COMPREHENSIVE MANAGEMENT COUNTERMEASURES TO COAL MINING SUBSIDENCE AREAS

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The characteristics of China's energy reserve structure are 'rich in coal, poor in oil, short of gas'. China's coal production is 34.1 tons in 2016 and coal consumption was 37.8 tons [1]. Coal was accounted for 62% of primary energy consumption. According to the Coal development 13th five-year plan, coal is the main energy in china for a long period of time.

Now, most of coal mining method in China is caving method. It is unavoidable to induce overburden movement and surface subsidence. With China governmental attention to ecological environmental protection, the management of coal mining subsidence area gradually became one of the important research contents of the sustainable development of the coal industry. At present, a lot of research has been carried out on the treatment technology of coal mining subsidence area at home and abroad [2]. The earliest countries to deal with coal mining subsidence area are Germany and the United States. In 1920s, Germany restored its ecological function by planting trees on abandoned coal mining subsidence land, then gradually made its use by multiple industries and multiple departments, and had formed a complete modern park, including legal system and management system. In 1996, the United States held an international conference on ecological restoration of abandoned mines, and promoted the development of reclamation of coal mining subsidence area.

The related research on China's coal mining subsidence area is relatively late. With the attention to ecological environment, the transformation and upgrading for coal industry, the comprehensive management in coal mining subsidence areas will be the focus of national economic and social development.

China had a long history of coal mining. In past, no measures for ground control and environmental protection were taken, which lead to a large area of coal mining subsidence and induced varying degrees of damage to environment.

Condition of distribution and collapse of coal mining subsidence

According to research data from China Coal Research Institute, The coal mining subsidence area in China is 8000 km2 in 2007. Under rapid development of coal industry, now all coal mining subsidence area is 20000 km2. They are in 151 counties located in 23 provinces. Compared with coal mining subsidence area in 2007, the area in 2017 is increased by about 150% during 10 years.

For example, the coal mining subsidence area in Shanxi province was close to 5 thousands km2, and the population affected by coal mining subsidence was 2.30 million by 2015.

The mine area damage due to traditional mining with caving method was serious. In the coal mining subsidence area, there is a great influence on the land resources, water resources, construction and so on.

Destruction of land resources

Traditional mining with caving method caused the land resources to destruct. In the hilly area, farm land collapsed, dry land production is declined sharply. In plain area, farm land cracked or collapsed, rice paddy could not be planted due to lack of water or submerge by water. For example, in high ground water level areas, such as Xuzhou, Huaiabei, Huainan, Zaozhuang, Jining city, mining with caving method causes a large area of impounded surface water, which inundated the farmland. According to statistics in 2016, the coal mining subsidence area in Huainan reached 74.69 km2 with the average subsidence depth of 6.5 m. At the end of 2014, Panan mining subsidence area in Jiaowang District of Xuzhou city, Jiangsu province, was 11.66 km2, of which, water area was 2.40 km2.

Destruction of water resources

Now, about 90% of the mining areas in China are located in the northwest with serious drought and water shortage area. After coal mining, the ground surface was cracked or collapsed destroyed. It was inevitable to destroy the surface water body and underground aquifer water body. According to the relevant data, coal mining per one ton will destroy water resources of 2.48 m3. At present, 70% of mining areas are short of water, of which, 40% are seriously short of water.

Damage of buildings and constructions

The coal seam roof collapse causes the subsidence and deformation in the surface foundation, and then causes the damage of buildings and constructions, such as: cracking and collapse of buildings and structures, uneven settlement and breakage of highway, sinking and dislocation of bridges, tilt of poles in power supply and communication, deformation of pipelines in water supply and drainage, and so on. Buildings and constructions are in danger of water immerse, if they are located in high ground water level areas.

It is necessary to implement the house relocation when the buildings and structures are seriously damaged and they affect people's daily lives. According to statistics in 2015, 74,966 households and 209,769 people in Shanxi Province, within 440 villages, 136 towns, 48 counties and 11 cities, were relocated due to coal mining subsidence damage.

Management countermeasures to coal mining subsidence areas

At present, the comprehensive management countermeasure system to the mining subsidence area has not been formed in domestic. Based on the related laws, mining technology and management technology on coal mining subsidence areas, we analyzed the management countermeasures in three different stages from before mining, during mining and after mining, as possible as to reduce the damage to the environment.
Countermeasures before mining

According to the principle of conservation of space, it is unavoidable for ground subsidence when coal mining applying caving method. The new law (Norm of pillar design and mining under buildings, waterbodies, railways, and main roadway) issued in 2017 [3] clearly states that the coal pillar for super protection (table 1) is set by boundary angle. These coal pillars are strictly forbidden to be mined.

