pipe section (m).

Steel pipe jacking because of the design of the bend radius is very large, the amount of over-excavation will be very small and negligible. But there is a problem of over-excavation in concrete straight jacking. For soft soil the situation will be better, but for hard soil this is the need for straight jacking, otherwise the pipe section is difficult to turn, and the friction resistance will be increased as a result. So concrete pipe jacking in hard soils has to be considered as a method of over-excavation.

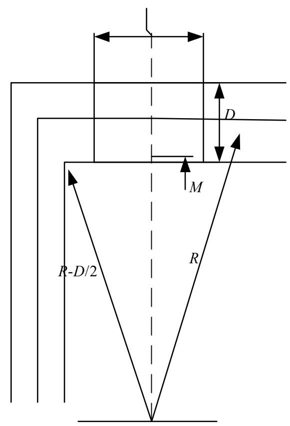

Figure 3: Schematic diagram of overcutting of straight pipe jacking

II. D.Numerical modeling

In the application of numerical analysis of municipal water supply pipeline river crossing construction, the main methods used are finite element method (FEM), boundary element method (BEM), discrete element method (DEM), Langrange element method, and block theory, etc., or the coupling of the above methods. Among them, the finite element method is a numerical method for solving mathematical physics problems according to the variational principle, which is a product of the combination of engineering methods and mathematical methods, and can solve problems that cannot be solved by analytical methods, especially for the boundary conditions and the structure with irregular and complex shapes, which is an effective numerical method, and therefore, the method has been widely used in practical engineering [23]-[25]. This municipal water supply pipeline river crossing construction investigation adopts the finite element analysis method, using the finite element simulation software MIDAS-GTS NX, to establish a model including geotechnical, water supply pipeline, pipe jacking, working well and receiving well structure. Step-by-step simulation is carried out according to the actual construction plan to analyze the safety and risk control in the construction of municipal water pipeline river crossing.

II. D. 1) Scope of calculation

According to the information related to the water supply pipeline line in the region, the water supply pipeline line present an up-and-down 57.7° oblique intersection relationship. MIDAS-GTSNX is used to establish a three-dimensional finite element numerical model, in which the vertical direction is 2-axis in three-dimensional modeling, and the x-axis satisfies the right-hand rule with the y-axis and z-axis. The calculation area is mainly determined according to the relative positional relationship between the new pipeline and the urban river, and meets the requirements of certain boundary effects. Therefore, the overall dimension of the 3D numerical modeling stratum is 160m (x) × 140m (y) × 90m (z).

II. D. 2) Network segmentation

In the computational modeling, the strata, bearing platforms and piers are simulated using a hybrid grid combining tetrahedral solid units and hexahedral units, and transitioning to pentahedral in the mutation position, the pile foundations are simulated using a one-dimensional beam unit, and the pipe jacking lining and work well lining are simulated using a two-dimensional plate unit. Railroad equivalent load and water pressure are added in the form of surface load; the whole model has 181,631 cells and 117470 nodes; the mesh is densely distributed around the piers, pile foundations, pipelines and work wells, and gradually becomes sparse outward.

II. D. 3) Selection of basic parameters

Referring to the detailed investigation report of the river crossing project of municipal water pipes in other regions and combining with the ground investigation report of the water supply pipeline, the abutments, bearing platforms and pile foundations are selected with reference to the relevant contents of the "Structural Design Specification for Municipal Water Pipe and River Crossing Project".

II. D. 4) Boundary conditions

In this model, the computational and analytical boundary conditions are taken as follows: the bottom surface of the soil body is computed to constrain the degrees of freedom in the vertical direction z, the sides of the soil body are computed to constrain the degrees of freedom in the lateral directions x and y, and the surface of the ground is a free surface.

(1) Self-weight: The program calculates the self-weight after automatically calculating its volume according to the established unit material capacity weight, and finally assigns it to each unit node for analysis.

(2) Equivalent load of water supply pipe: according to the main force + additional force of the railroad provided in the structural design data of the municipal water pipe river crossing project in the region, the equivalent load of the pipeline is calculated and applied, of which the water supply pipe is 22,163.2kN

(3) Water pressure: Consider according to 0.6 m water depth, and apply surface load in the river area.

