Structure Characteristics of Neogene and Engineering Response to Deep Excavation

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Abstract

Due to the impact of lithology, composition, groundwater and other factors, the formation of Neogene appear more differences in structure in different sections and depth in Xuchang coalfield, China. After the hydrogeological structure, broken and unconsolidated layers discussions and deformation simulations, the structural characteristics of Neogene and its effect on deep excavation are analyzed. The main understandings are list as follows: 1) The Neogene system in this areas consists of sandstone and mudstone, which are the basis of aquifers and aquifuges in macroscopic view. 2) The structure of the thick Neogene controlled by weak structural segments, soft stratum and bedding faces. And this changes the hydrogeological structure. 3) Model tests reveal that the soft-hard interlaying and structure network control the deformation of Neogene during mining. The failure zones appear in coal roof and the bottoms of Neogene system have some similar characteristics.

Keywords: Structural Characteristics, Neogene, Deep Excavation

1. Introduction

Neogene system is composed by Miocene and Pliocen, which was confirmed by the International Commission on Stratigraphy in 2009 (Berggren et al. 1995; GuiSen et al. 2005; Yupeng et al. 2010; Guisen et al. 2009). There are many coal basins are covered by thick layers of Neogene and Quaternary in Shandong and Henan Province, China. These overburden layers are simply regarded as unconsolidated layers in a large amount of research papers about coal mining. Xinjing et al. (2011) point out that the Neogene strata in the area around the Xiaolangdi Reservoir, China is a kind of incomplete consolidated argillaceous sediment and its mechanical properties range between that of soil and rock. Yongshuang and Yongxin (2000) find that this kind of geo-material is very easily to cause engineering geological problems after comparison the uniaxial compressive strength, which ranges from 0.3-1.5 MPa, of some Neogene strata.

The directly strategies of mining flood prevention under water body and aquifers is keeping mining deformation within the permitted limits. The experience way is to limit the mining thickness or the ratio of mining depth / mining thickness does not exceed a critical value. Another accurate measurement is to control the limit tensile strain caused by mining (Baohong, 1995). Due to the high content of clay in some Neogene layers in this area, the argillaceous sediment has good water-resisting properties to cut off the hydraulic connection between water body(s) and aquifer(s). But the discontinuity and weakness of Neogene strata are still obstacles to judge its engineering ability of water-resisting.

We take a coal field in Yuzhou, Henan Province as an example to reveal the distribution and structure of Neogene, and its effects on deformation.

2. Geology, hydrogeology conditions

Yuzhou coal field locates in the mid-west of Henan, China, where the II-1 coal seam of lower Shanxi formation in Permian is the main mining seam. Fig.1 and 2 give the location of Quandian Coalmine and the bottom elevation of Neogene.

The formations in this area include Cambrian, Carboniferous, Permian, Neogene and Quaternary. The Quandian Coalmine lies in a sedimentary basin covered the western Henan, the eastern Shanxi, the northern Hubei and the southern Shaanxi, which is a landlocked lake basin and has a huge thickness of Neogene and a thin layer of Quaternary system. The colors of this Neogene are usually gray and brown-red. Conglomerate, pebbly sandstone, argillaceous siltstone, mudstone and shale are the main compositions of the Neogene. It is over 300-900m’ thick for this Neogene in Quandian Coalmine and no more than 40-80m’s thick for the Quaternary on the top.

Beneath the Cenozoic is the Shanxi group of Permian, which is the main coal-bearing stratum in the Coalfield. Under the Shanxi group is Taiyuan group of Carboniferous, and it is not the focus of this discussion. The top boundary of the Shanxi group is the erosion surface, and that is also the bottom of the Neogene system. Above the coal seam II-1, it is a set of light gray to dark gray sandy mudstone, fine to medium grained sandstone and siltstone. These layers are the overburden above the coal seam II-1, and the residual thickness of this is only 30-60m.The fossil erosion surface above the Shanxi formation plunges from north to south as Fig.2 shows and the maximum inclination is 20-24°. The coal measures have the same dip direction with the fossil erosion surface while the dip angle is 15° to 20°. Fortunately, all the faults did not cut through the Neogene. The overburden rock mass above coal seam II-1 is no more than 60 m's height, and the aquifers in Neogene may bring troubles to mining.