Countermeasures during mining

During coal mining, it can effectively control roof settlement and reduce mining impact on ground surface, by the green mining technology, such as backfill mining, separated strata grouting or strip mining [4-6].

Backfill mining

More than 100 coal mines have used backfill mining such as Xinwen, Zibo and Jining mine in Shandong, Xingtai and Handan mine in Hebei, Pingdingshan mine in Henan. They have achieved good results. According to the different water content, backfill mining can be divided into the three types, including solid filling, paste filling (ratio of water to solid between 12% ~ 35%), high water and ultra-high water filling (ratio of water to solid between 66%~97%).

It can reduce the surface subsidence by 70~90% upon different backfill method. However, there are a few problems of backfill mining, such as high cost and low production efficiency. Backfill mining need to be further improved in the future.

Separated strata grouting

The principle of separated strata grouting is sending grouting materials into the separated zone of overlying strata by borehole from ground, in order to control the sinking of overlying strata and surface subsidence. According to statistics, the support area with grouting materials in the separated zone is 78% of the whole goaf. It can basically reduce 70~90% of the surface subsidence by separated strata grouting, but it needs the conditions of better roof and inadequate mining.

Coal recovery rate can reaches 40 to 60% when using strip (partial) mining technology. The key of strip (partial) mining design is to calculate the width of mining face and the pillar width. It can reduce 80~90% of the surface subsidence by Strip (partial) mining, but its disadvantages are low recovery rate and low production efficiency.

Countermeasures after mining

In the case of the situation that the coal mining subsidence area has been formed, in accordance with the principle of “adjusting measures to local conditions, applying policy to different type of conditions”, comprehensive management is conducted to develop agriculture when suitable for agriculture, to develop fishery when suitable for fishery, and to develop construction when suitable for building.

Generally, coal mining subsidence areas can be divided into four types according to the condition of its location and drylands or waterlogged lands. They are outer suburban dryland type, outer suburban waterlogged land type, suburb dryland type, suburb waterlogged land type.

Different technological managements can be adopted to achieve different effects in different coal mining subsidence area types, as shown in table 2.

Large coal mining subsidence area occurred due to high strength and traditional caving mining method. It causes a great damage to the ecological environment, especially for the land resources, water resources and buildings (structures). During analysis, effective technical measure system is put forward in three different stages, which providing references for the control of coal mining subsidence areas.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Super protection for different types</th>
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<tbody>
<tr>
<td>Types</td>
<td>Main objects in super protection</td>
</tr>
<tr>
<td>Buildings</td>
<td>National precious cultural relics buildings, super high buildings more than 100m, particularly important industrial buildings, such as nuclear power plants, etc.</td>
</tr>
<tr>
<td>Structures</td>
<td>Major bridges of highway, hydropower dam with fall more than 100m, main buildings in large power plant, runway in airport, important ports, major facilities of national defense engineering, large reservoir dam, etc.</td>
</tr>
<tr>
<td>Railways</td>
<td>National high speed railway, railway designed speed 200 km/h in intercity railway and passenger-freight line, etc.</td>
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| Table 2 | Countermeasures for comprehensive management of coal mining subsidence area |
|---|---|---|
| Coal mining subsidence area types | Managements technology | Countermeasures and its use |
| Outer suburban dryland type | Land consolidation | To be farmland for agriculture, forestry, commercial crop |
| Outer suburban waterlogged land type | Dig-deep and pad-shallow | To be dryland and water pond for farmland, fishery, aquaculture |
| Suburb dryland type | Ground anti-deformation and underground grouting | To be construction land for buildings and structures of town |
| Suburb waterlogged land type | Ecological planning reclamation | To be eco-park, landscape, and fishery for tourism |

Abstract

The ecological environment in mining area had been damaged seriously by mining subsidence, which made directly influence on the sustainable development of mining industry. The current situations and existing problems of the coal mining subsidence areas in china were analyzed. Three different management stages are divided, including pre-mining, during-mining, and post-mining, based on mining time sequence. After analysis, effective comprehensive management countermeasures were provided systematically for subsidence control, combined with the related laws, mining technology and management technology on coal mining subsidence areas.

Keywords: coal mining subsidence area; sustainable development; green mining; comprehensive management countermeasures.

References