III. Security analysis and risk management strategies

III. A. Security analysis

III. A. 1) Safety Evaluation of Pipeline Settlements

During the construction of pipe jacking working pit and pipe jacking, the foundation soil will be disturbed, resulting in redistribution of soil stress field, affecting the existing railroad roadbed and causing additional settlement and horizontal deformation. The soil quality of the river and the structural parameters of the pipe are shown in Table 1, the soil-pipe model and network division are shown in Fig. 4, the vertical deformation of the soil body after geostress equilibrium is shown in Fig. 5, the vertical stress distribution of the soil body after geostress equilibrium is shown in Fig. 6, and the simulation results of the displacement of the soil body are shown in Fig. 7. According to the design scheme, geological data, the basic situation of the river at the project crossing, etc., the settlement of the pipe jacking across the river was modeled and analyzed and evaluated using MIDAS-GTSNX finite element software. Reinforced concrete pipe through pipe jacking construction technology, wherein the reinforced concrete pipe is D2600, and the straight welded steel pipe through D2220×26mm. This section involves two pipe jacking construction measure Wells, namely working well H1# (14.8m*8.8m) and receiving well H2# (22.6m*13.6m). H1-H2 section top pipe buried depth design bottom elevation 387.445~388.433m, construction site design ground elevation 396.691-407.543 m, the maximum buried depth of pipe bottom 22.159m, the shallowest buried depth of 10.253m, the total length of the pipeline 440m. The loss of soil caused by the cutter over-excavation can be filled by grouting, but the bad effect of the filling is the main reason of the road settlement, and this time, the gap soil substitution is used to simulate the way. Pipe section outside the drawing of a certain thickness of gap soil line group, using MIDAS-GTSNX finite element software for simulation, the contact surface unit is used to Moore Kuei enterprise soil yield conditions. This time, the allowable value of pipeline settlement is controlled by 10mm. The calculation result is 1.237mm<10mm, so the pipe settlement meets the requirement. It is recommended that the engineering design stage should be supplemented with the results of physical exploration of existing pipelines, pipelines and other structures 10cm on both sides of the scope of the project, and the location of underground pipelines, elevation, pipe and road center location and cross-section topography should be re-tested before construction, and the topsoil within the range of 1.0m of the surface layer should be excavated by manual excavation in the course of construction to prevent the destruction of the established pipelines with shallow burial depths, and the evaluation of the safety of the construction is to reduce the risk of the established risk management and control of the powerful Guarantee.

Table 1: Soil quality and pipeline structure parameters of rivers

Materials	Elastic modulus /MPa	Poisson's ratio	Cohesion /kPa	Friction Angle/(°)
Subgrade soil	43	0.41	53	28
Undisturbed soil	17	0.45	18	15
Concrete pipe	38694	0.33		

