

Solutions to Drainage in Underground Coal Mining Below Waste Dump of Bac Coc Sau Mine, Quang Ninh Province, Vietnam

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Abstract: *Rock waste dumps at coal mines mainly consist of discrete rock particles with various sizes that are capable to contain water. Underground mining works are affected by the weight of rock and water in the waste dump. This increases the ground pressure on roof and sidewall of longwall, and accordingly rises the cost of support, maintenance, as well as reduces the longevity of underground excavations. On the other hand, when a large amount of water flows into mining area in a short period of time, water is potential to be bursted. Water burst could sweep all equipments and human working in the mine. This is a big challenge to underground mining in Vietnam. This paper first identifies the causes of water flowing into roadways from other areas. After that, the paper presents a research to use an effective solution to drainage for longwalls by long drillhole with a diameter of $\Phi 93$ mm, protective pipe for drillhole wall of $\Phi 76$ mm. The drilling machine KD150-1 is used to directly drill on the roof of the longwall for drainage.*

Keywords: *Surface water; underground water; accumulated water; waste dump; drillhole; longwall*

1. Introduction

Mining is one of the most environmentally harmful industries. However, due to the increasing demand of mineral productions, mining continues to develop that causes many water accumulation areas near the exploited resource blocks (Clarence et al., 1997; Wu, 2014; Dandan et al., 2008; Z et al., 2009; Maosheng et al, 2010; R. L et al, 2013). The demand for safe and environmentally friendly mining is of critical importance. For underground coal mining without backfill method, subsidence occurs as overburden strata move downwards the extraction area, as shown in Figure 1 (Jing et al, 2015; Krzysztof et al., 2015; Peng et al., 1996; Phong et al., 2003; G. Y, 2007). In the process of underground mining, fracture systems that are parallel or perpendicular to rock beds are formed. (Nianlong et al., 2008; Qian, 2014; Q et al., 2014; W et al., 2014; W et al., 2016; Yucheng et al, 2016). The system of fractures and displacement zones increase the hydraulic conductivity while reducing the connection between the water-contained rocks. (Ying et al., 2013; X et al., 2016) When it rains, a large amount of surface water can flow down into the underground mining area (Report of Hydrometeorology of Quang Ninh province from 2018 to December in 2020). According to the movement characteristics of rocks, the fractured overburden strata can be divided into four zones: caved zone, fractured zone, continuous bending or deformation zone; and surface zone, as shown in Fig. 2a (X. J, et al., 2010; Gabriel, 2017; K. R et al, 2002; Benqiang et al, 2006). These zones cause the primitive fractures to extend and form new fracture systems that are the main water paths running into the exploitation area (Fangtian et al., 2019; W. J, 2016; D. Z, 2015). When the mining area is close to surface ground, the rainwater can overflow into the workings, as shown in Fig. 2b. (Vladimír, 2020; R. L et al., 2013; G. Y, 2007; A.M 2014; Jing, 2015; Z et al, 2009; PG et al, 2010). Subsidence of these rock layers causes the sag (bend) of topographic surface. On that basis, water basins are formed and extended to a strip as Fig. 2a (Anil et al., 2014; Krzysztof et al., 2015; Cui et al., 2020; Brady, 2004; Nianlong et al, 2008). The central area of bending part will be gradually lowered and deformed inclined according to the exploitation progress (Fig. 2b). The beneath tensile strain causes the fracture system to form, which acts as a water path as mentioned above. When it rains, water will flow into the sag basins. Water accumulation areas are accordingly formed, as shown in Figure 2a. These tanks increase the pressure on underground mining area and are the main sources of water flowing into the exploitation area (K. R et al., 2002; Ali et al., 2016; Aryafar et al., 2007; Phong et al., 2003; Q. et al, 2010; D et al, 2013).

