

Study on Load-displacement Test of Rubber Pads of Coal Mine Roadway Constructed by Shield

Yue Yang ^{1, 2, *}, Xiaoguo Chen ^{2, 3} and Liyun Yang ²

¹School of Architecture and Civil Engineering, Heilongjiang University of Science & Technology, Harbin, China

²Heilongjiang Ground Pressure & Gas Control in Deep Mining Key Lab, Heilongjiang University of Science & Technology, Harbin, China

³School of Mining, Heilongjiang University of Science & Technology, Harbin, China

*Corresponding author e-mail: yybeijing@126.com

Abstract. Shield method construction of coal mine roadway is the future trend of the development of deep coal mining. The main shaft supporting is the segment. There is rubber pads between segment and segment. The performance of compression deformation of rubber pad is essential for the overall stability of lining. Through load test, displacement of the rubber pad under load, the thrust force law of the rubber pad deformation, and provide a theoretical basis for the stability analysis of coal mine tunnel shield construction.

1. Introduction

The deformation of lining segment structure is complicated in shield tunnels of underground engineering. There are a lot of numerical and experimental studies have been done on it [1-2]. It has provided a large number of engineering practices for guidance and reference. The rubber pads are between the segments. The mechanical property of rubber cushion is an important part of the study of deformation performance of shaft lining structure [3-5]. The research on the rubber pad in the segment assembly tunnel is of great significance. Its performance affects the stability and durability of the tunnel support structure indirectly. In view of the existing research ideas and methods, the loading rate method was used to test the same kind of rubber pad used in the field, and the relationship between the compressive load and the compressive displacement of the tested specimen was measured. According to the experimental data, the stress-strain curve of the material is drawn [6-7]. Through the integration and analysis of the curve, the basic mechanical parameters and the corresponding constitutive relationship of the segment rubber gasket are obtained. The constitutive relation, this paper analyzed the determination and calculation of the established project, surrounding rock deformation under the effect of circumferential segment at the contact surface of the rubber gasket. At home and abroad on the research on the segment structure considering the rubber pad deformation performance influence at home and abroad. The research will be little structural analysis provides a theoretical basis and technology support design and stability of tunnel segment is now backing for the domestic and foreign deep tunnel construction has a very important theoretical and practical significance [8-10].



2. Test equipment and test procedure

2.1. Test equipment and principles

The relation between the determination of compressive load and compression displacement by controlling the frozen soil testing machine loading rate, and obtain its constitutive relationship. The recoverable deformation amount of rubber cushion material under compressive load is measured in small load test, and the relation between the compressive load and its compressive displacement is measured and the curve is drawn, and then turned into the relationship between the stress and the displacement of the pressure and draw the curve. The load is controlled in the range between 0-12KN.

2.2. Test procedure and method

The rubber pad material (thickness is 2.0 mm) are processed into standard samples. The raw material is cut into the side length of 50 mm, the stacked thickness is 40mm. They are the 1 standard test pieces. 5 standard specimens are machined in the test processing. They are labeled 1#, 2#, 3#, 4# and 5#. the pad of raw materials and processed specimen are shown in Figure 1.



(1) Rubber cushion raw material (2) Test specimen after processing;

Fig.1 Rubber raw materials and the test-piece in processing

The compressed deformation test of the specimens was carried out in the order of numbers by using the test machine of frozen soil pressure.

The first test pressure can make the deformation of 20mm, which is a half of the height of the specimen. The preliminary estimate of the pressure size is about 9KN, the destruction of a try is observed at this time; if the specimen is intact, the pressure is continued respectively to 24mm (10.8KN), 28mm (12.6KN), 32mm (14.4KN)... Until it begins to break, the pressure applied are recorded at this time.

2.3. Experimental result

In the process of loading, and unloading, the compression displacement is in proportion to the load proportional loading. Namely the compressive displacement (deformation) increases when loading and decreases when unloading. When unloading to the initial value, the compression displacement does not decrease, but there are about 10mm of the irreversible deformation. Through one cyclic loading can be found second, the load corresponding with the maximum displacement in every test is basically the same. The resulting irreversible deformation is about 10mm-11mm, the corresponding single irreversible deformation is about 0.50mm-0.55mm.

3. Fitting equation

The curve of load-displacement is transformed into the stress-displacement formula. Then the empirical curve formula of the mechanical property test of rubber cushion is as follows:

$$\sigma = 0.2393\Delta l + 0.2693 \quad (1)$$

In action, σ is the action stress, l is the compression displacement of the 20 rubber pads.