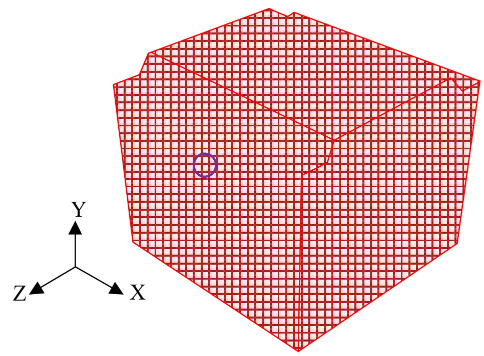

Figure 4: Soil - pipeline model and network division

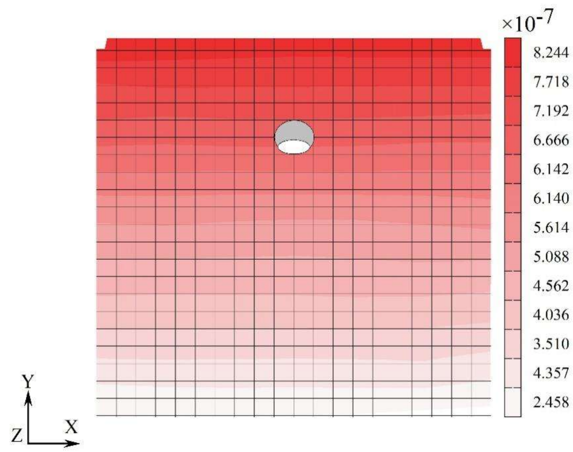

Figure 5: Vertical deformation of soil after ground stress equilibrium

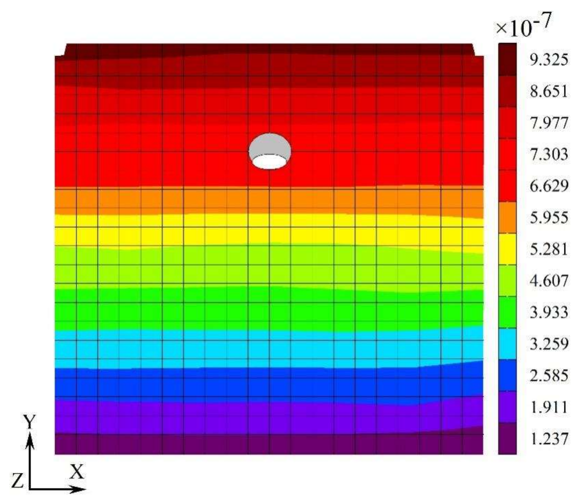

Figure 6: The vertical stress distribution of the soil body of the soil

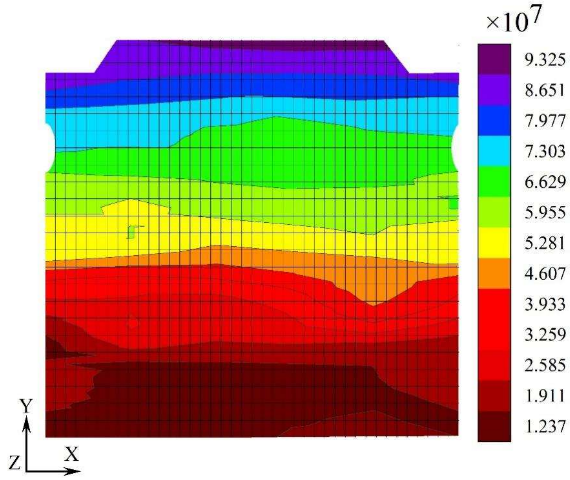

Figure 7: Soil displacement simulation results

III. A. 2) Impact of pipe wall friction on engineering safety

The friction between the pipe jacking surrounding and the excavated soil is the main component of the pipe jacking resistance, which has many unfavorable effects on the pipe jacking construction. In engineering practice, factors such as jacking deviation, stratigraphic change, equipment failure, construction stagnation and so on will cause a sudden increase of pipe wall friction resistance, and the use of reasonable grouting means can effectively reduce the pipe-soil friction coefficient and improve the pipe wall friction resistance. In this subsection, the influence of pipe wall friction resistance on engineering safety is investigated, and it can be seen from the formula that the key to influence the pipe wall friction resistance lies in the pipe-soil friction coefficient. Namely:

$$f_2 = \mu' 2\left(B + D\right)\tau_a L + W\mu' L \tag{11}$$

where, f_2 denotes pipe wall friction, μ' denotes pipe-soil friction coefficient, B denotes pipe section span, D denotes pipe section height, τ_a denotes pipe-soil shear stress, L denotes advancing length, and W denotes gravity per linear meter of pipe section.

The pipe joint axial force, pipe joint bending moment, and pipe joint safety factor are shown in Fig. 8, Fig. 9, and Fig. 10, respectively. When the friction coefficient is 0.43, the maximum settlement value is 16.82mm, at which time the structural force is most unfavorable. Affected by the left line excavation, the maximum value of pipe section axial force appears in the upper left corner, and due to the large span of the pipe section, the maximum bending moment value appears in the center of the top plate, and its safety coefficient is calculated according to the axial bending moment of the pipe section. Due to the large bending moment in the center of the roof plate, the safety coefficient is controlled by the tensile strength and is the smallest, while the safety coefficients of the rest of the parts are controlled by the compressive strength, and the safety coefficients are larger than those in the center of the roof plate. The center of the roof slab has the most unfavorable structural stress, but the safety coefficient is much larger than the requirement of bearing capacity. When the pipe-soil friction coefficient is greater than 0.43, the construction disturbance range is larger due to the surface uplift in front, and due to the existence of the model boundary, with the increase of the jacking force, a certain degree of persistent uplift is generated on the surface outside the construction disturbance range. As long as the pipe-soil friction coefficient is maintained at less than 0.43, slight settlement occurs in front of the work, the scope of construction disturbance is relatively small, and the surface outside the scope of construction disturbance returns to the level, so that the construction risk is minimized.