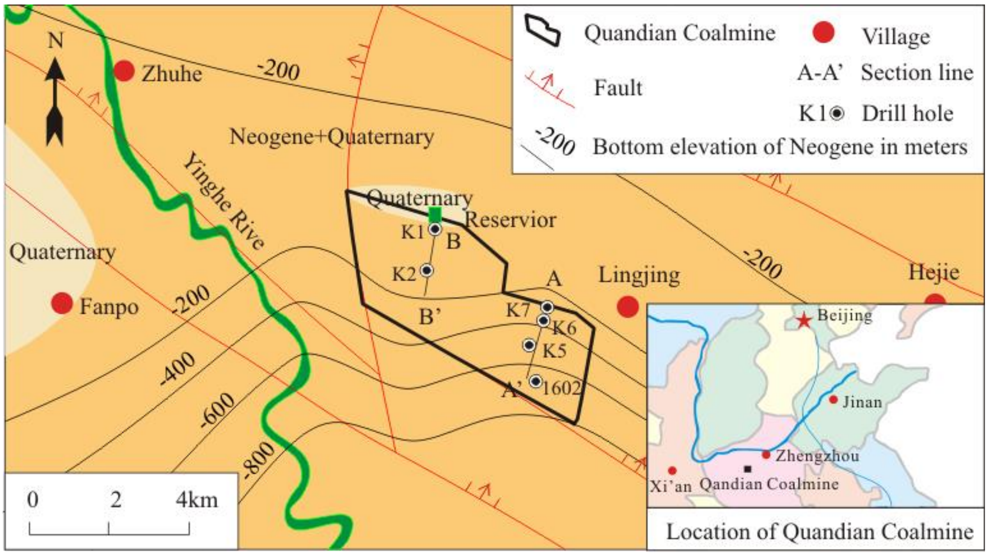


Fig. 1 Geological conditions and the bottom of Neogene around the Quandian Coalmine

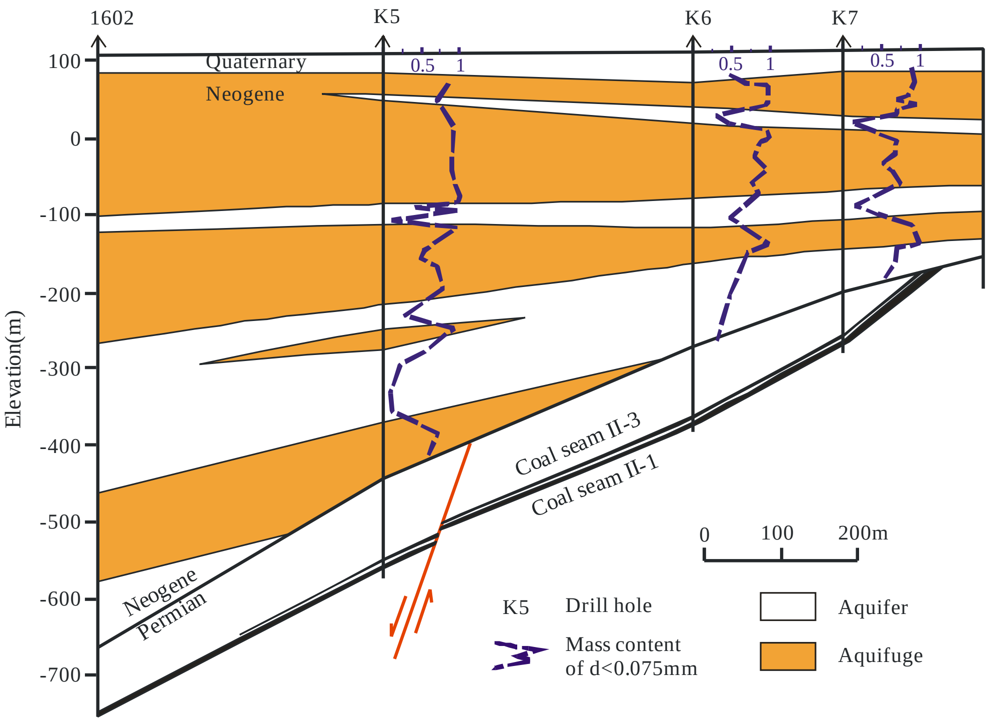


Fig. 2 Granularity variation and hydrogeological structure of section A-A'

The surface water has a very close hydraulic connection with Quaternary in this area. Ying River, one of the tributary of the Huaihe River, is flowing through the western of this area. The river valley is about 300-500 m's wide, and transport 177.6 million m^3 water annually. A crisscrossed artificial irrigation network connects with the Ying River and its upstream reservoir. It can be seen from Fig.1, there is a small reservoir locates hereabout the outcrop of coal seam II-1 in the northwest of Quandian Coalmine, which has a storage capacity of 325000m^3. The reservoir basin is composed of sand and gravel layers of Quaternary, and they are porous aquifers. It is only 40 m' thick of this Quaternary layers and all have water contact with the surface water bodies. Hence, the mining engineering in this area has to face the problems of shallow water resource protection and mining water inrush prevention in deep level.

