Scholars Journal of Engineering and Technology (SJET) **ISSN 2321-435X (Online)**
Sch. J. Eng. Tech., 2015; 3(3B):267-272 **ISSN 2347-9523 (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublisher.com

Research Article

Research on the effection of the construction of tunnel adjacent to high-rise building in different surrounding rock conditions

Shen Liang*, Chen Hao, Fang Fei
School of Civil Engineering and Architecture, Chongqing Jiaotong University ,Chongqing 400074, China

***Corresponding author**
Shen Liang
Email: 937918368@qq.com

Abstract: As the construction of urban tunnel close to building increased obviously, it is difficult to ensure the safety of the upper buildings and tunnel structure in construction. By using finite element software, this article makes numerical simulation analysis for new tunnels through the foundation of high-rise building. Considering many factors as the level of surrounding rock, tunnel size, building foundation forms, building height, the distance of the tunnel and foundation, obtaining analysis results with different surrounding rock conditions. The foundation overall tilt, foundation settlement, variation of stresses of adjacent high-rise buildings caused by the construction of new tunnel was studied thoroughly, and obtained some significant conclusions that can provide a reference for stipulation of control techniques for safety of adjacent buildings during construction of similar tunnels.
Keywords: tunnel; approaching construction; high-rise building; numerical simulation

INTRODUCTION

With the development of cities, the scale of the development and utilization of urban underground space expanded gradually, functional categories of underground facilities were also increased. Major cities have begun large-scale development and utilization of underground space in China. It can be said that the underground space is playing an increasingly important role in the development of city. The development and utilization of underground space is a trend of the current city construction. However, a vast amount of underground pipe network, pile box foundation, underground parking, shelter room, storage room, and other commercial facilities occupied the limited urban shallow underground space. Tunnel and the underground space resource occupied by the ground buildings began to form a crowded state. It is difficult to evade effectively and thus there must be approaching excavation. When construct the tunnel adjacent to building, the foundation of neighboring buildings will be affected to produce certain subsidence and tilt. The internal force and deformation adjustment will happen to the internal structure of the building; In serious condition, the tunnel will collapse, the construction foundation will become instable or produce cracks and the integral bearing capacity will be damaged. There are a lot of related engineering accidents in history. There are several typical cases. The excavation of inter-zone tunnel in line No.4 light rail transit of Shanghai once led to instability of tunneling face. And the podiums of nearby 8 layer building collapsed. 20 floors riverside garden building subsided as well (subsidence value reaches 15.6mm). A nearby 6 layer building suddenly sank and tilted when excavated Dong Xiao Nan tunnel of Guangzhou Metro's 2th lines. Fortunately there are no casualties[1]. So requirements of deformation control are extremely stringent for tunnel. Correct prediction of deformation of building foundation after excavation is very important. According to the specific circumstances, the corresponding treatment measures are needed to ensure the construction safety in the tunnel and the foundation capacity and guarantee the normal use of the upper buildings.

In this paper, we performed numerical simulations through the finite element software, and analyzed the influence of tunnel closely through high-rise building under the condition of III-V surrounding rock. The high-rise building has 24 floors with independent column foundation. The vertical clear distance Y between the two-lane tunnel and foundation is 8m. The horizontal distance X between the tunnel and base line is 9m. Location relationship between tunnel and building foundation is shown in Fig.1.

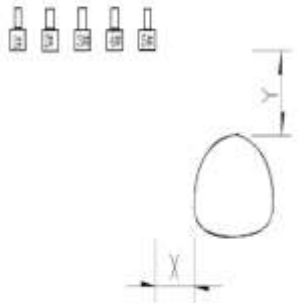


Fig.1 Tunnel and building foundation position relation

OVERVIEW OF FINITE ELEMENT ANALYSIS

(1)Calculation software and mechanical model of rockmass

The calculation and analysis use large-scale finite element software MIDAS/GTS. Rock mechanics model uses the ideal elastic-plastic constitutive relation and obey the Mohr—Coulomb yield criterion. Mohr—Coulomb failure criterion is comprehensive combination of tension and shear.

