Research and Application of Green Filling Mining Technology for Short Wall Mining in Aging Mine

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Abstract: In view of the problems of "three lower" coal pressure in Dongping Coal Industry and the difficulty in moving villages and the exhaustion of mine resources, it is necessary to explore new mining techniques to realize the sustainable mining of existing coal resources. By means of theoretical analysis, laboratory test and field measurement, the paper puts forward the continuous green filling mining technology. The working face layout, filling material ratio, branch and lane parameters and surface deformation law were studied. This method has been used in the experimental mining of No. 15 coal seam of Dongping Coal Industry, and has obtained great economic and environmental benefits.

1. Introduction
According to incomplete statistics, the "three lower" coal pressure in aging mines in China currently amounts to 13.97 billion tons. Filling mining, as the main "three lower" coal displacement mining technology can effectively alleviate the surface subsidence and deformation[1]. Academician Qian Minggao put forward the scientific mining theory, pointed out the direction for green mining[3]; Zhang Jixiong et al. put forward the technology of mining with waste gangue filling, so that the gangue is not transported and the surface deformation is not obvious, and it is not necessary to repair the building. Zhou Huaqiang et al. studied paste filling and put forward 5 mining methods without moving villages[2].

Based on the problems of shallow mining and the source of filling material, this paper studied the technology of continuous mining and filling mining by rock and gypsum roadway, and predicted the surface subsidence. Based on No.15 coal seam of Dongping Coal Industry as the engineering background, this paper proposes the short wall continuous mining green filling mining technology, which effectively alleviates the problems caused by the long wall filling mining and has a great prospect of popularization.
2. Geology

Dongping Coal Industry Co., ltd. is located in Dongping village, 3km southeast of Yangquan Yu county. After merger and reorganization, the mine field area is 16.242km², and the mine production capacity is 1.2 million tons/year.

The coal pressure in Dongping coal industry is large, and the village is difficult to move, which seriously affects the mining deployment and sustainable development of the mine. How to liberate and exploit the precious "three lower" overburden resources, improve the recovery rate of coal resources and extend the mine service life is the main problem facing Dongping coal industry.

Coal seam No. 15 is located at the bottom of Taiyuan formation, 71.99 ~ 87.12m above coal seam No.9. The thickness of coal seam is 5.49 ~ 8.91m, with an average of 6.82m. It contains 0-4 layers of dirt, and the structure is simple ~ complex. The old roof is K2 limestone, and there is about 1m-mudstone direct roof in some areas. The floor is mudstone, sandy mudstone and fine-grained sandstone. The hydrogeology is simple, the gas gushing quantity is low, the mining condition is good, belongs to the whole region stable coal seam.

3. Material ratio

The filling materials for continuous mining and filling in Dongping coal industry are composed of gangue, part of construction waste, cement, fly ash and additives. Among of them, the filling coarse aggregate is coal gangue and construction waste after crushing, the cementing material is ordinary 325 Portland cement, and the pipeline transport performance improver is fly ash and additives.

Therefore, in this paper, ordinary 325 Portland cement was used to study the backfill performance under different ratios of cement and fly ash. For a gangue with a grain size of 20 ~ 25 mm and a total mass ratio of 100 (including 20% water, cement, gangue and fly ash is 80%). The mold was formed in turn, and the upper and lower sections were cut and polished at the same time. The standard specimens were obtained, within 1 to 28 days. When the cement concentration is 8%, 10%, 12% and 14%, the uniaxial compressive strength curve is shown in Fig. 1.

With the continuous increase of cement concentration, the overall compressive strength of the specimen significantly increased. The uniaxial compressive strength of the specimens from 1d to 7d increased rapidly, and reached 80% of the final strength at 9d. Subsequently, the uniaxial compressive strength increased slowly from 10 to 28 days, and the maximum
compressive strength of the specimens was 4.8 MPa with the cement mass concentration of 14%. In order to study the effect of fly ash in the ratio, the control cement mass concentration is 10%, and the uniaxial compressive strength curve of specimens is shown in Fig. 2 under the concentration of fly ash of 9%, 12%, 15% and 18%.

![Fig. 2 Uniaxial compressive strength of specimens with different concentration of fly ash](image)

In general, the impact of fly ash on the compressive strength is relatively small. In the case that the cement mass fraction is 10%, the fly ash mass fraction increases slightly with the increase, but the influence is not obvious. After 10 days, the specimen strength was basically stable, and kept at about 2 MPa.

The uniaxial compressive strength under the condition that the ratio of fly ash and cement is 1:0.5, 1:1, 1:1.5 and 1:2 is studied. When the proportion of cement is small (1:0.5), the uniaxial compressive strength increases linearly and slowly, the final strength is close to 2 MPa; When the cement ratio exceeds 1:1, the curve increases sharply at first, then slowly, reaching the final strength of 80% at 15d. At the ratio of 1:2, the final strength of the specimen reaches 5.1 MPa. The uniaxial compressive strength of the specimen is shown in Fig. 3.

