Risk Assessment for Coal Mining Under Sea Area

W. H. Sui and Z. M. Xu

Abstract

This paper presents a case study of risk assessment for coal mining under sea area in the Beizao Coalmine, Shandong Province, China. The coalmine is facing the risk of sea water inrush hazards because most of its panels are under the Bohai Sea. To forecast water disaster, three important factors, including efficient aquifuge, water flowing fractured zone and the water pressure bearing capacity of aquifuge, are considered to assess the mining safety situation for Panel H2301 in the Beizao Coalmine. The efficient aquifuge is identified by lithological analysis and water chemical comparison between sea water and groundwater. The water flowing fractured zone under different mining conditions is obtained by statistically analyzing the field measurements and numerical simulation. The safety mining condition under the Bohai Sea is assessed and the upper mining limit of Panel H2303 has been proposed.

Keywords

Underground coal mining • Mining under sea area • Risk assessment • Upper mining limit • Underground water inrush

1 Introduction

There are over 2.5 billion tons of coal resources located under surface water bodies in China. In recent years, China has been a rich experience of coal mining under water body such as lake, river and reservoir (Sun et al. 2008, 2009; Xu et al. 2010; Liu et al. 2010; Wu et al. 2009; Peng et al. 2011). Coal mining under surface water has been successfully carried out in some locations but there have also been many water-inrush disasters caused by the surface water when the overburden strata were damaged by the coal mining.

In addition, there are six countries having the experience of coal mining under the sea area all over the world, they are Britain, Australia, Chile, Japan, Canada and China. At the early 1980s, nearly 60 % of the coal production from 15000 of the underground coalmines in Britain was extracted from the sea area. Coal production from the sea area of Japan and Australia also accounts for a large proportion of the national coal production. In these countries, due to the special coal mining under the sea, mining activities were managed strictly by the government regulations and orders [John et al. 1982; Laxminarayan 1987; Niskovskiy and Vasianovich 1996; Sun 1999; Gill 2000; Singh and Jakeman 2001; Gandhe et al. 2005; Winter et al. 2008; Winter et al. 2008; Sun et al. (2008, 2009); Xu et al. 2010].

Current prediction methods for water flowing fractured zone are: field measurements, physical or numerical simulation and theoretical analysis (Liu 1995). There are many methods concerning the risk assessment for mine water inrush, such as Neural Network Method, Multi-sources

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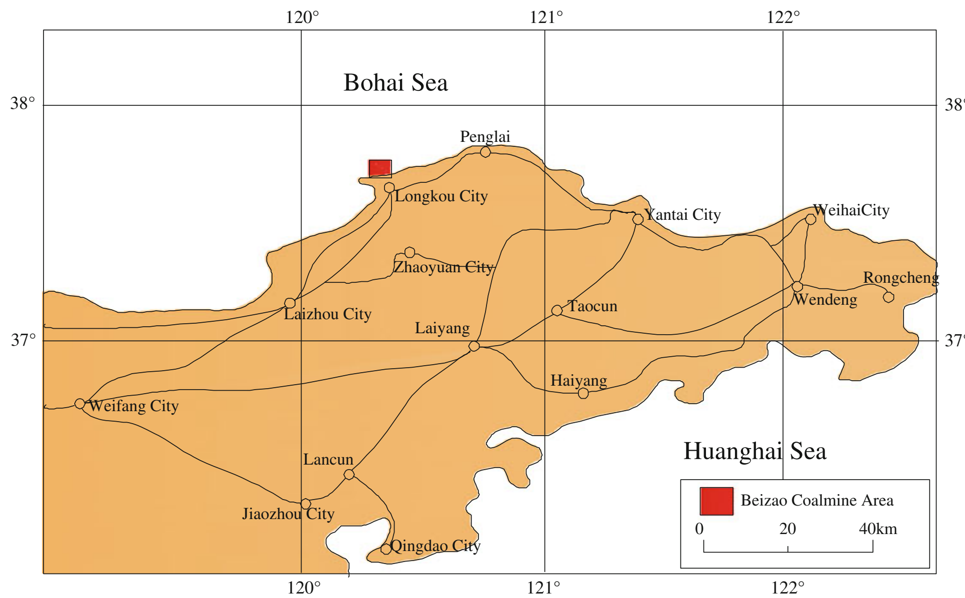


Fig. 1 The location of the Beizao Coalmine in Shandong Province

Information Fusion Method, Vulnerable Index Method and GIS (Sun et al. 2008).

