# Numerical Simulation Analysis of the Influence of Underground Pipeline by Shield Construction

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**Abstract.** This test using MIDAS/GTS simulated the effect of shield tunnel excavation on the surrounding pipeline. Numerical analysis of the soil is using Mohr - Coulomb model and the pipe and lining Linear elastic model. In the process of simulation, the tunnel stress gradually release are considered and the linings are added gradually at the same time. Fully considering the shield advance displacement of the pipeline to a different location and give full consideration to the shield construction influence on displacement of different buried depth of underground pipeline. The results show that the settlement of pipeline meet certain changes while tunnel excavation to different distances. When the line is not at the same time with the relative position of the tunnel, the settlement of pipeline have relatively obvious changes.

## Introduction

As more and more shield construction are used in city subway project construction, the urban underground structures are complex and different kinds of pipe are complex, too. The phenomenon of pipe deformation increased obviously caused by shield excavation. In the process of excavation of shield machine. The stratum loss caused by excavation and tunnel surrounding strata disturbance or shear failure and consolidation is the root cause of deformation and displacement of pipeline[1]. Different kinds of pipelines will be destroyed when the deformation is serious, such as communication system short circuit, power line obstacle, sewage conduit blowout and gas leaks. All of this will have a very large influence on social and personal safety.

How to prevent the occurrence of these phenomena and protect the safety of the burial depth of the engineering route line are the necessary problem to be solved in the process of underground excavation.

For a long time, scholars at home and abroad are more interested in the influence of underground pipeline by shield.

Bi Jigong, liu Wei and others established three-dimensional model by using ABAQUS finite element analysis software to simulate the influence of underground pipeline by tunnel excavation, fully considering the different buried depth, material quality, the bottom layer stiffness and so on[2]. The results showed that properties of soil around pipeline, and the relative position of double line tunnel and pipeline itself stiffness, different pipe diameter will have great influence on the deformation and internal force, thus drawing some meaningful patterns. Peng Jimin used ANSYS to simulate the influence on adjacent underground pipeline displacement during the process of shield advance. Discussing influence on displacement of underground pipeline by shield cutterhead propulsion, different distances between shield excavation and underground pipeline, grouting and so on[3]. Ma Tao etc. write the finite element program based on the Power station 4.0.Simply simulate the influence of urban tunnel excavation on the pipe deformation, without considering the excavation process and it is just a two-dimensional calculation which is far from the actual[4].Gao Wenhua[5] analyzed the vertical displacement and horizontal displacement of the underground pipeline that were caused by foundation pit excavation with the theory of Winkler elastic foundation beam, to deduce the corresponding calculation formula and discuss the elements caused by the deformation of underground pipeline, for example, bedding coefficient, subsidence area

 

underground pipe length and the corresponding amount of surface subsidence, showing the different pipe deformation control standards and rules of safety evaluation. According to the theory of elastic foundation beam, Gaotianzhilang[6] conducted the underground pipeline model under four kinds of situations which were influenced by the foundation settlement, putting forward the design formulas which were used to calculate maximum bending deformation, joint line angle and maximum joint elongation. Zhou Chengjun put forward a method of deformation control based on the empirical formula[7], stablished the direct relation between the pipeline parameters such as vertical displacement, strain and rotation and the maximum ground settlement value, which can be used to determine the tunnel allows maximum subsidence value above the surface by the relative position between the pipelines and the tunnel axis, formation characteristics and the allowing strain value and deformation value of pipelines or the Angle's joint allowing value, to determine the tunnel's allowing maximum subsidence value above the surface.

According to the discussion above, the research is not deep enough on the influence of underground pipeline by the shield process. Performed in: 1)A lot of researches put the process of excavation tunnel as a two dimensional problem; 2)Most studies have failed to fully consider the soil of different impact on the change of displacement of pipeline; 3)Failing to consider the excavation to different position, pipeline settlement changes.

Based on the above issues, this test imitates the effect on the line by shield tunnel excavation with MIDAS/GTS, in which the shield advance displacement of the pipeline to a different location and the shield construction influence on displacement of different buried depth of underground pipeline are fully considered.

## Project Summary

Line 1of Hefei city is the backbone of the north and south direction,whose beginning is at the North of the intersection of New bengbu road and Tangchi road, and the finish is at the east of the intersection between Guangxi road of Binhu new area's planning and Zunyi road. The road is 28.75 km long, which are all underground. There are totally 23 station,Five of them are transfer hub. The investment of this project reaches 13.398 billion yuan. The line covers major traffic corridors, joining Hefei station area, the old new hefei station hub region, north of binhu new area center, binhu new area starting area and new binhu district CBD, thus provides a quick connection between the main area and Binhu new area. The line has been expected to be opened to traffic by the end of 2014.The city's rail transit plan is shown in Fig.1.


