http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (23): 7604-7609, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.7604.7609

Analysis of Surrounding Rock and Supporting Interaction Mechanism of Soft Rock Tunnel

[1]Yang Cheng-Zhong, [2]Huang Zong-Qiang and Wang Shu-Fang
[1]School of Rail Transit, East China Jiaotong University, Nanchang, Jiangxi 330013, China
[2]School of Civil Engineering and Architecture, East China Jiaotong University, Nanchang, Jiangxi 330013, China

Abstract: The ability to withstand loads of rock itself and supporting structure are the fundamental principle of NATM supporting. Solving the interaction between rocks-supporting structures well is the key to fully play the role of support the principle. Especially in soft rock tunnel, because of the rheological properties of soft rock, the interrelation between surrounding rock-supporting structures is more important. Based on the creep characteristics of soft rock and the actual project, analyzed the deformation law and the interrelation during soft rock tunnel excavation. The results shows that: in soft rock tunnel the secondary lining is also a major force structure and to construction second lining supporting appropriately early is advantageous to enhance the stability of surrounding rock

Key words: Soft surrounding rock, interaction mechanism, supporting structures, creep, NATM

INTRODUCTION

Currently, New Austrian Tunneling Method has become one of the main methods in tunnel engineering design and construction and is also one of the main theories in soft rock supporting. In China, many scholars have suggested soft rock tunnel supporting theories. However, due to the complexity of soft rock, these theories also have some limitations in the actual project application. For the interaction problems between surrounding rock and supporting in soft rock tunnel, it should be consider from three aspects such as the soft rock deformation characteristics, supporting structure deformation and supporting structure stress.

DEFORMATION CHARACTERISTICS OF SOFT ROCK TUNNEL

According to tunnel longitudinal deformation characteristics(Guan, 2011), tunnel deformation can be divided into three stages: (1) Ahead deformation stage in front of the tunnel face; (2) sharp increase deformation stage behind tunnel face; (3) Stable deformation stage. As shown in Fig. 1.

Whether rock rheological deformation occurred, it depends on rock stress levels and support reaction force. Typically, rheological deformation mainly refers to rock creep deformation.

Rock creep curve are shown in Fig. 2. The four curves in Fig. 2 are gotten under different stress conditions. Where, $\sigma_1<\sigma_2<\sigma_3<\sigma_4$. Figure 2 is typical creep curves. Depending on the strain rate, creep process can be divided into three stages: The early creep stage (stage I, deformation rate gradually decreases), the stable creep stage (stage II, deformation rate is usually constant) and the accelerated creep stage (stage III, deformation rate usually rapidly increase), which eventually leads to the rock destruction (Yang, 2008).

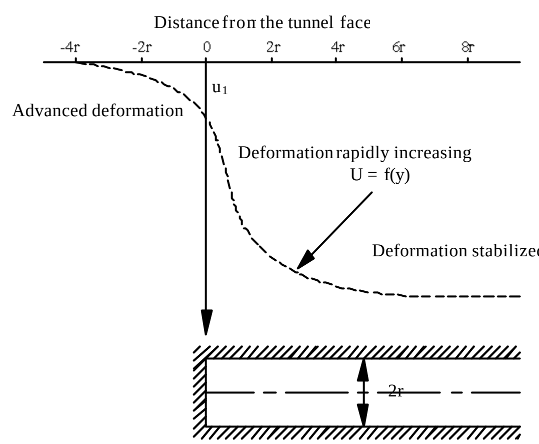


Fig. 1: Deformation curve in excavation tunnel excavation process

Corresponding Author: Yang Cheng-Zhong, School of Rail Transit, East China Jiaotong University,Nanchang, Jiangxi 330013, China