(2) The physical and mechanical parameters

Table-1: The table of physical and mechanical parameters

Type	Density ρ （Kg/m^3）	Elastic ModulusE （GPa）	Poisson's ratio μ	Cohesion C/KPa	Friction angle φ （^{0}）
Surrounding rock of grade III		6	0.30	700	40
Surrounding rock of grade IV	2200	3	0.33	400	33
Surrounding rock of grade V	2200	1	0.40	200	25
Shotcrete	2300	23	0.20	—	—
Building Foundation	2400	31	0.20	—	—

(3) Building load calculations

The construction of tunnel adjacent to building is simulated by building foundation and upper load. The upper load is calculated as follows:

- Roof and floor live loads take 3KN/m^2 according to the specification.
- Weight of partition wall take 3 kN/m^2.
- Value the weight according to brick wall materials of the frame - shear wall structure. The weight of the structure takes 12kN/m^2.

Calculate according to the design value controlled by the permanent load effect.

$$S_d = \sum_{j=1}^{m} \gamma_{G_j} S_{G_j k} + \sum_{i=1}^{n} \gamma_{Q_i} \gamma_{L_i} \psi_{c_i} S_{Q_i k}$$

Where $\gamma_G = 1.35$, $\gamma_Q = 1$, $\gamma_L = 1.4$, $\psi_C = 0.7$

The uniform force loaded in the middle foundation of the high-rise building is 10800KN/m^2 in the simulation. The uniform force of surrounding foundation is 5400KN/m^2.

（4）Boundary conditions

A two-dimensional plane model is adopted in this paper, the upper model takes the ground and the lower takes 30m below the bottom of the tunnel. Considering the existence of the building, it is 52m distance outside of the tunnel on the left side of the model in horizontal direction as 36m distance outside of the tunnel on the right side. The ground of the model is the free surface. Constraints are imposed on the left and right sides. Vertical constraints are imposed at the bottom of the model[2,3].

（5）Construction sequence

Construction of tunnel adjacent to buildings is a process of long and complex procedure, mainly divided into three stages:

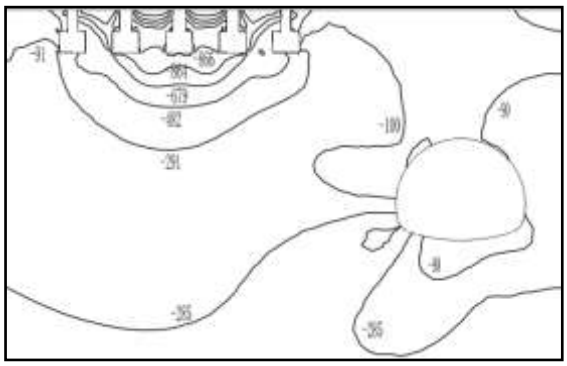
- Simulate the original ground stress, reset the displacement;
- Building foundation and apply the upper load;
- Simulate the tunnel excavation.

CALCULATED RESULTS ANALYSIS

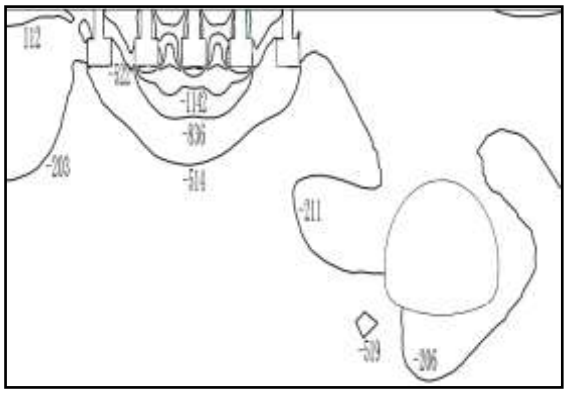
Analysis of surrounding rock stress when excavate tunnel in the building foundation.

Different with the behavior of excavating the single tunnel in semi-infinite body, tunnel excavation is in the influence of additional stress in the foundation when construct the tunnel adjacent to building. Also, the stress redistribution caused by tunnel excavation disturbs the original stress field. They interact with each other and have complex stress[4,5]. As shown in Fig.2, there is overlap between additional stress field of building foundation and the redistributed stress field

caused by tunnel excavation. Additional stress field of foundation is no longer a regular light bulb line. Stress field in left and right side of the tunnel is no longer symmetrical distribution.