According to the exploration works mainly by drill holes, the Neogene system in this area can be divided to several interbed aquifers and aquifuges that illustrated in Fig.2. The aquifuges are always composed by weak cemented clay, sand and gravel layers. Its structure has obvious relevance with its particle size distribution, especially with the degree of clay content. Pumping tests have been arranged in the upper, middle and bottom of Neogene and the results of these pumping tests are listed in Table 1. The sequence of these aquifers in Table 1 is consistent with the drill K6 in Fig.2 and these results assure the main aquifers are all of weak water abundance. It is easy to see that the three terminal water level from aquifer Top, Mid and Bot have obvious differences. The units-inflows are relative uniformity in aquifer Top and Mid. But it is not so uniformity like these two aquifers, there is a large variation scope of units-inflow appears in the Bot aquifer because of the heterogeneous of gravel layers in the bottom Neogene system. These three aquifers also have different permeability and it is clearly that the aquifer Top and Bot have a more well conductivity than that of the Mid aquifer. Such situation shows there is a good impermeability layer in the middle of Neogene. That is the Top, Mid and Bot aquifer have not direct hydraulic connection with each other. As the aquifer Bot has weak water abundance, water inrush prevention is not a very serious problem to mining safety. But when there appears drastic excavation engineering in underground, the deformation or failure happened in the aquifuges and weak water aquifers would disturb its ability of cutting off the water contact with the upper water body.

3. Structure characteristics of Neogene

According to the observation experiences from the around coalfields, the mining cracks can extend up to 14-17 times mining thickness. Because the thickness of the overburden rock mass above the coal seam II-1 is no more than 60 m and the average mining thickness is 7 m, it is easy to predict that the top of the mining cracks in this area may reach 98 to 119m' height. That is to say the cracks zone may cover the aquifer or aquifuge at the bottom of Neogene.

On aim to gathering the structure characteristics, physical and mechanical properties of the Neogene and Permian, three drill holes are arranged around the reservoir in the west of Quandian Coalmine. The section B-B' as Fig.3 shows include drill K1 and K2 can reveal the stratigraphic sequence of this area. Density, moisture content, specific gravity, particle analysis, expansion, uniaxial compressive strength, shear strength, elastic modulus of the cores from drill K1, K2 and K3 are tested according to Chinese soil test standards. The tests illustrate the uniaxial compressive strength ranges from 0.5 to 2 MPa. These results are very closely similar with that from Yongshuang and Yongxin (2000). But almost all the gained properties are randomly distributed or discrete distributions. These data cannot reflect any obviously differences varying with depth except the internal friction angle as Fig.4 shows. These superficial results are difficult to assist analyzing the hydrogeology conversion trend of the Neogene caused by mining and also may hid some essential factors such as discontinuities for mine safety. The main reason may be the test specimen is more complete.

Basing on the drilling records, it can be found there are several crushing parts and aquifers in each drill hole. The results of pumping tests for each aquifer are list in Table 1. These segments can be connected with each other in a cross-section through the drills contrast. From Fig.3, it can be seen the broken or unconsolidated segments mainly exist in

Table 1 Results of pumping tests

Aquifer	Units inflows (L/s·m)	Water level in elevation (m)	Permeability coefficient (m/d)
Top	0.0307-0.0545	+62.88-+80.16	0.2177-0.5477
Middle	0.0032-0.0078	+46.07-+42.58	0.01075-0.031
Bottom	0.004-0.219	+31.28-+121.96	0.02050-0.3795