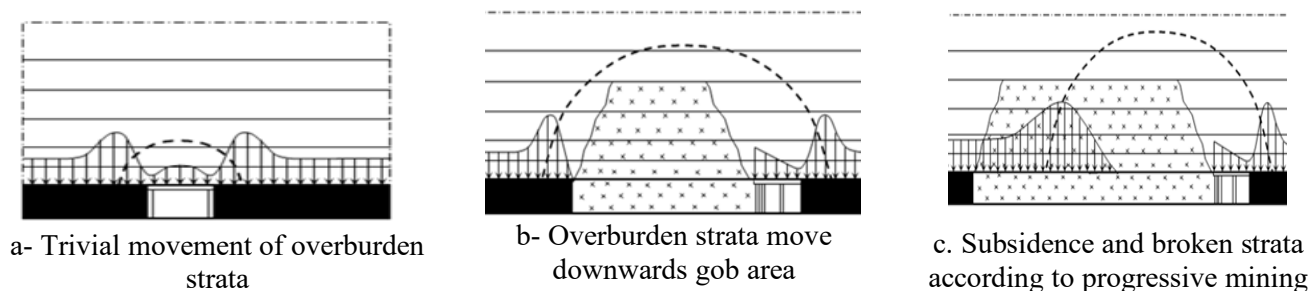


Fig. 1. Movement of overburden strata. (Phong et al., 2003)

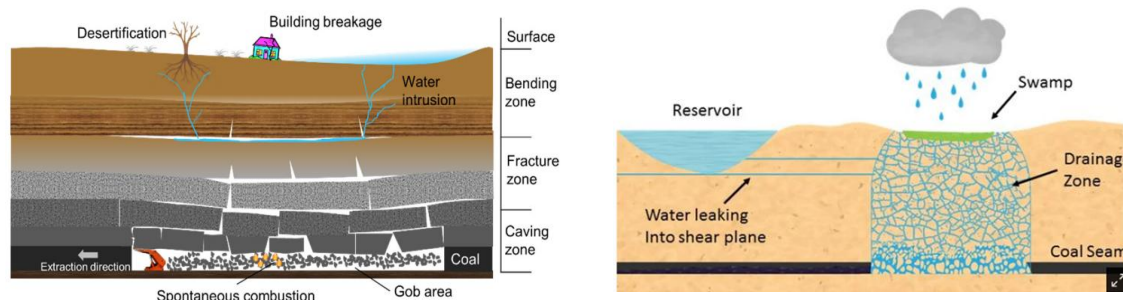


Fig. 2. Formation of water paths into underground mining area.

2. Status of area being studied

The mine in this study is located in the northeast of Cam Pha town, Quang Ninh province. Primitive topography of this area is divided by valleys and streams. In general, the topography is type of the low and gentle mountain, lower in the centre and gradually higher to four sides. The elevation of the lowest and highest places are +27 and +145, respectively. Due to the fact that this area has been used as the waste dump of Coc Sau mine for many years, its terrain has entirely changed. At present, the waste rock layers are covering the entire terrain surface, about 50–120 metres high (Report of production at the mining area of the waste dump foot in the North Coc Sau, HaLong coal one member limited liability company, 2019).