This paper presents a case study of risk assessment for coal mining under sea area in the Beizao Coalmine, and deals with three key scientific problems: features of efficient aquifuge, height of the water flowing fractured zone and the water pressure bearing capacity of aquifuge, to present the water disaster forecasting results.

2 Geological Background

The Beizao Coalmine, which involves the first coal mining panel under the sea area in China, located in the northern part of Longkou city, Shandong Province, is facing a great risk of sea water inrush hazards. Fig. 1 shows the location of the Beizao Coalmine.

The major coal seam to be excavated in the Beizao Coalmine is Seam No.2 located in the Lower Tertiary System and the thickness ranges from 3.84 to 5.93 m. The overburden rock consists of mudstone, sandy mudstone, calcareous mudstone, oil mudstone and oil shale, which are easy to be expanded when mudding and have perfect water insulation. The inflow of mine water ranges from 25 to 30 m^3/h, among which the maximum is 42 m^3/h when the aquifer was exposed in the Beizao Coalmine.

The thickness of the overburden rock of Seam No. 2 is about 100 m, which can usually interrupt hydraulic connection between coal measures and the Quaternary aquifers. According to the observation in the Beizao and Liangjia Coalmine, the marl aquifers groundwater level is decreased by almost 30 m slowly, while the water level in the Quaternary unchanged. This result shows that there is not any significant hydraulic connection between the Quaternary and marl and marl-inter-bedded aquifers.

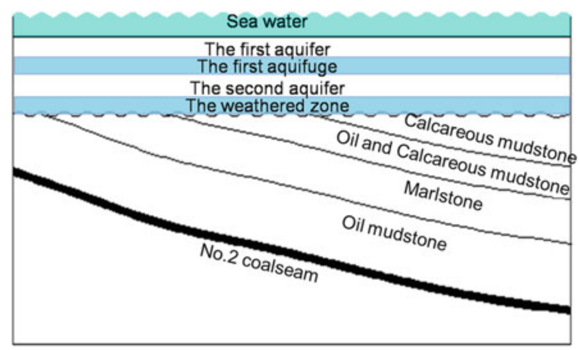


Fig. 2 The effective aquifuge in the Beizao Coalmine

3 Effective Aquifuge

The effective aquifuge is an impermeable seam which can prevent sea water from infiltrating into the coalmine. The impermeable clay layer of the first aquifuge of the Quaternary was determined to be an effective aquifuge (Fig. 2).

The first aquifuge, with the lithological composition of mainly clay and sandy clay, and a thickness about 20 m, effectively obstructs the hydraulic connection between the first and the second aquifer. The different chemical composition of the Quaternary groundwater, coal seam aquifer and sea water also show the effective aquifuge is reliable.