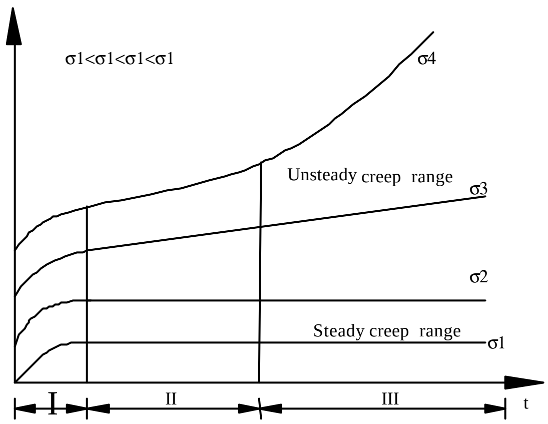


Fig. 2: Rheological properties of rock

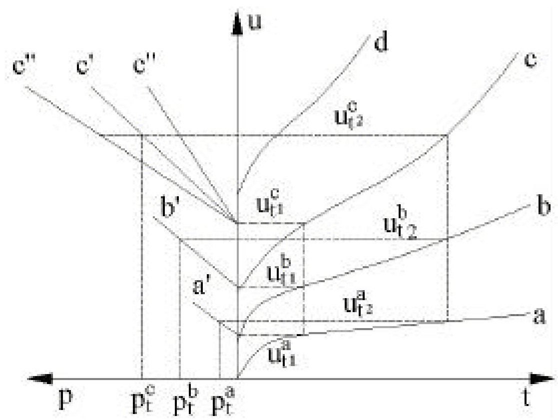


Fig. 3: Relations between surrounding rock creep and supporting reaction force

SUPPORTING SYSTEM OF SOFT ROCK TUNNEL

NATM fully play the self-supporting capacity of rock. It makes surrounding rock become one part of supporting system. So, surrounding rock is the direct source of rock tunnel load, but it is also the supporting structure to bear the load. For the supporting system of tunnel, apart from the effect of rock self-supporting, early supporting and secondary lining etc, the contact surface between the different supporting structures also have certain effect.

However, because of existence of the contact surface; the stress concentration phenomenon is more obvious.

MECHANISM OF SURROUNDING ROCK AND SUPPORTING OF SOFT ROCK TUNNEL

Analysis of displacement: As shown in Fig. 1, longitudinal deformation of tunnel will go through three stages. For soft rock tunnel, generally only after a certain treatment on soft surrounding rock, surrounding rock deformation can gradually stabilize. From soft rock tunnel excavation to the supporting period, the plastic deformation of surrounding rock can be considered to have completed. Therefore, interaction between surrounding rock and supporting mainly occurs in rock rheological deformation stage.

The monitoring data from multiple soft rock tunnels show that tunnel deformation curve can be divided into three categories: (1) The deformation rate gradually decreases and finally reaches to zero; (2) The deformation rate tends to a constant value, but the total amount of deformation continuously increase; (3) Both the deformation rate and the total amount of deformation continuously increase.

Analysis of supporting force: Figure 3 is the relations between surrounding rock creep and supporting reaction force. Combined Fig. 3 with Fig. 2, it can be seen that, for soft rock tunnels, supporting reaction force mainly depends on the geostress level and second liner timbering opportunity.

In Fig. 3, a, b, c and d represent different stress or creep deformation of rock under adverse geological environmental, u_{ti} and u_{t2} represent deformation amount before supporting and after supporting.

As can be seen from Fig. 3, there is a certain proportional relationship between supporting reaction force and surrounding rock creep. For soft rock tunnel, because of the obvious creep effects, a reasonable choice for supporting time has a certain influence on the stability of supporting structure.

Analysis of surrounding rock and supporting interaction under rheological deformation: In the tunnel excavation process, the elastic deformation, plastic deformation and creep deformation begins almost simultaneously. In stage I of Fig. 2, rheological deformation has being occurred. In field, the deformation cannot be supported; the deformation that can be supported is mainly creep deformation of stage 2 and 3.

As can be seen from Fig. 2, the initial supporting early can protect the surrounding rock and improve self-supporting capacity, but the supporting reaction force necessary to provide supporting structure is greater, the supporting structure is easier to destroy. The later the initial supporting time, the smaller the reaction force that needs to be provided, but the self-supporting capacity of surrounding rock decreases. Thus, for soft rock tunnel, it should support early.

After the initial supporting, surrounding rock creep has entered into stage II, rheological deformation increase continuously. Under the self-stability of surrounding rock and initial supporting work together, surrounding rock remain in creep stage II or enter a similar creep stage I.

As can be seen from Fig. 2, the larger the rock stress level, the larger the creep rate, the greater the supporting reaction force. Therefore, after the initial supporting, to do monitoring and measurement work well and to timely reinforce parts with the excessive deformation rate are keys to support success fully.

ANALYSIS OF PROJECT EXAMPLE

Project profile: The research object in this study is a separate tunnel with more than 2400 m long. Tunnel surrounding rock is gray schist. Tunnel use composite supporting structure. Arrangement of monitoring points is shown in Fig. 4. Strain gauges were embedded in the surrounding rock and early supporting interface or early supporting and secondary lining interface.