The compression amount of the formula (1) is converted into a single rubber pad (1 pieces of 20 pieces) is

$$\sigma = 4.786\Delta l + 0.2693 \quad (2)$$

From the formula (2) we can get the deformation of one rubber pad is

$$\Delta l = 0.209\sigma - 0.056 \quad (3)$$

4. Example analysis

4.1 Engineering background

The Shenhua Group Taigemiao mine shield construction of long distance mine shaft test project as an example. By using the shield machine thrust force 10000KN, tunnel lining structure within a radius of $b=3.3\text{m}$, radius $a=3.65\text{m}$, segment width $d=1.5\text{m}$, thickness $h=0.35\text{m}$, rock pressure p_1 is 15MPa, segment concrete grade is C40, density is $\rho=2440\text{kg}/\text{m}^3$. Poisson ratio is $\mu=0.22$, elastic modulus $E_1=3.25\times 10^4$ MPa.

Table 1. Physical and mechanical parameters of rock mass in specifications

Basic quality grade of rock mass	Gravimetric density γ (KN/m^3)	Internal friction angle φ ($^\circ$)	Cohesive strength c (MPa)	Deformation modulus E (GPa)	Poisson ratio ν
I	>26.5	>60	>2.1	>33	<0.2
II	26.5-24.5	60-50	2.1-1.5	33-20	0.2-0.25
III	24.5-22.5	50-39	1.5-0.7	20-6	0.25-0.3
IV	<22.5	39-27	0.7-0.2	6-1.3	0.3-0.35
V		<27	<0.2	<1.3	>0.35

4.2 Deformation of rubber pad

According to the actual engineering background parameters and the existing research results, the pressure of the rubber pad between the segments is obtained. The deformation of the rubber pad between the segments is

$$\Delta l_{n \sim n+1} = \frac{(10000 - 5.83n^{\frac{n-1}{2}}) \times 10^{-3}}{8.02} - 0.27 \quad \text{mm}.$$

In which n is the order number. If $n=1,2,3,\dots$ are brought respectively into the formula, the deformation of every rubber pad can get as follows, 0.2056mm, 0.2045mm, 0.2040mm,.....

5. Conclusion

Using the mechanics theory, combined with the actual technical parameters of shield construction, the rubber pad compression test is designed and finished. The jack thrust interaction and backfill layer friction resistance is simulated; compression deformations of rubber pads are measured. The stress-deformation formula of the rubber pad is obtained and finally draw the following conclusions:

The rubber pad between the segment rings will produce a certain amount of compression deformation under the action of the jacking force of the jack. The compression deformation of the rubber pad between the segment rings is related to jacking force of Jack.

Acknowledgments

This paper is funded by the open foundation of Heilongjiang Ground Pressure & Gas Control in Deep Mining Key Lab (F2315-01) and Youth Foundation of Heilongjiang Natural Science Foundation of China (QC2015055).

References

- [1] Terzaghi K, Riehart F E. Stress in rock about cavities[J]. *Gdotechnique*, 1952,3:57-90.
- [2] Singh B, Goel R k, Jethwa J L. Support pressure assessment in arched underground opening through poor rock masses[J]. *Engineering Geology*, 1997, 48:59-81.
- [3] Bhasin R, Grimstad E. The use of stress-strength relationship in the assessment of tunnel stability[J]. *Recent Advances in Tunneling Technology*, 1996,12(2):20-29.
- [4] Goel R K, Jethwa J L, Paithankar A G. Indian experiences with Q and RMA system[J]. *Tunneling Underground Space Technology*, 1995,10(1):97-109.
- [5] Yangsong Zhang, Xiaozhao Li . Finite Element Analysis of the Stability of Tunnel Surrounding Rock with Weak Rock Layer[J]. *Modern Applied Science*, 2009, 3 (12):22-27.
- [6] Greenspan M. Effect of a small hole on the stresses in a uniformly loaded plate[J]. *Q.d.Appl.Math*, 1944,2:60-71.
- [7] Hasan Gercek. An elastic solution for stresses around tunnels with conventional shapes[J]. *Int.J.RockMech*, 1997,34:3-4.
- [8] Mendinal, Rodrlguez J M. Prediction and analysis of subsidence induced by shield tunneling in Madrid metro extension[J]. *Canadian Geotechnical Journal*, 2002,39(6): 1-10.
- [9] Hoek E, Brown E.T. Practical estimates of rock mass strength[J]. *Rock Mechanics*, 1997, 34(8):1165-1186.
- [10] Sharan S.K. Elastic-brittle-plastic analysis of circular openings in Hoek-Brown media[J]. *Rock Mechanics*, 2003,40:817-824.