International Journal of Mining Science and Technology 25 (2015) 497–501

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Characteristics of in situ stress field at Qingshui coal mine

Yang Xiaojie [a,b,c], Pang Jiewen [a,b,c,*], Lou Haopeng [a,b], Fan Lipeng [a,b]

[a] State Key Laboratory of Geomechanics and Deep Underground Engineering, China University of Mining & Technology, Beijing 100083, China
[b] School of Mechanics and Civil Engineering, China University of Mining & Technology, Beijing 100083, China
[c] Key Laboratory of Deep Mining and Hazard Prevention, China University of Mining & Technology, Beijing 100083, China

A R T I C L E I N F O

Article history:
Received 2 March 2014
Received in revised form 15 April 2014
Accepted 15 July 2014
Available online 20 April 2015

Keywords:
Soft rock
In situ stress
Overcoring method
Roadway stability

A B S T R A C T

In this study, the characteristics of geological structure at Qingshui coal mine were analyzed. And the hollow inclusion strain cell overcoring method was used to obtain the in situ stress. The effect of in situ stress on the stability of soft rock roadway was analyzed. The results show that the maximum principal stress is in the horizontal direction with a northeast orientation and has a value of about 1.2–1.9 times larger than gravity; the right side of roadway roof and floor is easily subject to serious deformation and failure, and the in situ stress is found to be a major factor. This paper presents important information for developing countermeasures against the large deformation of the soft rock roadway at Qingshui coal mine.

1. Introduction

The Qingshui coal mine is located in the southeast of the Shenbei coalfield and has a mining history of over 50 years. At present, the mining depth is about 520 m, and the mine has entered the deep mining stage. The Qingshui coal mine has a complex geological structure that is primarily composed of faults. There are up to 115 faults in Qingshui coalfield with about 9.2 faults/km^2. The coal-bearing strata belong to the Paleogene system and mainly consist of oil shale, mudstone, and sandstone. During mining process, serious deformation and failure phenomena including floor heave, roof subsidence, and walls shrinkage of the soft rock roadway appear, which seriously affects the production safety. In order to study the failure mechanism of deep soft rock roadway and solve the large deformation problem, the various factors impacting roadway stability need to be analyzed. The in situ stress is the fundamental force that causes the deformation and failure of underground rock mass during the excavation process [1–4]. Therefore, it was necessary to measure the in situ stress and study its distribution for the Qingshui coal mine.

In situ stress measurement is the most effective and direct means to obtain the in situ stress [5]. At present, hydraulic fracturing and overcoring are the most widely used methods for measuring the in situ stress. Small bore hydro-fracturing measurement technology and the hollow inclusion strain cell overcoring method are the most widely used methods for testing the in situ stress in coal mines. The small bore hydro-fracturing measurement technique was invented by the Coal Science Research Institute of Beijing Mining Institute [6–10]. It does not need the rock's physical and mechanical properties or the stress–strain relationship; it only needs the pressure–time curve which can be recorded during the fracturing process of surrounding rock. The magnitude of principal stress can be obtained from the curve, and the azimuth of principal stress can be determined from the cracking impression. However, this method cannot be used to obtain the stress measurements in 3D until the hydraulic fracturing test is performed on three or more boreholes in different directions [11–13]. The hollow inclusion strain cell overcoring method obtains the strain data for the rock's elastic recovery during the overcoring process by pasting a strain gauge rosette to the hole wall. The constitutive stress–strain relationship of rock mass can be used to establish a corresponding mechanics calculation model. The observed strains or displacements can be used to calculate the six components of in situ stress and the magnitude and azimuth of three principal stresses [14]. However, these two methods are intended for a certain point and cannot objectively reflect the distribution of in situ stress for a certain area. In this study, the point-area combined analysis method proposed by He and Qian [1], was used at Qingshui coal mine. First, the geomechanics was analyzed to determine the direction of in situ stress field. The situation of geological structure was summarized, and the evolution of geological structure and present tectonic stress field were analyzed because of their great impact on the stress field of Qingshui coal mine. Second, the in situ stress was obtained through geomechanics analysis and compared with the measured values for verification. Finally, the distribution laws of

* Corresponding author. Tel.: +86 15201325192.
E-mail address: pjwfanfan@126.com (J. Pang).

http://dx.doi.org/10.1016/j.ijmst.2015.03.026
2095-2686/

in situ stress field at Qingshui coal mine were obtained through the point-area combined analysis method. The hollow inclusion strain cell overcoring method was used for the in situ stress measurement because of its high accuracy and capability of obtaining the 3D stress from the single hole test.

2. Geological structure features and analysis on direction of in situ stress field

2.1. Regional geology structures analysis

The formation of the Shenbei coal basin was closely related to the activities of Tanlu fault. The Tanlu fault zone controls the geological structure of the Shenbei coalfield. The history of Tanlu fault in Shenbei coalfield can be divided into three stages: the sinistral strike-slip stage is the Late Jurassic–Early Cretaceous; the gaping movement stage is the Late Cretaceous–Paleogene; and the compression movement stage with a right-lateral strike-slip has been developing since the Neogene [15].