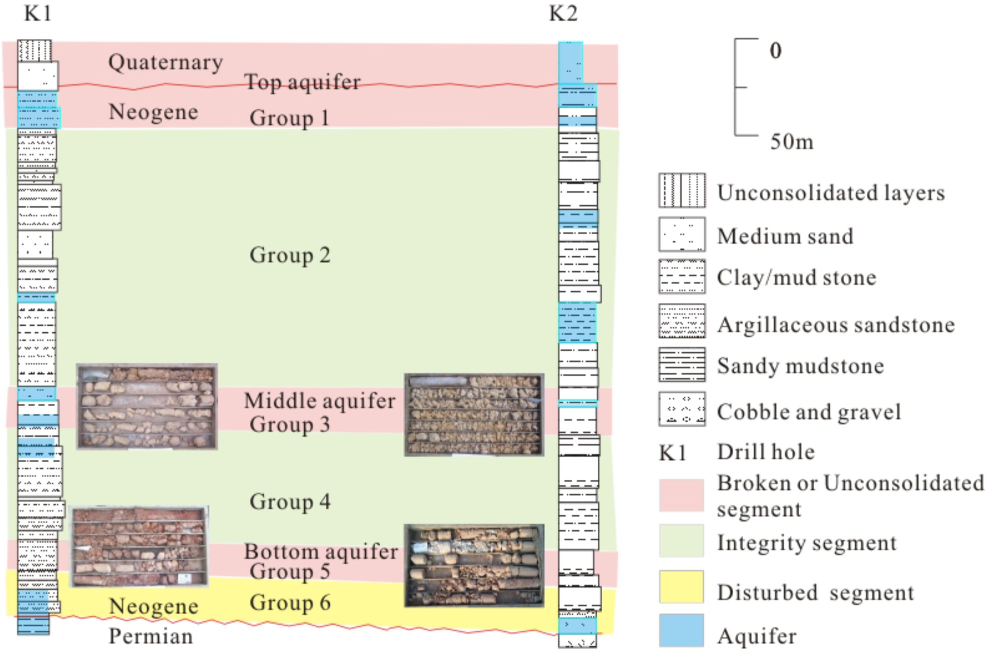


Fig. 3 The weak segments imbedded in Neogene of section B-B'

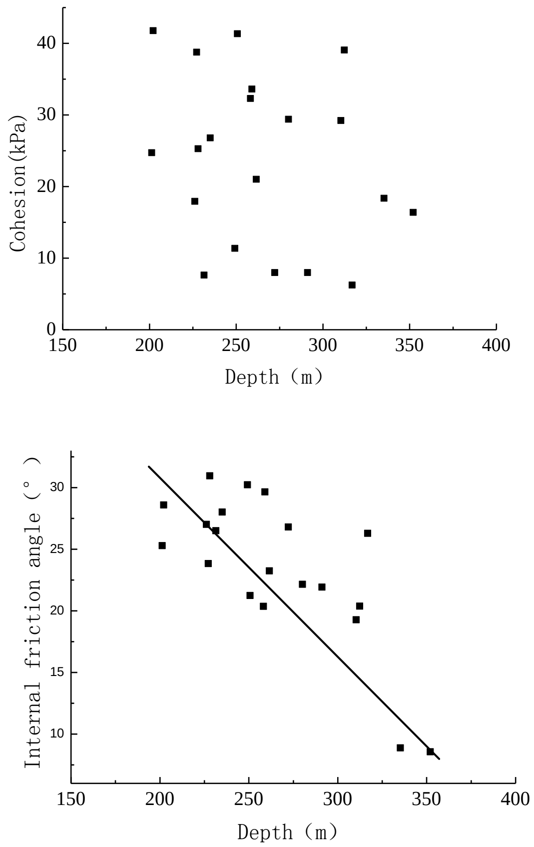


Fig. 4 Mechanical properties changing with depth

two main layers. On considering the aquifers and aquifuges, particle distributions and crushing parts, the Neogene system of this area can be divided into 6 groups. Among these, the group 6 at the bottom of Neogene system consists of clay, clayey sand and gravel has been considered to be an aquifer and will be disturbed by mining inevitably. The group 5 is a weak layer and may probably lead to the separation between group 6 and 4. While the group 4 is an aquifuge with great thickness and slice aquifer imbedded in it. It is a stable layer that spread all the study area and has more clay content. This segment is a mix group of intact and relatively fractured layers. The group 3 is also a broken or unconsolidated segment. The cores of this group consist of large content of illite and most of them disintegrated rapidly. The group 2 has the similar structure with the group 4. The top is the group, which is a combination of Quaternary and weathered Neogene, and this is an aquifer that has good water contact with the surface water body. According to the above information, the layer interfaces and the weak groups have made up the structure of Neogene system, which is a not uniformity system.

If the mining caused deformation or damage extends to the bottom of Neogene system, the structure of Neogene system and properties can bring some special effects to mining safety.

