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Condition evaluation of a unique mining site

Liu Junsheng [a,b], Chen Frank Y. [c,d,*], Ma Yan [b], Zhang Siya [b]

[a] *Civil Engineering Academy, Xi'an University of Architecture & Technology, Xi'an 710055, China*
[b] *Shaanxi Academy of Building Research, Xi'an 710082, China*
[c] *Institute of Architecture and Civil Engineering, Taiyuan University of Technology, Taiyuan 030024, China*
[d] *Department of Civil Engineering, 777 W Harrisburg Pike, The Pennsylvania State University, Middletown, PA 17057-4898, USA*

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ABSTRACT

The primary objective of this study was to evaluate the existing conditions and the stability of a mining site in which the unique features of seismicity, mining activity, hydrological conditions, geological conditions, environmental conditions, and future development plans were considered. In particular, the potential subsidence locations near the proposed construction site, the effects of mining boundary profile, and the influence scope of the mining activity on the neighboring areas were investigated using the finite element method. The study results indicate: (1) the overlying sandstone layer to the coal layer is the key to the stability of the mining roof; (2) the broken boundary has the most effect, followed by the arc boundary and linear boundary; (3) the safe distance from the mining boundary should be at least 400 m if the proposed structure is to be built near an active mining site. Other relevant engineering recommendations are also proposed. The concluded results from this study may serve as a guide to other similar sites in the world.

1. Introduction

The investigated site is located in a place called Yulin which is essentially a coal field beneath the loess plateau in northwest China, a desert area widely covered with sand dunes and virtually no vegetation (Fig. 1). The topography is relatively flat with the elevation varying from 1115 m to 1200 m. The rock formation at the site is a gentle large monoclinal structure oriented west to northwest with an average drawdown angle of less than 1° with some similarity to the one reported by others [1]. Drilling tests indicate no magmatic rock distribution, drape structure, or structural irregularity. There are some tectonic faults existing at the site, however.

A new construction project was proposed at a mined-out area of approximately 61 acres (Fig. 2). The main purpose of this study was to evaluate the stability of that area based on the existing conditions, which is an important issue as also pointed out by others [2]. Specifically, two coal layers were investigated at the site. Layer I is 3.7–5.57 m thick (average thickness = 4.66 m), fully mineable, and in a relatively stable condition. Layer II is thinner and also fully mineable. The mining opening is located at 90–110 m beneath the ground surface and is supported by a 3.8–4.5 m thick roof. The exact scope and boundary profile of the mining area are unclear, however.

The physical properties of the geological materials in coal layer I, as obtained from the tests, are summarized in Table 1, where E is the modulus of elasticity and ν is Poisson's ratio (layer II similar).

2. Considerations

Important evaluation considerations, reflecting the unique features of the investigated site are briefly described as follows.

2.1. Seismicity

Only two significant earthquake events are reported in the historical records: the 1448 Quake (magnitude 4.7) and the 1621 Quake (magnitude 6.7) [1]. Over the past 100 years, several smaller earthquakes at the site were reported. It should be noted that some degree of seismicity was felt from the earthquakes occurring in the neighboring areas such as the 1477 Yinchuan Earthquake (magnitude 6.5), the 1739 Yinchuan Earthquake (magnitude 8.0), the 1920 Haiyuan Earthquake (magnitude 8.5), and the 1996 Inner Mongolia Earthquake (magnitude 6.4), and even from a place more than 1000 km away like the 2008 Wenchuan Earthquake (magnitude 8.0), Fig. 3 [3]. In general, the seismicity at the investigated mining site is considered moderate. The predominant period of the seismic

* Corresponding author. Tel.: +1 7179486146.
E-mail address: yxc2@psu.edu (F.Y. Chen).

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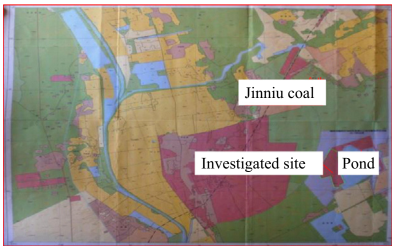

Fig. 1. Investigated site.

response spectra (T_m) is 0.35 s and the maximum peak ground acceleration (PGA) is 0.05 g, based on 10% probability of exceedance in 50 years.