The sinistral strike-slip movement of Tanlu fault produced the convoluted structure (see Fig. 1). The structure expands outward in a clockwise direction along northeast Wanghua–Qingshuitai. In the southern part of the coalfield, synclines and anticlines alternate from west to east and from south to north, and are accompanied by reverse faults. There are many tensor–shear faults at the Daqiao and Wanghuajing brachyanticline, and the Wanghua brachyanticline is exactly in the column pillar position.

The Shenbei coalfield developed into a fault basin after Tanlu fault rifted during the Mesozoic. Xintaizi–Damintun fault on the east wing of Tanlu fault also developed during this period and became the western border of the coalfield. It controls the faults along the east–west tectonic boundary of the coalfield.

Tanlu fault has had right-lateral strike-slip movement with compression since the Neogene. During this period, Shenbei coalfield experienced a reversal in movement. However, this had a small impact on the geological structure because large graben and horst were formed by the gaping movement during the Late Cretaceous–Paleogene, which offset the impact of compression during the late period of the coalfield formation.

Based on the analysis of the evolution history of Tanlu fault in Liaozhong, the Tanlu fault zone's effect on the geological structure of the Shenbei coalfield can be divided into three periods. During the Late Jurassic–Early Cretaceous, Tanlu fault showed strong sinistral strike-slip movement that controlled the shape of the sedimentary basin and generated many left vortex structures along the fault zone. The dynamic background was the Pacific plate subducting toward the North China plate in the NE direction [15,16].

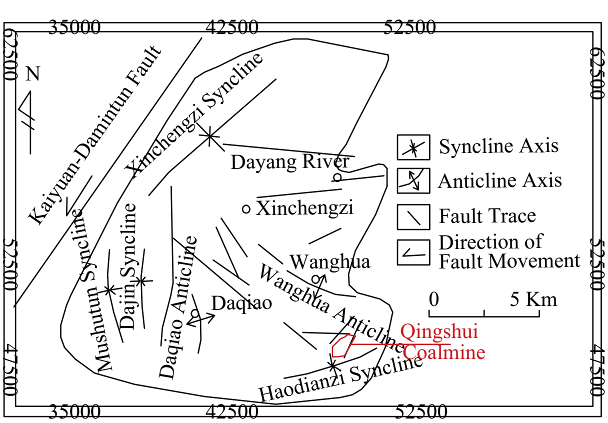

Fig. 1. Geological structure of Shenbei coalfield [15].

During the Late Cretaceous–Paleogene, the Shenbei coalfield experienced gaping movement, which controlled the boundary of the coalfield. During the Neogene period, right-lateral compression movement further changed the sedimentary formation of this area but only slightly affected the geological structure of the coalfield.

2.2. Geological structure analysis of mining area

The Qingshui coal mine is located in the southeast of Shenbei coalfield at the south wing of the Wanghuatai–Daqiao anticline and north wing of the Haodianzi syncline. The coal-bearing strata trend northwest. The strike is southwest, and the strata inclination angle is 5°-15°. The Qingshui coal-bearing strata are the monocline structure and are inclined southwest, and the junior fold developed locally. In general, the stratum altitude is simple, and the fold structure is rare.

There are 115 faults in the mining area (see Fig. 2) with nearly 9.2 faults/km^2. There are 16 faults with a fault throw of more than 50 m, 12 faults with a fault throw of 30–50 m, and 28 faults with a fault throw of less than 30 m. All the faults in the mining area are normal faults, and most of them have the shape of circular arc. Branch faults, where the scale decreases with the increasing distance from main fault, are mostly located in the northwest of the main fault.

All the faults in the mining area formed after coal formation. Because of later tectonic activities, the occurrence state and integrity of coal seam were destroyed. Based on the occurrence state, the faults can be divided into two groups. One group consists of faults nearly parallel to the F1 fault in the eastern boundary. They are the principal geological structures and have strikes of NE 30–50°. The other group consists of faults with strikes that are nearly east-to-west. They are mainly distributed at the center of mining area and include faults namely F88, F83, and F89. Most of them are cut by faults whose strikes are nearly northeast.

2.3. Analysis of in situ stress field

The sinistral strike-slip movement of Tanlu fault during the Late Jurassic–Early Cretaceous was the main factor behind the formation of vortex structures at the Shenbei coalfield. These structures

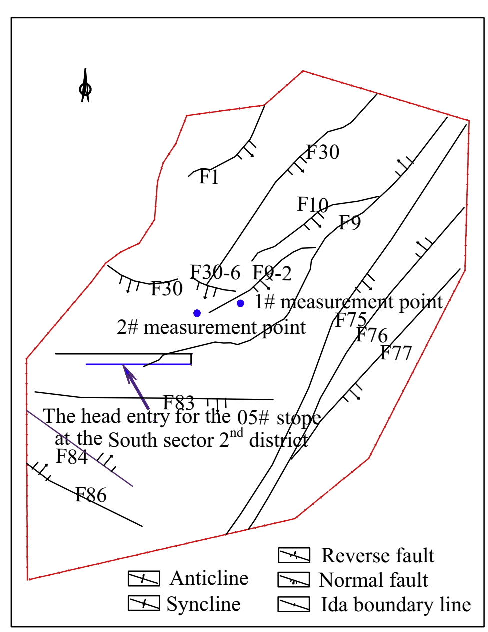

Fig. 2. Geological structure of Qingshui coal mine.