Surrounding rock of grade III



Surrounding rock of grade V

Fig. 2 The maximum principal stress diagram of tunneling in the building foundation (unit:kN.m).

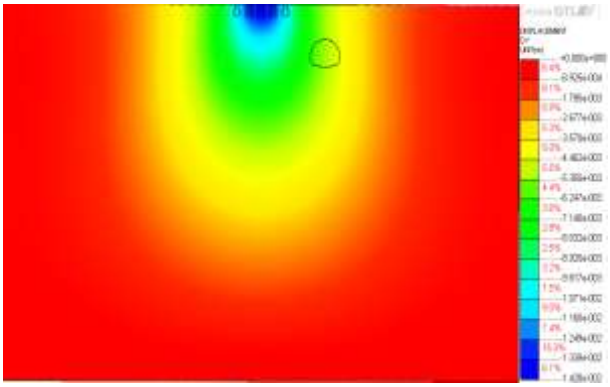
Analysis of vertical displacement of foundation caused by excavating tunnel.

Vertical displacement cloud picture of surrounding rock when building houses and tunnels are respectively shown in Fig.3 and Fig.4. The vertical displacement of foundation caused by tunnel excavation are shown in table.Where the symbol "+" indicates a downward vertical displacement value while the symbol "—" indicates upward. Under the condition of surrounding rock ofgrade III-V , the size order of the displacement value of each foundation is as follows: 5#>4#>3#>2#>1# .Construction of tunnel adjacent to building foundation causes redistribution of foundation displacement field. Generally speaking, the farther the horizontal distance of tunnel and building foundation, the smaller the building foundation settlement caused by tunnel construction.

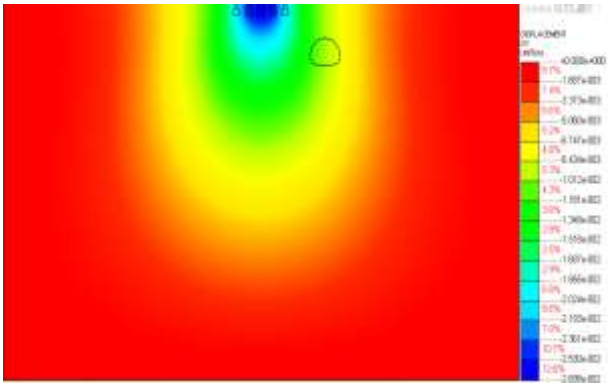
In III level surrounding rock, the value of building foundation's overall tilt is -0.0003 and the maximum differential settlement of adjacent foundation is -2.30mm. In IV level surrounding rock, the value of building foundation's overall tilt is -0.0006 and the maximum differential settlement of adjacent foundation is -4.58mm. In V level surrounding rock, the value of building foundation's overall tilt is -0.0019 and the maximum differential settlement of adjacent foundation is -13.84mm. Allowed value of building foundation overall settlement and incline is 0.0023 in accordance with《code for design of building foundation》(GB 50007-2011).

Table-2: The vertical displacement of foundation caused by tunnel excavation (unit:mm).

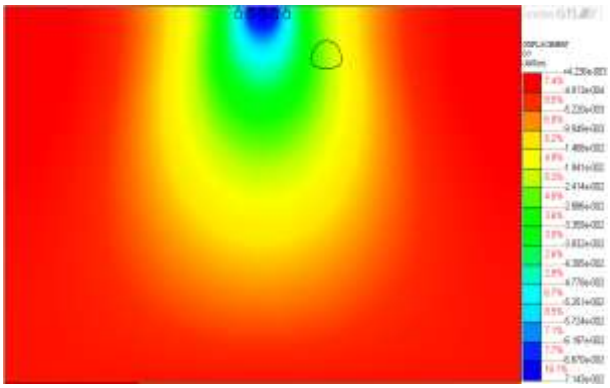
Foundation number	1#	2#	3#	4#	5#
Surrounding rock of grade III	0.05	0.08	0.11	0.16	0.39
Surrounding rock of grade IV	0.06	0.11	0.25	0.46	0.77
Surrounding rock of grade V	0.45	0.76	1.17	1.86	2.69