Fig.1 The Rail Transit Plan of the City

## The Establishment of Calculation Model

### Assumption of the Model and Selection of the Soil Parameter

Soil engineering mechanics analysis is to analyze the structure of soil mass and connected to the loads of the response. Factors such as the material properties of soil, topography and groundwater

are uncertain, So the input conditions influence the result of the analysis. At the same time the composition of the soil is very complicated, it is very difficult to completely truly simulate the characteristics of stiffness of soil materials and is also not realistic and not economic. So in the case of a clear purpose, it is necessary to properly simplified the analysis model. The calculation of presupposition is as follows:

Formation using solid elements, with the material simulation of Mohr - Coulomb;

Using surface unit segment lining, with the Elastic material simulation lines;

Using the Mohr - Coulomb yield criterion;

Model boundary around and under the surface using a one-way hinge constraint, using free constraints on the surface.

**Calculation of the Determined Size**

The tunnel center is 20 meters from the ground, the size of shield outer diameter is 3 meters and the inner diameter2.7 meters, thickness of shield segment lining is 0.3 meters, the segment width is 1.5 meters. The depth of pipeline buried 3 meters, its outer diameter is 1 meter and the thickness is 0.2 meter, the tunnel goes across the pipeline vertically. The model size is 50 m*50m*30m, the soil is divided into five layers, clay1 (0-7m), clay2 (7-40m),clay3 (40-43m), fully weathered rock (43-45m), strong weathered rock(45-50m). The relative position between line and tunnel is shown in Fig.2 and the soil parameters are shown in table 1:

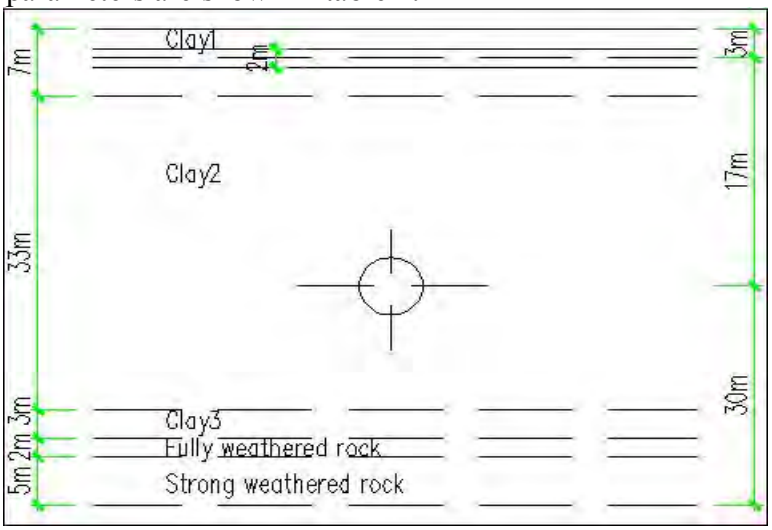


Fig. 2 The Relative Position between Line and Tunnel

Tab. 1 The Formation and Material Parameters in 3d Model Calculation

| Clay | Cohesive force ($KN/m^2$) | Internal friction angle(℃) | Unit weight ($KN/m^3$) | Modulus of compression ($KN/m^2$) | Poisson ration |
|---|---|---|---|---|---|
| Clay1 | 40 | 13 | 19.8 | 10 | 0.32 |
| Clay2 | 45 | 15.9 | 20 | 12 | 0.31 |
| Clay3 | 42 | 16.5 | 20 | 12 | 0.31 |
| Fully weathered rock | 20 | 16 | 19.7 | 18 | 0.3 |
| Strong weathered rock | 20 | 16 | 20 | 20 | 0.3 |

**The Establishment of a 3D Model and Simulation Steps**

MIDAS model size selected as 50 m (x direction) * (y direction) 50 m * 30 m (z direction). Numerical analysis of the soil is using Mohr - Coufomb model, Meshing is shown in Fig.3:

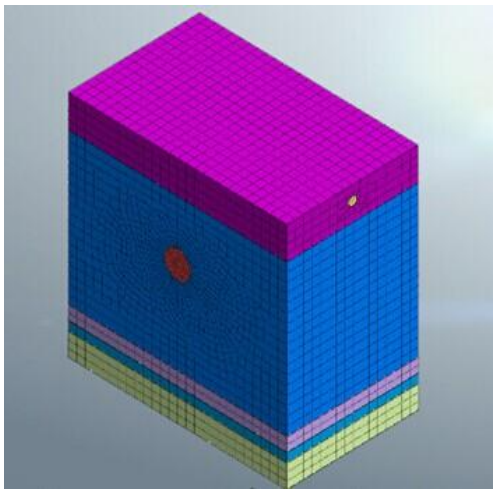

Fig. 3 Mesh Divided by GTS

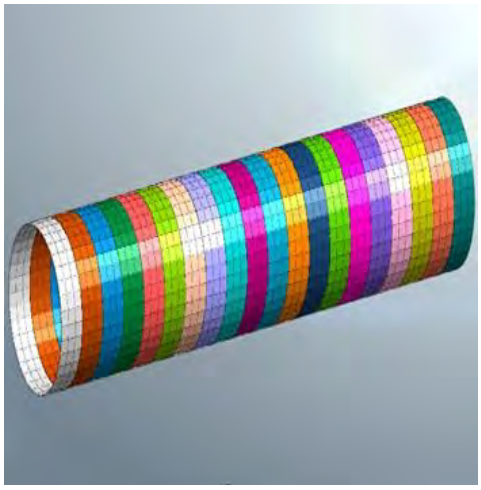

Fig. 4 Mesh of Lining Segment

Every 1.5m for a excavation step, Shield segment selected elastic model, according to the"Concrete structure design code", select mechanical parameters. Elastic modulus E = 30000 MPa, The poisson's ratio u = 0.2.Mesh lining is shown in Fig.4.

**Simulation Steps**

According to the characteristics of the shield tunnel construction, simulating the shield tunnel construction process with MIDAS/GTS, the steps are shown as follows:

Step1: Calculate the initial stress field, the initial unit node displacement is zero;

Step2: Construction stage analysis, "passivate" the first ring unit of soil, constraint goes on, "activate" shield shell;

Step3: "passivate" the second ring unit of soil, constraint goes on, when the shield tails by the first ring, "activate" segment ring to assemble unit simulation, loop simulation of shield construction in turn until the tunnel excavation end.

**Simulation Analysis Results of the Calculation in Shield Construction Process**

**The Settlement of Pipeline**

Shield in the process of advancing will disturb the primary soil which causes the surface subsidence. Pipeline are buried in the soil that must lead to the deformation of the pipeline. The model simulation of tunnel excavation is 30 meters, every 1.5 m for a excavation step, and it contains 20 steps excavation. The settlement curve of pipeline after the completion of excavation is shown in Fig.5. As it is shown, pipeline displacement curve is fall curve approximation, which means it is a symmetrical curve with the center line of the tunnel.

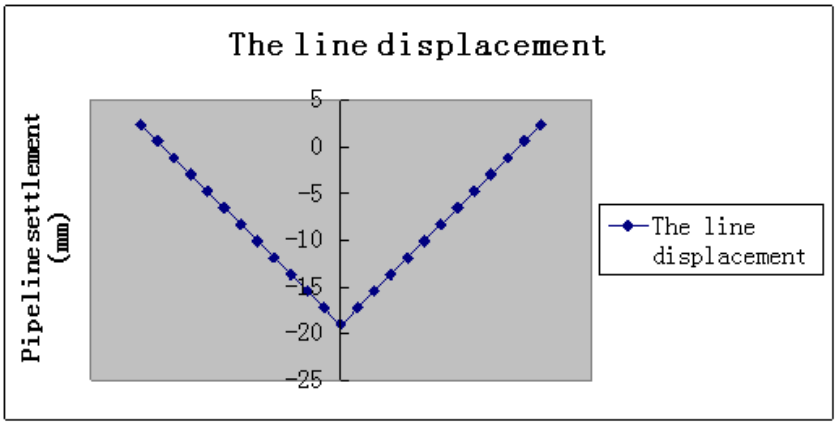


Fig.5 Vertical Displacement of the Pipeline

**Different Settlement Changes of the Pipeline in Different Excavation Steps**

In order to reflect the settlement changes of the pipeline in the process of shield advance clearly, I choose five of the excavation steps, step1, 5, 10, 15 and20, to compare the vertical displacement of the pipeline.

From the Fig.6, we can conclude that, the shield advances every step, the settlement of pipeline increases gradually and then gradually become smaller, the maximum is at the top of the tunnel axis. The farther the distance from the axis, the smaller the subsidence of the pipeline is.

With the advancing of shield, the settlement of pipeline increases gradually. But the speed of change becomes larger first then smaller.