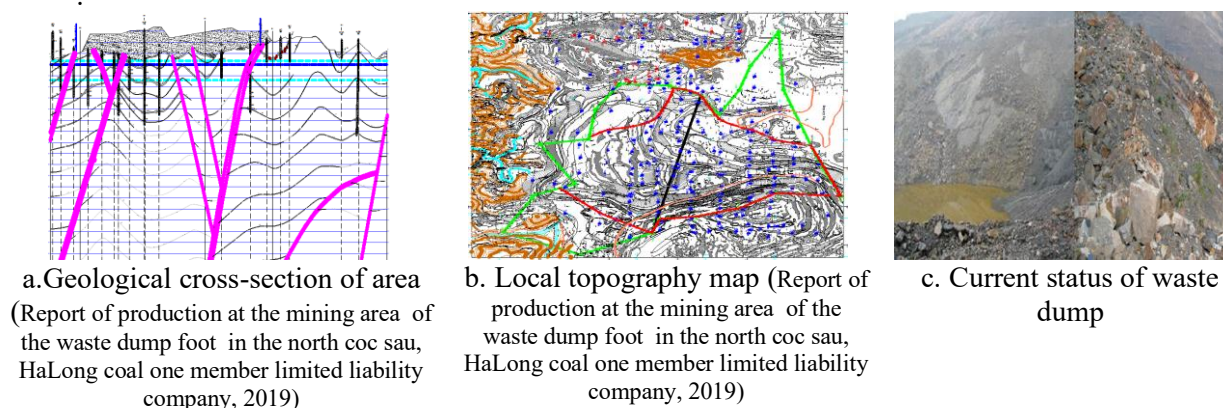


Fig. 3. Location and topographic map of the studied area

The rainy season in this area usually lasts from May to September with a water volume of 1527 mm/year (Vietnam meteorological and hydrological administration, Nation center for hydro-meteorological forecasting, of data from period of 2000 to 2020). During the time, surface water pressure increases dramatically, along with accumulated water in major faults H-H, T-T and C-C. The rate of permeability in pebbles, gravel and sand rock is about 20–40 percent (Report of production at the mining area of the waste dump foot in the north coc sau, HaLong coal one member limited liability company, 2019). Water in the open pits, rivers or streams overflows, easily breaking the roof and fall into the roadways. It destroys the supporting structures of mining space, or corrodes steel materials and mining equipments.

3. Assessment of influence ability of water basin on underground mining area

Underground mining without using the backfill method causes rock collapse down to longwall along with development of working face and gravity of upper rock strata, which forms caving zone, fracture zone and bending zone. The bending zone is the water accumulation place. The fractured zone is place that conducts the water from the subsidence trough through caving zone to flow into longwall, as shown in Fig. 4 (Gabriel, 2017; Yves, 2003; Auler et al., 2017; Carrera J et al., 2005; Q. Wu, 2014; Q. Wu, 2017). From Fig. 4, it can be seen that the height of the influence zone is the sum of heights of bending zone (S_{max}), fractured zone (H_2), and caving zone (H_1). The calculation is as follow:

Vertical displacement when exploiting all coal seams in the ground, (S_{max}), m

$$S_{max} = \eta \cdot M, \text{ m} \quad (\text{Q. Wu, 2014; Q. Wu, 2017}) \quad (1)$$

Where: M – thickness of seam; η - dimensionless coefficient, in mining without backfill $\eta = 0,7-0.95$

$$\text{Height of caving zone due to mining: } H_1 = \frac{100 \cdot M}{2,1 \cdot M + 16} (\pm 2,5)(5 \div 10) \times M, \text{ m} \quad (\text{Q. Wu, 2014; Q. Wu, 2017}) \quad (2)$$

$$\text{Height of fractured zone: } H_2 = (30-50) \times M, \text{ m} \quad (\text{Q. Wu, 2014; Q. Wu, 2017}) \quad (3)$$

$$\text{Height of water influence zone): } H_{KN} = H_1 + H_2 + S_{max}, \text{ m} \quad (4)$$