Surrounding rock of grade III

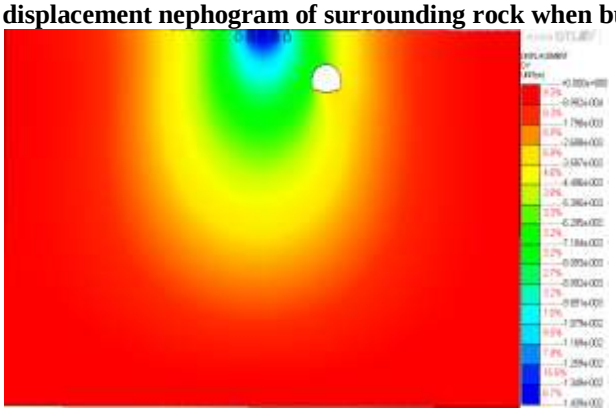


Surrounding rock of grade IV

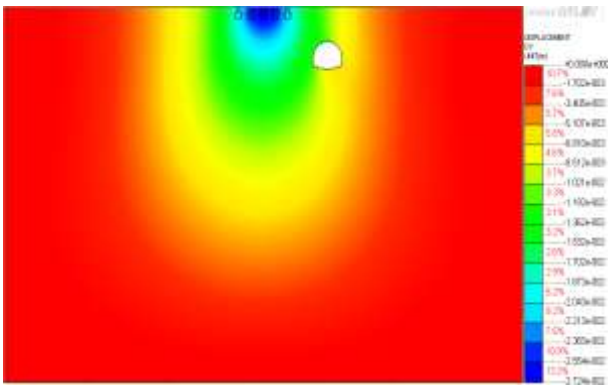


Surrounding rock of grade V

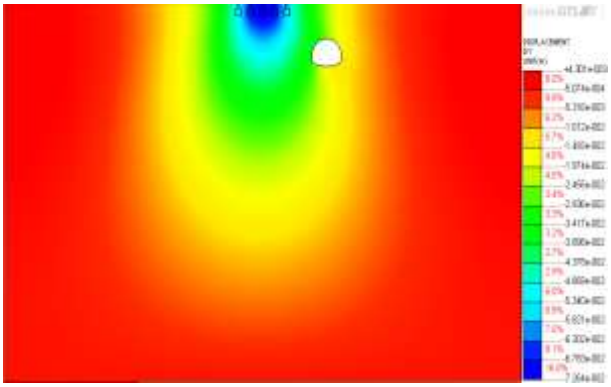
Fig. 3 Vertical displacement nephogram of surrounding rock when building houses.



Surrounding rock of grade III



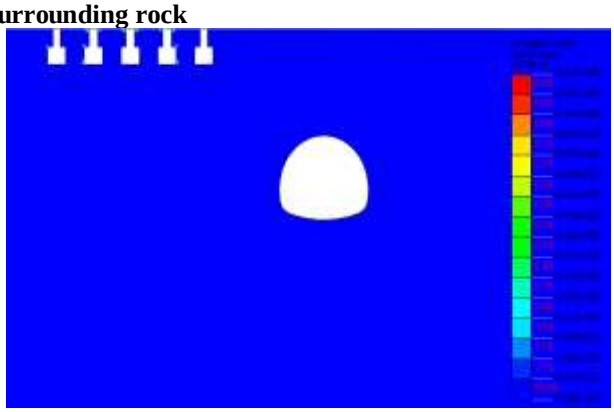
Surrounding rock of grade IV



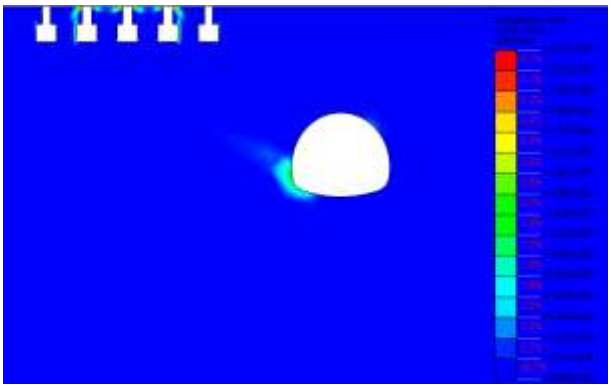
Surrounding rock of grade V

Fig. 4 Vertical displacement nephogram of surrounding rock when building a tunnel.