Fig. 3 Simulation model

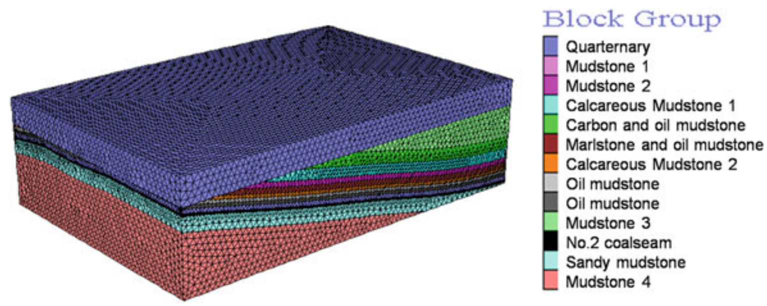
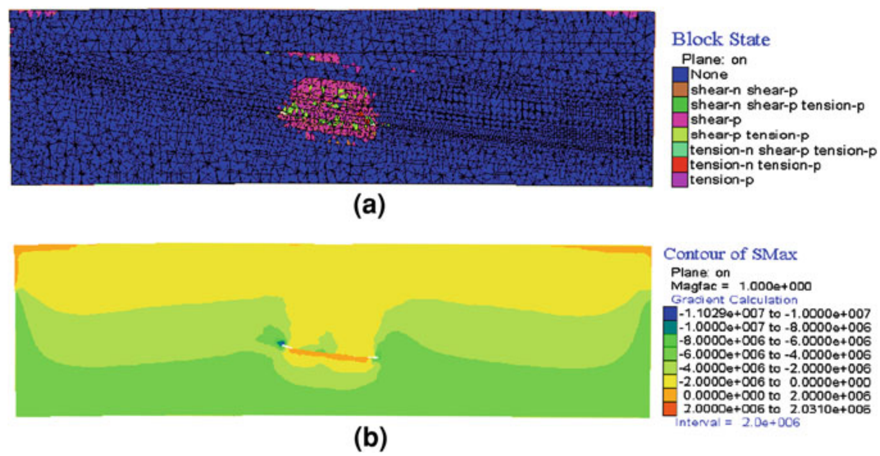


Fig. 4 Plastic zone and stress distribution **a** Plastic zone distribution. **b** Stress distribution



4 Water Flowing Fractured Zone

Studies of the failure process and range in the overburden rock after coal mining have been done. Numerical simulations are often the first choice for these studies. The plastic zone and the stress, which are often chosen when estimating the range of water-flow fractured zone. The Fast Lagrangian Analysis of Continua (FLAC) has been parameterized and used with some success (Sun et al. 2009; Xu et al. 2010).

A numerical model was created following the known structure of the overburden stratum of Panel H2303 of the Beizao Coalmine. The model for Panel H2303 is 1000 m × 660 m × 270 m in size and had 11 overburden strata (Fig. 3).

The simulation concentrated on the failure of the overburden rock. The height of the water flowing fractured zone was obtained by analyzing the plastic zone and the stress distribution.

Figures 4 a and b show that the changed plastic zone in the overburden rock, subsequent to coal mining, visually indicates the range of disturbance in the overburden. The plastic zone increases as the mined area moves when mining to 150 m the plastic zone increases continuously to reach a maximum of 55 m.

Then, the field measurements are used to validate the height of the water flowing fractured zone in this research. The field measurements method and the actual data showing the failure range under specific conditions in the four Coalmines, which have the similar geological and hydrological condition, at Longkou coalmining area, are shown in the manuscript (Xu and Sui 2012).

5 Water Pressure Bearing Capacity

The water pressure bearing capacity of the overburden rock was assessed with a certain thickness and properties, especially the bearing characteristics of the protective layer. Evaluation formula is as follow:

$$H = \frac{AL}{4K}\left(\sqrt{r^2L^2 + 8KP} + rL\right) \tag{1}$$

where H is the safety thickness of the aquifuge (m), P is water pressure (MPa), L is the width of the panel (m), K is the tensile strength of rock (MPa), r is the density of rock (kg/m^3) and A is the safety coefficient (ranges from 1.2 to 1.5).

The parameters of Panel H2303 are substituted into Eq. 1, the required minimum thickness of the security barrier under the current sea water head pressure is 7.6 m, which is much smaller than the thickness of the effective water barrier 39 m. According to the level of the Quaternary bottom −76 m, it is determined that the upper mining limit for 6 m cutting height is −160 and −130 m when the cutting height decreased to 3 m.

6 Conclusions

(1) The effective aquifuge of sea water infiltration is the first aquifuge, an impermeable layer of clay in the Quaternary, which effectively obstructs hydraulic connection between the Bohai Sea and the overburden rock of Seam No.2 .
(2) The results of field measurements and numerical simulation show that the range of the overburden rock failure zone shows an exponential relation with the cutting height of seam.
(3) According to the overburden rock structures of Panel H2301, the level of the Quaternary bottom is −76 m. The safety mining condition under the Bohai Sea is assessed and the upper mining limit of Panel H2303 has been proposed.

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