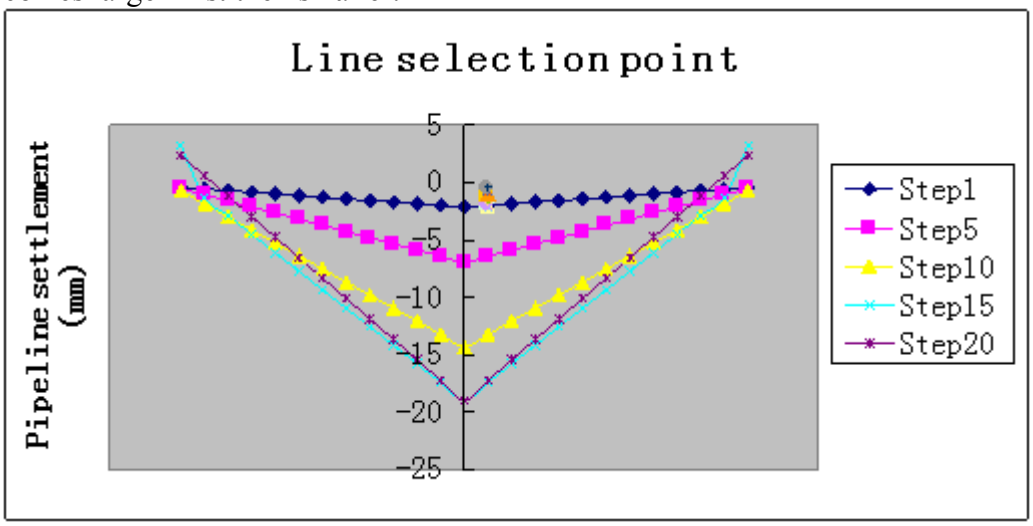


Fig. 6 Pipeline Settlement in Shield Advance Process

**The Settlement of Different Embedded Depth of Pipeline**

Respectively to simulate the form and each parameter in the tunnel under the same condition, two different cases of settlement changes while the pipeline is buried at 3 m and 1.5 m in soil. From the Fig.7, we know that the pipeline is affected differently by the tunnel excavation due to the different distance between the pipeline and the tunnel. With the increasing distance between pipeline and tunnel, the influence becomes smaller.

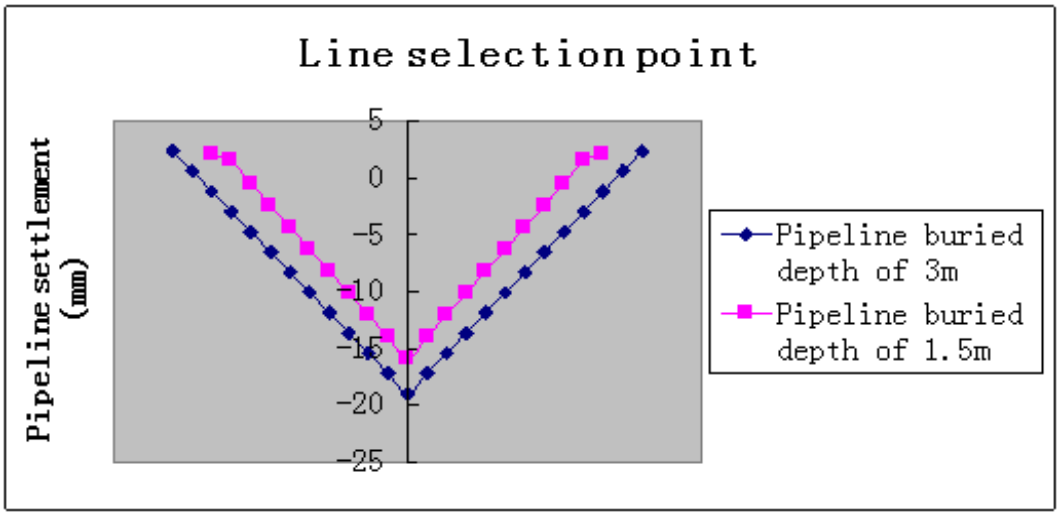


Fig. 7 Different Depth of the Line Displacement Diagram

**Conclusion**

In this paper, from the simulation of tunnel excavation on the influence of the pipeline, we can conclude as the followings:

As the excavation of shield machine, the line displacement increases gradually, the settlement of the position of the pipeline center is the largest of all.

Pipeline displacement curve is fall curve approximation.

In the same conditions, the closer vertical distance between pipeline and tunnel, the larger the settlement changes.

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