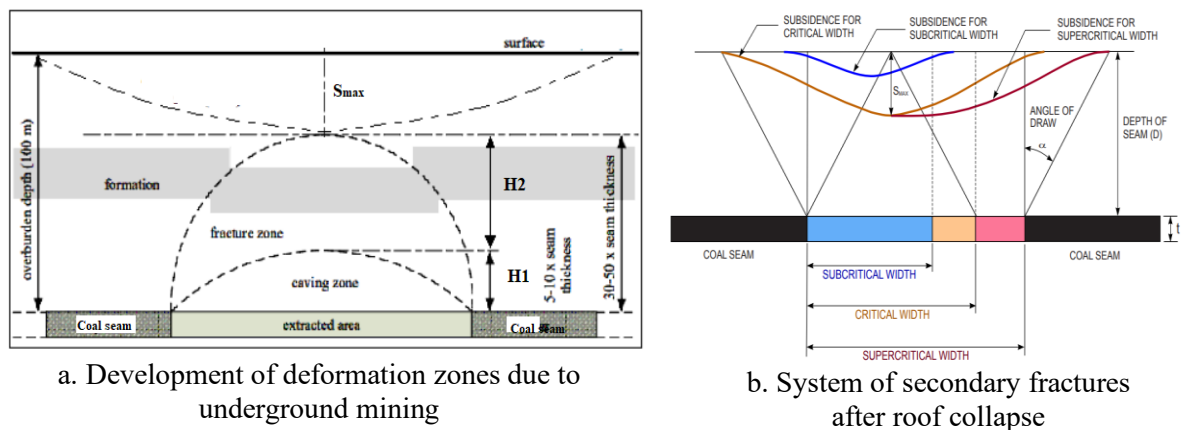
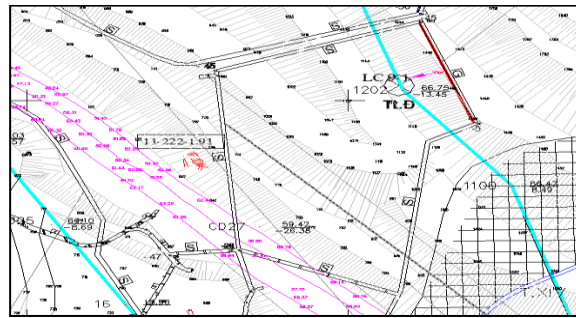


Fig. 4. Determination of affected zone during underground mining

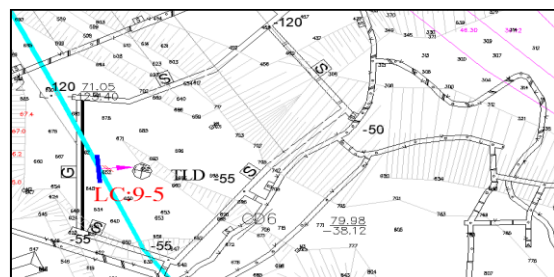
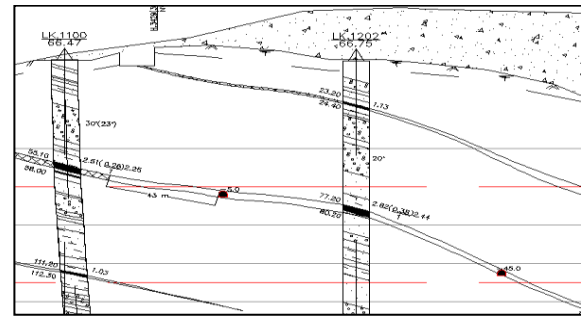
At the foot of waste dump, the mine is operating the longwalls LC 9-1, LC 9-5, and LC 9-8. Fig. 5 shows that longwall LC 9-1 is near the foot of the waste dump. The distance from the ventilation roadway to the foot of the dump is about 60 metres. Fig. 6 shows that longwall LC 9-5 is about 50 metres far away from the finished longwall at seam 10. The distance from the longwall at seam 10 to the foot of the dump is 60.5 metres. The distance from LC 9-5 to the foot of the dump is 110.5 metres. Fig. 7 shows that longwall LC 9-8 is 84 metres far away from the foot of the dump. From formulas (1), (2), (3), and (4), the height of influence zone to longwall is determined as follow:

Tab. 1. The height of influence zone to longwalls

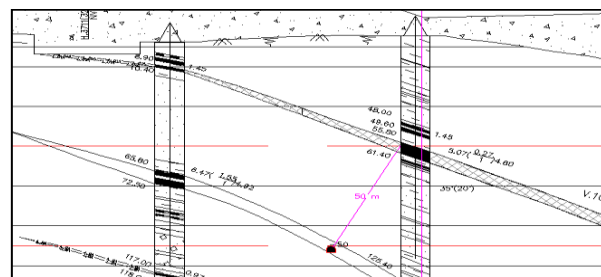
Longwall	M	η	S_{max} (m)	H_1 (m)	H_2 (m)	H_{KN} (m)	Distance from waste dump to longwall of influence zones (m)	Assessment
LC -9-1	3.00	0.70	2.1	30	150	182.1	60	Influence
LC -9-5	4.14	0.70	2.898	41.4	207	251.298	110.5	Influence
LC -9-8	2.2	0.70	1.54	22	110	133.54	128.2	Influence



a. Layout of coal extraction at longwall 9-1
Fig. 5. Location of longwall LC 9-1 (Report of production at the mining area of the waste dump foot in the north coc sau, HaLong coal one member limited liability company, 2019)

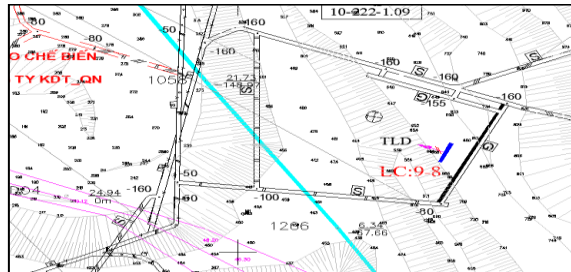


a. Layout of coal extraction at longwall 9-5

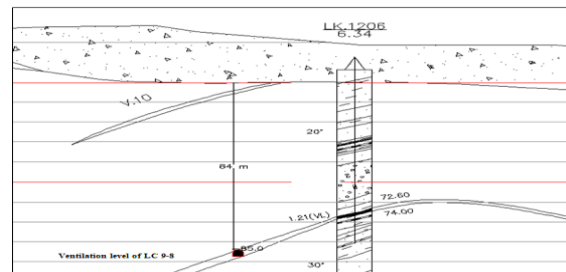


b. Cross-section of line XVI through longwall 9-5 and the finished longwall at seam 10

Fig. 6. Location of longwall LC 9-5 (Report of production at the mining area of the waste dump foot in the north coc sau, HaLong coal one member limited liability company, 2019)



a. Layout of coal extraction at longwall 9-8



b. Cross-section of line XV through longwall 9-8

Fig. 7. Location of longwall LC 9-8 (Report of production at the mining area of the waste dump foot in the north coc sau, HaLong coal one member limited liability company, 2019)

4. Solutions to drainage

The first solution: Drill holes at waste dump and pumping water out.

The solution is implemented by drilling holes with diameter of $\Phi 125\text{mm}$ down to the bottom of underground mine. High pressure pump is then used to push water from pipes out to rivers and streams. In this solution, the number of boreholes and pumps are numerous, so cost for implementing is high. On other hand, the construction can be very difficult, causing potential risks of labor accidents because landslide easily happens due to loosed rocks at the waste dump (Fig. 8).

The second solution: Drive a new roadway to drain water.

The solution is to drive a new roadway located on the exploiting area. The new roadway is responsible for collecting water through the boreholes with diameter of $\Phi 93$ from the roof, erecting protective tubes of drill hole wall $\Phi 76$. Water is collected and pumped out. In this solution, the number of drill holes are fewer than that in the first solution, but the expense for driving is high because it is difficult to construct when the rock structure was broken. On the other hand, this is an unsafe solution as there is risk of water burst at the waste dump and at the upper finished longwall (Fig. 8b).

The third solution: Drill long holes to directly drain water in working longwall

In the working longwall, machine KD150-1 is used to drill boreholes with diameter of $\Phi 93$, erecting

protective tubes of drill hole wall $\Phi 76$ and using the water collecting pipes from upper area (Fig. 8). Out of the boreholes, water comes to the temporary pond, through PE pipe, flowing into the trench at level -100 then to the main tank and is forcedly pumping upto the surface at level +17.