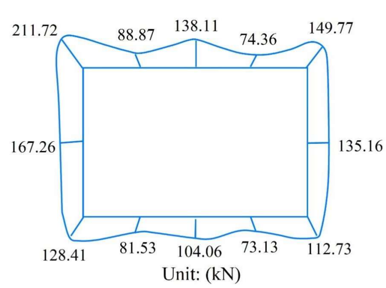

Figure 8: Pipe joint axial force

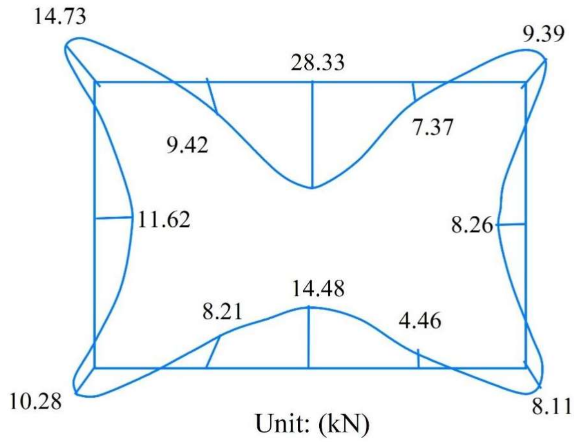

Figure 9: Pipe joint bending moment

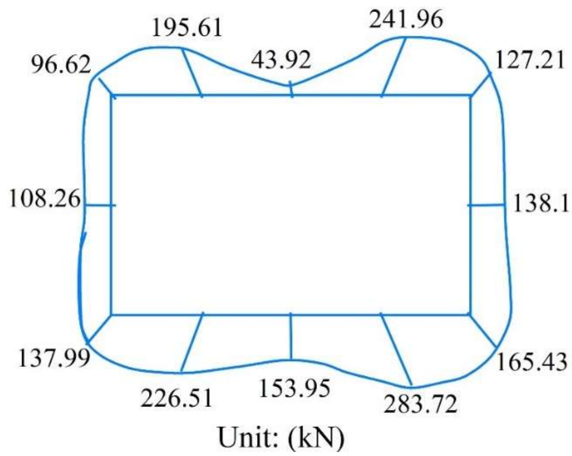

Figure 10: Safety factor of pipe joint

III. B. Risk management strategies

There are more safety risks in pipe jacking construction, which may lead to safety accidents under the joint action of multiple risk factors, and the risks must be controlled to prevent safety accidents from technical measures, safety education measures, safety inspection measures and emergency disposal measures.

III. B. 1) Technical measures

(1) Strictly control deep foundation pit operations.

Do a good job of safety construction measures for key processes such as excavation, locking ring beams, vertical excavation, timely closure of exposed surfaces, support, etc., improve the deployment of working well facilities (guide rails, jacks, back walls), and improve the relevant contents of formwork erection and concrete pouring and maintenance. In the process of deep foundation pit construction, the construction shall be organized in strict accordance with the approved construction plan, and the construction shall be stopped immediately when there is a significant difference between the actual geological situation and the ground investigation report, and the construction shall be re-programmed according to the actual situation before construction. Immediately after the completion of the pit in the work well should do a good job of edge protection and cage ladder to prevent people from falling.

(2) Do a good job of municipal pipeline protection.

Further verify the type, location and elevation of pipelines within the pipe jacking work area, and refine the control measures and emergency plans for pipe jacking through various types of pipelines. Prepare a pipeline protection manual, set up two pipeline protection specialists, and strictly implement the operation procedure of “exploring before digging and double confirmation”. Use pipeline detectors, supplemented by manual excavation of exploratory holes, exploratory grooves (trenches) for detection. Before the earth excavation area needs to be excavated along the excavation boundary line manually circular trench (ditch), probe hole and probe trench (ditch) must be dug to the ground below 3 m. The pipeline ownership unit to the site to confirm, and the pipeline ownership unit to the site to confirm, the pipeline ownership unit to the scene. Pipeline property rights unit to the site to confirm that the technicians measure the line after the coordinates of confirmation.

III. B. 2) Security education measures

Personnel entering the limited space must be in good health and undergo a health checkup before entering the site. After passing the medical examination, the operating personnel must carry out special safety education and training, focusing on the safety operation procedures of limited space, the main points of safety control of work at height, and the safety of underground pipeline card control red line and other safety knowledge. Innovative training methods, through safety experiential education and VR safety education, combining theory and practice. All members are equipped with practical cognitive ability and hands-on ability for actual operation.

III. B. 3) Emergency response measures

Pipe jacking construction is a dangerous operation, and it is especially important to do a good job in emergency response. The project department formulated a special emergency plan and set up an emergency disposal leading group with the project manager as the leader. The first time to the project manager to report the emergency on site, the project manager to start the emergency plan of the emergency disposal process. Emergency disposal cards are issued to the site personnel, so that the operating personnel are familiar with the emergency disposal process, keep in mind the emergency escape routes, and master the basic emergency skills, which greatly improves the emergency disposal capability.

IV. Conclusion

Pipe jacking construction is an important part of urban engineering construction, which has the advantages of low comprehensive cost, less land occupation, and less impact on traffic, etc. However, due to its great danger, special attention should be paid to safety control. The article takes a regional municipal water supply pipeline river crossing construction project as the background, explores the safety and monitoring risks in pipe jacking construction, and puts forward corresponding control measures for the construction personnel's reference and reference.

(1) In this paper, the pipe settlement in the construction of municipal water supply pipeline river crossing is strictly controlled within 10mm, and its mathematical form is 1.237mm<10mm, which is better to avoid construction accidents, and well practices the principle of safe production and construction.

(2) As the pipe-soil friction coefficient decreases, the pipe differential settlement increases and then decreases, and when the pipe-soil friction coefficient is 0.43, the pipe differential settlement is the smallest, and its safety coefficient is significantly improved, which effectively ensures the personal safety of the staff in the construction process.

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