![Fig. 3 Uniaxial compressive strength of specimens with different ratio](image)

In general, the cementation effect of cement and fly ash is basically similar in 0-8 days. In the later stage, the cementation effect was obviously better than that of the fly ash. After 10 days, the specimen basically reached the final strength of more than 80%. Based on the above analysis, combined with material price, filling cost, slurry conveying effect and actual production conditions, the slurry was prepared according to the ratio of fly ash, cement and water of 1:1.5:4. It is delivered to the port on the backfill roadway by special pipeline, and the discharging material is 1:2 proportional to the waste rock to fill the backfill roadway.
4. Technical scheme of continuous mining and filling mining

4.1 Roadway layout of working face
The working face of the filling test mining area is arranged according to the strip mining roadway. Along the vertical direction of 15600 transportation lane and return air lane, the belt filling working face is arranged to transport along channel and return air along channel. The width of the working face between the two parallel grooves is 50m, and the transport channel and the return air channel are connected through stoping and cutting, forming the full negative pressure ventilation system of the working face\(^4\). The design divides the self-cutting hole between the working face transportation chute and the return air chute from the inside to the outside according to one strip per 5m. The included Angle between the stoping strip and the transportation channel is 90°. Taking each strip as a stoping lane, serial Numbers 1, 2, 3... ... , the branch and lane openings are located in the transportation chute. The heading direction is from the bottom to the top (transportation chute to return air chute). The length of each branch and lane is 50m. Each adjacent working face shares a channel, that is, the transportation lane on the upper working face serves as the return air lane on the lower working face. The roadway layout of the working face in the test mining area is shown in Fig. 4.

4.2 Mining sequence of branch roadway
The mining sequence of inner branch roadway of working face is 1, 5, 9, 13... . After the completion of filling and stabilization of the backfill (28 days of solidification period), mining 3, 7, 11, 15... . After the completion of filling and stabilization of filling material (28 days of solidification period), mining 2, 6, 10, 14... . After the branches and lanes are filled and solidified, the mines are finally mined from the inside out 4, 8, 12, 16... , to realize the replacement mining of the whole coal seam on the working face\(^5\).

4.3 Filling process
The ground construction gangue crushing station and the cementation material pulping station\(^6\). The broken gangue is transported down the well by feeding well 2. The pulping station will mix the cementing material and water into a slurry of a certain concentration, which will be delivered to the well through the feeding well 1 through the pipeline. Gangue
and cementing materials are fed by weighing and batching equipment in the mine in accordance with the proportion with the mixer. After the paste is made by the mixer, which is delivered to the goaf through the pumping pipeline. The process is as follows:

![Diagram of downhole agitation pumping system]

The supporting roadway of the working face adopts interval stoping and stoping technology[7]. Odd number of supporting roadway is firstly adopted, and then even number of supporting roadway is adopted, as shown in Fig. 6. According to this stoping process, in order to control the surface subsidence to the greatest extent, the working face adopts the method of full filling and full mining, in order to maximize the cost savings. Backfill with different strength requirements was set. High-strength backfill was used in the odd number of alleys first, and low-strength backfill was used in the even number of alleys later.

![Diagram of stoping and filling process of spacer bar]

5. Conclusion:
1. The implementation of gangue cementing and filling mining project of Dongping coal mine with an annual output of 300,000 tons of continuous sheavers meets the current development needs of Dongping coal mine, and realizes the sustainable development of the mine to a certain extent and improves the resource recovery rate of the mine.
2. Based on the geological conditions of Dongping coal industry, the paper puts forward the green filling mining technology of short-wall continuous mining gangue, the best ratio of filling slurry is 1:1.5:4, and the slurry and gangue are mixed and filled with branches and
tunnels according to 1:2. Self-flowing + filling pipe fills under the action of dead weight. Based on the theory of ultimate strength, the optimal width of branch lane was determined to be 5 m.

3. The technology of green filling and cementing of gangue in the short-wall mining realizes that gangue cannot be transported out and that the mining and filling can be carried out in parallel. Ton of coal has the characters of low cost, little environmental damage, wide source of filling materials. With the small ton of coal cost, large economic and environmental benefits can be obtained, which has certain reference significance and application value for "three under" mining.

References
[1] Lu Bin, Zhang Xinguo, Li Fei, et al. Study and Application of Short—wall Gangue Cemented Backfilling Technology [J]. Journal of China Coal Society, 2017, 42.
[2] Zhang Jixiong, Miao Xixing, Guo Guangli. Development Status of Backfilling Technology Using Raw Waste in Coal Mining [J]. Journal of Mining & Safety Engineering, 2009, 26(4): 395—401.
[3] Qian Minggao, Miao Xixing, Xu Jialin, et al. On Scientized Mining [J]. Journal of Mining & Safety Engineering, 2008, 25(1): 1—10.
[4] Xu Jialin, Xuan Dayang, Zhu Weibing, et al. Study and Application of Coal Mining with Partial Backfilling [J]. Journal of China Coal Society, 2016, 40(6): 1303—1312.
[5] Zhou Huaqiang, Hou Chaojiong, Sun Xikui, et al. Solid Waste Paste Filling for None—Village-Relocation Coal Mining [J]. Journal of China University of Mining & Technology, 2004, 33(2): 154—158.
[6] Feng Guangming, Wang Chengzhen. Process System of Goaf Filling with Ultra—high-water Materials and Application [J]. Journal of Shan-dong University of Science and Technology(Natural Science), 2011, 30(2): 1—8.
[7] Feng Guangming, Wang Chengzhen, Li Fengkai, et al. Research on Bag—type Filling Mining with Super-high-water Material [J]. Journal of Mining & Safety Engineering, 2011, 28(4): 602—613.

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