The third solution is easy to construct, low cost and safer than the two above solutions. Experiment of drainage in Bac Coc Sau mine showed good result with an expense for draining is about 3.000 VND/ton of coal. Thus, the third solution is feasible to use in Bac Coc Sau mine and other areas having high risk of water burst.

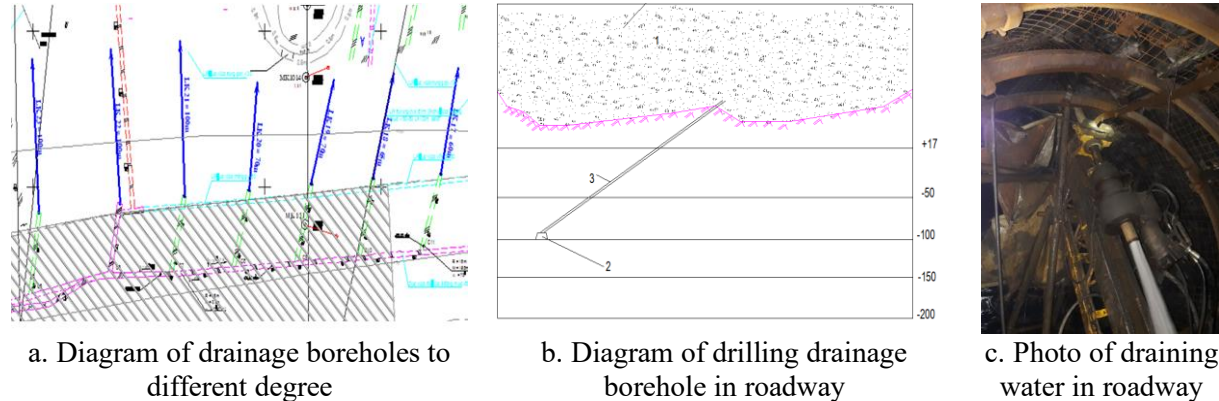


Fig. 8. Diagram of constructing drainage in roadway
1- Waste dump ; 2- roadway: 3- drainage boreholes

5. Results and discussion

For the first drainage solution, high ground pressure can break water pipe. Mud and sediment may obstruct the pipe that reduces drainage efficiency. Also, energy cost for maintaining continuous pumping is high. All these things increase the cost of mining. For the second drainage solution, the new roadway is driven near previously extracted area. The construction is complex due to broken rock and mining-induced fractures. Ground pressure is also great, resulting in increased maintenance cost and thus mining cost.

The third drainage solution uses boreholes to directly drain water onto roadway being driven. Potential energy is used to collect water into trench existing in roadway, flowing into pump station, and being pumped out for treatment at surface. Compared to the first two solutions, the third solution shows efficiency with low cost (mostly for costs of pipe material and work for drilling). More importantly, when draining water from upper strata, ground pressure acting of mining excavations is reduced. The cost for maintenance is reduced and longevity of excavations is increased. The implementation at site shows good results, proving that the solution is applicable to not only below waste dump but also below abandoned mining or Karst areas.

6. Conclusions

Underground mining without backfill method can cause subsidence of surface and fractures that are formed after rock strata collapse down to working space, which becomes the water conducting path to mine. The exploiting area at the foot of waste dump accumulates water and is affected by the fault system. This increases the risks of water burst, labor accidents, and equipments damage. Therefore, the problem of drainage needs to be controlled actively in any seasons in order to reduce danger from water burst.

Drainage solution using direct boreholes from the roof (the third solution) to foot of the waste dump is the low cost, safe, active method. The solution is easy to construct and to be widely applicable in similar areas. The solution can also be used for the area where is not affected by the waste dump but having upper aquifers, or areas previously exploited but water is accumulated. Some other solutions can be additionally implemented such as spreading layers of waterproof padding on surface or building a system of surface large canals to disperse and prevent water from flowing into the mining area.

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