Data analysis

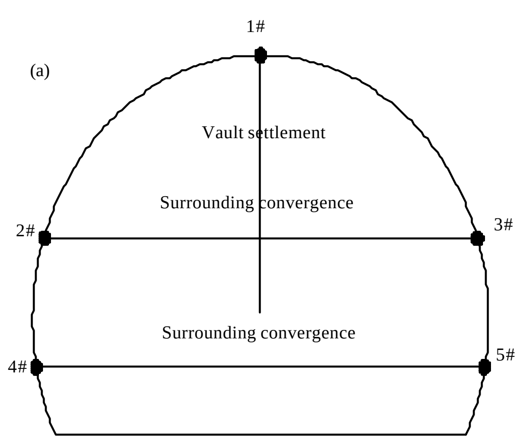
Vault settlement and surrounding convergence: At the tunnel early supporting, monitored vault settlement and surrounding convergence. Due to space restrictions, select representative three groups monitoring point data (No. 1, 2, 3) to analyze. Analysis process follows as:

In Fig. 5, the tunnel was excavated with the layer-step method, data collection interval of vault settlement and surrounding convergence are two days and the rate of the first day are assumed to be zero. The same is in Fig. 6 and 7.

As can be seen from Fig. 5, in the previous few days due supporting has not reached sufficient strength so that the deformation rate reaches larger. Then it stabilized and eventually fell to 1 mm day^{-1}. That is, after the initial supporting, with self-supporting of the surrounding rock and supporting working together, rock creep stay in stage II, then develop slowly to stages I.

As can be seen from Fig. 6a, after the deformation rate experienced a larger fluctuation in a few days before the supporting, it slowly changes to stabilized. As can be seen from Fig. 6b, the deformation increases linearly. It is similar to Fig. 2 stage II unsteady creep stage and the deformation will continue to grow. This means supporting reaction force provide early support is not sufficient to make surrounding rock reach a steady creep state and in the case without reworking early supporting it is necessary to reinforce early supporting or to increase the intensity of the second lining appropriately make surrounding rock reach a steady creep state.

As can be seen from Fig. 7a and b, after a period of time the deformation rate of surrounding rock and deformation amounts increase sharply. This is similar to the creep stage III (that accelerated creep stage) in Fig. 2. This shows that: The early supporting reaction forces provided by supporting structure are not enough; surrounding rock entered into the acceleration creep stage; without reinforcement processing, the deformation of surrounding rock will continue until early supporting damage. At this time, early supporting should be



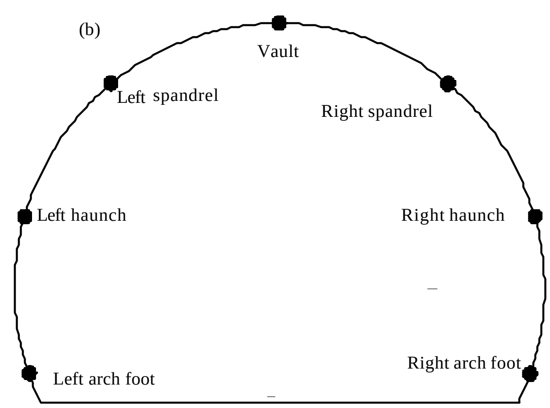


Fig. 4(a-b): Arrangement of monitoring points, (a) Vault settlement and surrounding convergence and (b) Manometer

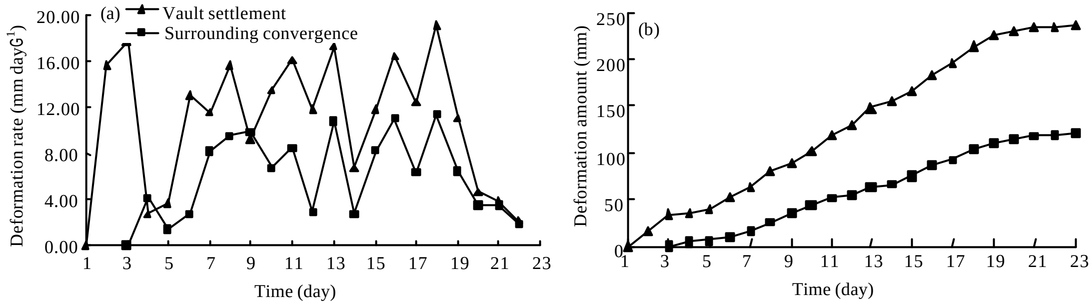


Fig. 5(a-b): Monitoring curve of monitoring point 1, (a) Deformation rate of monitoring points 1 and (b) Deformation amount of monitoring points 1

