Integrated methods to determine the optimal underlying grouting strata against hazardous waterinrush (China) – a case study

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Abstract Floor grouting reinforcement technique is widely and successfully used by many coal mines in North China to prevent upwelling disasters from the underlying late Paleozoic karst aquifers. However, this technique failed to avoid mine flooding and excessive grouting fluid consumption for two coal mines in Yanlong coalfield. On the basis of a finished project, the article showed an integrated method to optimized their grouting technique. The late Carboniferous Benxi formation actually doesn't serve as a traditional aquifuge, but a real aquifer. It's the Benxi that consumed the excessive grouting fluid. Benxi is the optimized target grouting layer.

Keywords underlying karst aquifer, fragmented aquifuge, water inrush, strata reinforcement, optimal grouting strata;

Extended Abstract Since 1950s, coal mines in the Carboniferous-Permian coalfields of North China platform have been yearly contributing most of the annual coal production of China. However the geologic structures of these coal mines are complicated and the carboniferous coal seams have to undertake great water pressure of underlying early Palaeozoic carbonate karst aquifers. Coal mining of China is somewhat the history of coal mines in North China to fight against early Palaeozoic karst water upwelling disasters.

During these years, floor grouting-reinforcement technique was developed in order to strengthen the coal floor formations into effective aquifuges against accidents of the underlying karst water inrush. So far, the technique has been widely and successfully adopted by coal mines of Feicheng, Jiaozuo, Fengfeng, Huaibei and the like mining areas in North China, who had ever been well-known for their excessive mine water inflows and frequent mine water disasters.

Yanlong coalfield locates in the south edge of North China platform and had been undergoing strong geologic actions from the Caledonian to Himalayan period. Geologic structures of this coalfield can be characterized by layer-slip structures, tectonic coal, and overgrown faults. Its deposition sequence consists chiefly of the Cambrian neritic carbonate rocks, the late Carboniferous paralic thin-coal-seam-bearing deposits with 4—7 limestone interlayers, the early Permian terrestrial coal deposits, the late Permian terrestrial clay-silt-sand rocks, and the Pleistocene non-consolidated deposits. The only workable 2_{-1} coal seam in the lower Permians belongs to mylonitic anthracitic coal. Hydrogeologically, the Cambrian aquifers are the regional karst water reservoir; the early Permian limestone interlayers are also nonuniformally water-bearing and inclined to conduct and burst the Cambrian karst water into coal faces when mining.

Changcun and Longmen are the two active coal mines in Yanlong coalfield. They adopt conventional machine mining. Floor grouting-reinforcement technique is the only choice for them to prevent hazardous karst water upwelling. However, even so the Longmen mine had ever been flooded three times before 2000 and the Changcun mine was inundated again in 2007. Another big issue is excessive grout consumption. Sometimes one grouting hole can eat up over 10^4 t of grouting fluid. Therefore, it is imperative for the two

mines to improve floor grouting efficiency and reduce grout consumption.

From 2011 to 2013, we accomplished the project, sponsored by the two mines, to optimize their floor-grouting-reinforcement technique. (1) We analyzed the past drilling and grouting data from the two mines to reveal the water yielding and grouting consumption features of underlying formations. (2) Supplementary hydrogeologic drillings and lithologic analysis were used to calibrate and uniform the early Permian thin limestone aquifers; (3) Hydrogeochemical analysis and hydrological isotope tracing were used to identify the hydrologic connections between the early Permian limestone interlayers and the Cambrian karst aquifers; (4) By tracing the fractures along the underground incline drifts for 6 months, we investigated the attitude, density, filling and water-bearing features of joints and fissures in the floor strata. (5) Virgin ground stress and geologic structure analysis were conducted to judge how excessive faults and layer-slip structures to control floor grouting. (6) *In situ* test and mechanical numerical simulation were used to identify the underlying mining-induced fissure zones (7) Mercury porosimeter was used to test the type and quantity of tiny void of the rock.

The results showed that

1. it is owing to complicated geologic structure, fragmented and thin floor aquifuges, and high Cambrian karst water pressure that floor grouting in Yanlong coalfield can't ideally work.
2. Judging from the grouting holes, the water yield of the underlying late Carboniferous thin limestone aquifers accounts for 56 % of the total grouting hole inflow, that of the late Carboniferous Bensi silt-clay rocks accounts for 18 %, and that of the top Cambrian accounts for 26 % (Fig. 1). It indicates that the Carboniferous limestone aquifers have the biggest water availability. Bensi formation doesn't traditionally serve as aquifuge, but a real aquifer. For a single grouting hole, it often yields the minimum water when piercing into the top Cambrian. Not as the regional karst aquifer, the top Cambrian is only weak water bearing.
3. From the perspective of grouting fluid consumption, the grouting holes consume 41 % of the total grouting fluid in the Carboniferous limestone aquifers, 41 % in the Benxi silt-clay formation, and 18 % in the top Cambrian (Fig. 2). It showed that the Carboniferous limestone aquifers and the Benxi formation consumed most the total grouting fluid and the top Cambrian used a little. The excessive grouting consumption happened in Benxi formation. The top Cambrian is not the target

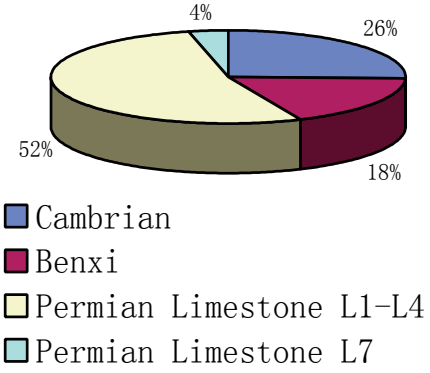

Fig 1 *Pie chart of the ratio of the water yields from underly aquifers*

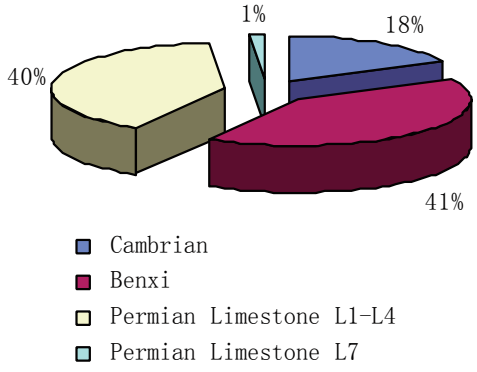

Fig 2 *Pie chart of the ratio of the grouting fluid consumption in different underly aquifers*

grouting strata. The thin carbonate strata don't uniformly occurs in the two coal mines and the two mines actually grouted different strata.

4. Hydrogeochemical analysis and hydrological isotope tracing showed that the two coal mines lie in the discharge area of the regional Cambrian karst system, all the underlying aquifers have similar water fingerprint, and excessive fissures and faults make it possible for the water interaction. Most of fractures in target strata strike northeast, are half filled with calcite, weakly contain water.
5. *In situ* test and mechanical numerical simulation showed that the underlying mining-induced fissure zones is 14 m in depth. Only under the precondition that the Benxi formation be solidly reinforced, the floor of 2_1 coal seam can be enough to stand 2.5—3.5 Mpa water pressure of the Cambrian karst aquifer. Benxi formation is the optimized target grouting strata.

Our integrated work indicated that it is the specific geologic and hydrogeologic backgrounds of Yanlong coalfield that made the floor grouting-reinforcement technique not ideally work. Benxi formations in Yanlong coalfield is not only the targeted but also the easily ignored grouting strata. Timely optimizing the targeted grouting strata is necessary and an effective way to overcome the water control inefficiency.

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