In recent years, the investigated site has experienced more frequent ground shaking due to the collapse of the inactive mining field and rock bursting. For instance, there were 13 such events occurring between December 2011 and June 2012. The corresponding earthquake magnitude is between 2.5 and 3.3. This mining-induced quake has become quite common in the studied area since then. Although no destructive collapse was reported, such ground movement did cause increasing degree of panic and psychological breakdown to the public.

2.2. Hydrological conditions

The surface water at the investigated area originates from the main river, the Yellow River. Around the investigated site, there are creeks flowing into the lakes. The water flow varies significantly from 0.057 to 11.75 m^3/s. The statistical data show that the total number of water-filled lakes in the area has been reduced to 79 in recent years from the original number of 869. The loss of water is largely due to the surface cracks caused by the mining activity. The water loss problem is expected to worsen over time.

2.3. Geological conditions

Three different geological materials beneath the mining zone were discovered: (1) loose sands having larger porosity, low bearing capacity, and poor stability; (2) muddy rocks (20–40 m thick) with softening property, poor quality of rock mass, and low compressive and shear strengths; (3) sandstones having fair rock quality, relatively stable formation, and favorable strengths. The geological material above the mining cavity roof consists of powdery sandstones in the upper layer and moderate-strength argillaceous siltstones in the lower layer. The geological condition is somewhat similar to that reported by Colwell et al. [4]. Hoek [5] provides a detailed description on rock formation and properties.

2.4. Future development plans at the mine field

Much of the mine field has been exploited, except for the south side. Further mining on the south side is anticipated according to the development planning. The proposed construction site (350 × 700 m^2 on plan) is located at the south coal mine where a coal layer thickness of 3.7–5.57 m (average = 4.66 m) is underlain, Fig. 4. The planned mining excavation involves two stages. Stage 1

Table 1
Physical properties of the geological materials at coal layer I (layer II similar).

Geological layer	Geological material	Conditions	Volume-weight (g/cm^3)	Water content (%)	Compression strength (MPa)	Friction angle (°)	Cohesion (MPa)	Elastic modulus (MPa)	Poisson's ratio
Layer above the coal	Sandstone	Dry	2.21	6.3	74.8	31	13.2		
		Saturated	2.37		35.2	17	4.5		
		Moist			41.7	34	3.3	892	
	Siltstone	Dry	2.40	4.2	76.3				
		Saturated			27.8				
		Moist				33	11.2	795	
	Mudstone	Dry			81.4	31	13.2		
		Saturated			22.0	17			
		Moist							
Coal layer	Coal	Dry	1.24						
		Moist	1.33		29.2				
Base of coal layer	Mudstone	Dry	2.36		79.1				
		Saturated							
		Moist				20	15.5		
	Siltstone	Dry	2.37			30	19.1		
		Saturated			121.2	33	6.3		
		Moist	2.39		67.0			146	0.15

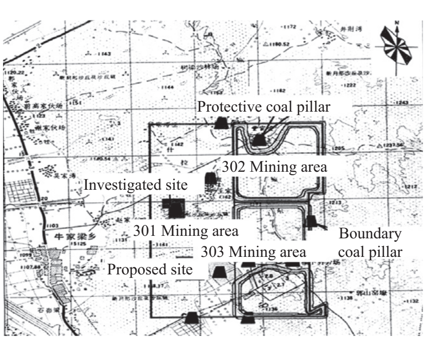

Fig. 2. A new construction area.

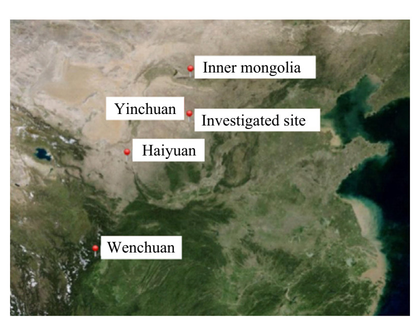

Fig. 3. Earthquake sites.