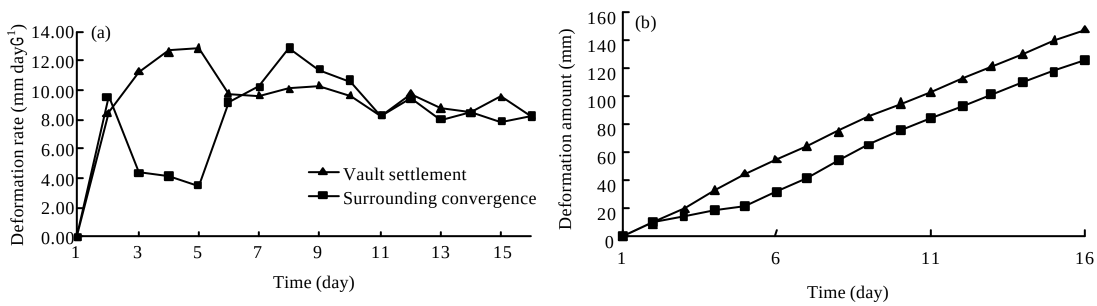


Fig. 6(a-b): Monitoring curve of monitoring point 2, (a) Deformation rate of monitoring points 2 and (b) Deformation amount of monitoring points 2

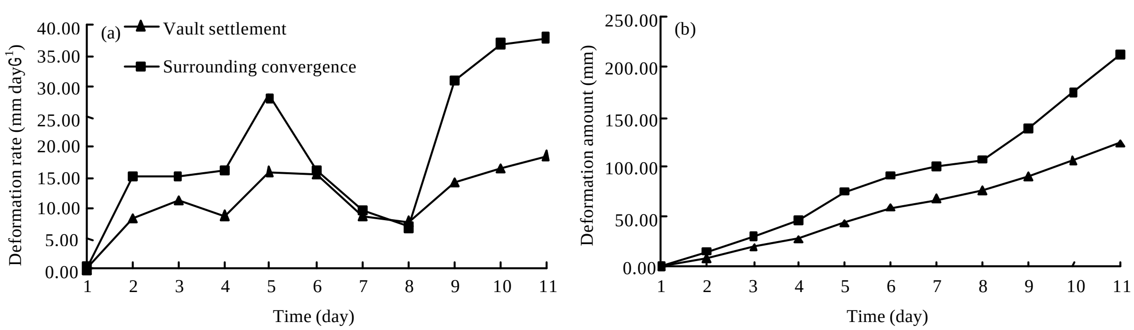


Fig. 7(a-b): Monitoring curve of monitoring point 2, (a) Deformation rate of monitoring points3 and (b) Deformation amount of monitoring points 3

immediately reinforced until the deformation rate can be controlled. Then, construct the secondary lining supporting.

Supporting reaction force: Here, this article only takes the data with early supporting and lining normal. The following is the pressure graphs of the two monitoring section.

As can be seen from Fig. 8a and b and Fig. 9a and b:

- In Fig. 8, the early supporting reaction force of the right spandrel is 1.8 Mpa and the secondary lining supporting reaction force of right spandrel is 0.2 MPa; the early supporting reaction force of right arch foot is 0.15 Mpa and the secondary lining supporting reaction force of right arch foot is

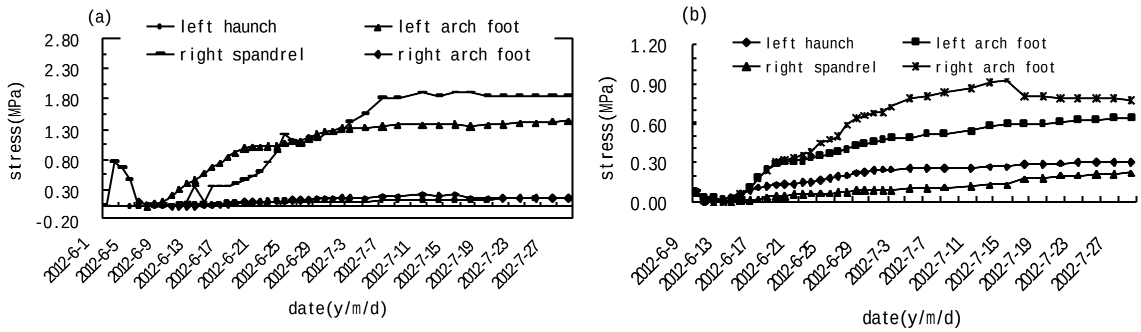


Fig. 8(a-b): Supporting reaction force curve of monitoring section?, (a) Supporting reaction force of early supporting and (b) Supporting reaction force of secondary lining supporting