Analysis of plastic district of surrounding rock



Surrounding rock of grade IV



Surrounding rock of grade V

Fig. 5:Distribution of plastic zone of surrounding rock after tunnel excavation

Influenced by additional stress of the building basement, there will be plastic zone on both sides of 2-4 foundation with small scale after tunnel excavation in IV level surrounding rock. There will be plastic zone on the left wall of tunnel and both sides of 2-4 foundation with big scale after tunnel excavation in V level surrounding rock. There will not be plastic zone after tunnel excavation in III level surrounding rock. It is harmful to the tunnel construction and its near buildings and may lead to instability and damage because of the plastic zone of surrounding rock.

CONCLUSION AND RECOMMENDATION

(1) For the construction of the tunnel adjacent to existing building, subsidence is one of the most important factors of the damage to both building. Uneven settlement caused by tunnel excavation can produce secondary internal force and irregular deformation within the structure[6].In this article, vertical displacement of 5# foundation caused by tunnel excavation is the maximum value of 0.39 mm in III level surrounding rock. The value of building foundation's overall tilt is -0.0023. Tunnel excavation has little effect on buildings and the influence can be neglected. The vertical displacement of 5# foundation

caused by tunnel excavation is the maximum value of 0.77 mm in IV level surrounding rock. The value of building foundation's overall tilt is -0.0006. Tunnel excavation has less effect on buildings and the influence can be neglected. The vertical displacement of 5# foundation caused by tunnel excavation is the maximum value of 2.69 mm in V level surrounding rock. Thus it can be seen that. The settlement of the foundation for building does not much affect and the influence can be neglected. But the value of building foundation's overall tilt is -0.0019. Tunnel excavation has stronger affect to building. Therefore, the deformation and strength of the building should be analyzed and researched, the construction plan should be demonstrated. At the same time it is needed to take reasonable engineering measures and strengthen the monitoring management.

(2) When tunnel excavation has a strong effect on buildings, adopting reasonable tunnel construction technology and construction steps and supporting parameters as far as possible. Reinforce the formation in order to reduce the influence of the surficial construction caused by tunnel excavation. If this measure does not meet the requirement of the housing stability, could lift the foundation and improve the foundation strength by grouting the foundation and adopt section enlargement method, enclosed concrete method, enclosure steel method and sticking carbon fiber method for weak positions of building to improve the structural integrity and the resistance of structure, and ensure the structure safety.

(3) Specific building foundations have different bearing capacity. It's hard to avoid disturbance on the rock mass of surrounding foundation during the approaching construction. Try to avoid disturbance of surrounding soil in the construction of underground, so as to avoid harmful to bearing capacity of building foundation.

REFERENCES

1. Zheng Xuegui, Guo Jun, Wu Shengzhong; Safety Analysis on Engineering Characteristics of Multi-arch Tunnel Passing underneath Highrise Buildings. Chinese Journal of Underground Space and Engineering, 2010; 6(4): 867-869.
2. He MeiDe, Liu Jun, Le Guiping et. al.; Study of Impact of Shield Tunneling Side crossing on Adjacent High Buildings;Chinese Journal of Rock Mechanics and Engineering , 2010; 29(3): 604-608.
3. Xiong Gang, Huang Siyong, Xiang Jinghui; Tunnel near by the construction of both the research advances in the effect of pile foundation. Railway Engineering, 2011; 7: 72-74.
4. Qiu Wenge; The Study on Mechanics Principle and Countermeasure of Approaching Excavation in Underground Works. Chengdu; Southwest Jiaotong University, 2003.
5. Pan Changshi; Numerical Method Applied in Tunnel Mechanics. Beijing: China. Railway Publishing House, 1995.
6. Wang Chunhe; Research on Tunnel Construction by Subsurface Excavation under Buildings. Building Science, 2010; 26(3): 93.