4. Deformation, failure simulation

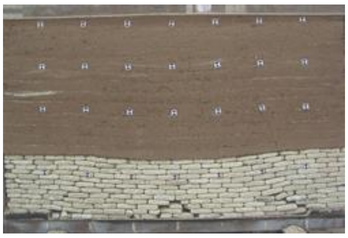
Laboratory simulation experiments on considering three factors and three levels were conducted in order to analyze the influences of different mining thickness, overburden thickness and lithological of Neogene (Photo. 1). The geometrically similar scale is 1: 200 for all the models. They are all plane models and 2 meter' long, 0.25 meter' thickness. The rock materials are prepared according to its laboratory intensity. The rock mass above coal seam II-1 is a uniform layer of argillaceous sandstone. The thickness of this argillaceous sandstone is the height from the bottom of Neogene system to the roof of the coal seam II-1, which is represented by H and called overburden height. Among the photos, M is the thickness of mining slice. Another changing factor is lithology of the group 5 to 6 in Neogene system. In order to examine the impact of intensity level on the deformation and failure in group 5 or 6 , three types of material formulation are designed to represent a soft, a soft-hard interbed and a hard Neogene layer covered on the surface of Permian. These materials are made of soft clay, interbedded combination of soft clay and hard sandy clay, hard sandy clay.

As seen in Photo.1(a)-(c), under the same overburden height, the damage area extended higher significantly with the increase of mining thickness, so did the damage area in Neogene system near the erosion surface. Tension fissures, bedding subsidence and breakage will appear in the layered strata of Neogene system in the circumstance of mining thickness increasing.

When the mining thickness is kept 4m, we can see in Photo.1 (d)-(f) that the damage area of overburden rock mass decrease with the overburden thickness decreasing. The damage range of Neogene system is closed affected by the layered combination. The pure soft clay combination lead to the minimum damage in Neogene system and the second, third are the soft-hard interbed combination, the hard combination respectively.

When the bottom layer of Neogene consists by soft-hard combination, as shown in Photo.1 (g)-(i), the thickness of the overlying rock varying from 30 m to 50 m, the Neogene and overburden rock mass have good synergistic deformability while the mining thickness changes from 2 m to 6 m, although different scales of fractures will appear in Neogene.

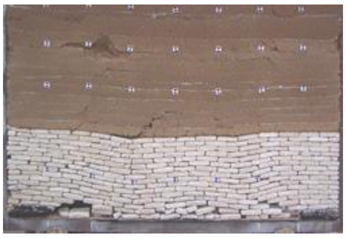
Qingxiang (2003) and Qingxiang et al. (2009) had established a mining caused "Arched beam" model to describe the deformation of the thick soil layer covered on the shallow buried thin bedrock. Hanfu (2012) had analyzed the instability criterion of huge clay layer during mining. The basic precondition of their researches is the assumption that soil or rock is uniform and continuous. But the in fact situation of the Neogene system is a relatively complex network structure and the deformation, damage of Neogene are coupled by its native or mining induced structure. So more microscopic structure analysis need considering in the future.

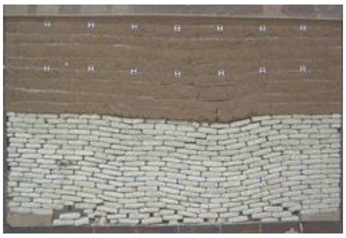

(a) *M*=2m, soft


(b) *M*=4m, soft-hard interbed

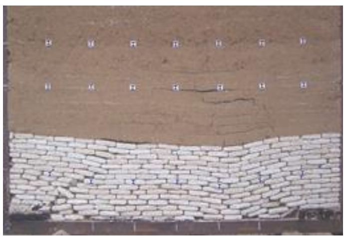

(c) *M*=6m, hard


(d) *H*=30m, soft-hard interbed


(e) *H*=40m, hard


(f) *H*=50m, soft


(g) *H*=30m, *M*=4m


(h) *H*=40m, *M*=2m


(i) *H*=50m，*M*=6m

Photo. 1 Destruction in overburden rock mass and the bottom of Neogene

5. Conclusions, suggestions

This paper formed the following understandings:

The Neogene of Yuzhou coalfield could be divided into 6 groups according to grain composition and core fragmentation degrees, which is a structural influential factor in determine the characteristics of deformation and failure after the deep excavation.

The structure of the thick Neogene layer in this area is controlled by weak structural segments, soft stratum and bedding faces. It was found soft-hard interlaying and structure network control the deformation of Neogene during mining.

Experiments considering complex network structures of Neogene are important direction to further analyze and evaluate deformation-seepage action of Neogene.

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