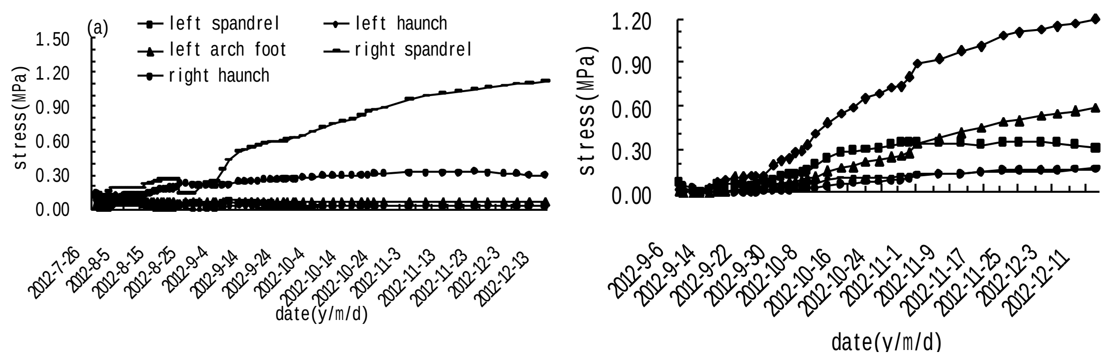


Fig. 9(a-b): Supporting reaction force curve of monitoring section II, (a) The supporting reaction force curve of early supporting and (b) The supporting reaction force curve of secondary lining supporting

-0.78 Mpa. In Fig. 9, the early supporting reaction force of the right spandrel is 1.1 Mpa and the secondary lining reaction force of right spandrel is 0.17 MPa; the early supporting reaction force of the left spandrel is 0.08 Mpa and the secondary lining supporting reaction force of left spandrel is 1.2 MPa. This shows that both early supporting and secondary supporting are likely to bear most of the stress

- In Fig. 9, both the early supporting reaction force and the secondary lining reaction force is still increasing trend. This shows that the creep of soft rock tunnel take place in quite a long time after in supporting
- As can be seen from Fig. 8 and 9, the secondary lining of section I should be constructed after 8 days of early supporting, while the secondary lining of section II should be constructed after 42 days of early supporting; after 35 days of secondary lining of section I, both early supporting and secondary lining tends to be stabilized, while after 2 months of secondary lining of section II, both early supporting and secondary lining still increase. This indicates that the ahead of secondary lining supporting time appropriately is beneficial for protecting the stability of the surrounding rock

CONCLUSION

From the view of the creep, we can reach the following conclusions:

- During the construction process, the deformations of soft rock tunnel undergo three main stages: advanced deformation stage, sharp deformation stage and the rapid growth deformation stage. Creep deformation goes throughout the three stages. The interaction of surrounding rock and supporting occurs mainly in the creep deformation stage
- After early supporting of soft rock tunnel, tunnel deformation curve can be divided into three

types:?Deformation rate gradually decreases and finally to zero; ?Deformation rate tends to a constant value and the total deformation amount continuously increase;?After a period of time, deformation rate continues to grow

- For soft rock tunnel, in quite a long time after constructing secondary lining supporting, the creep of surrounding rock has been happening. Within this period, the early supporting and secondary lining are likely to be the main force structure
- For soft rock tunnel, the construction time will directly affect the creep, constructing in advance duly has an important influence on the stability of the surrounding rock and supporting structure

ACKNOWLEDGMENT

The authors would like to thank for the support by the Science and Technology Support Plan of Jiangxi the Grant No. 20123BBG70216.The authors also thank for the support by the Higher Education Science and Technology Plan of Jiangxi the Grant No. GJJ12301 and GJJ13325.

REFERENCES

Guan, B.S., 2011. Soft Rock Tunnel Construction Technology. People's Communications Press, Beijing, China.

Yang, S.Q., 2008. Rock Mechanics. Mechanical Industry Press, Beijing, China.