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Technology Research of Large Underwater Ultra-deep Curtain Grouting in Zhong-guan Iron Ore

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Abstract

Problems in Zhong-guan Iron Ore are complicated hydrogeological conditions, larger water inflow in mine ore, all ore bodies buried under the water table, ordovician limestone aquifer in the system directly to the roof for the ore body. Paper used ring-type single-row curtain grouting closed ground plan. This has not only achieved the safety of mining, but also protected ground water resources and hydro-geological environment. Study has shown that: the elevation of purdah base is -96 m ~ -568 m, the average drilling depth is 523.92 m, the minimum hole depth is 321 m, and the maximum is 810 m, holes depth greater than 600 m take up about 30.8%. A single slurry material can allow seepage gradient and the curtain can withstand the maximum head difference design curtain thickness $T \geq 10$ m, grouting hole spacing is designed to 12 m; curtain grouting pressure is 2 times of the head pressure. Research improves reference for similar mines.

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Keywords: Large underwater, Ultra-deep curtain grouting, Grouting parameters

1. Introduction

With China's rapid economic development, the demand for mineral resources has become increasingly urgent, the past two years China's imports of iron ore was more than 600 million tons. Iron ore prices are around \$ 32 in 2003 rising to \$ 200 quickly, making iron ore also has economic value which is previously hard to mine. High grade in Zhong-guan Iron Ore, it is rare high-grade ore in China. It had been proved in

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the 1960s, as in the flood conditions and the mining complex technical difficulty has not been mined. Meanwhile, China's severe water shortage especially in the north region, while in the past in the mining process, when the resources below groundwater, often using drainage to the exploitation of resources in order to ensure safe mining, a lot of this way of exploitation of groundwater discharge, resulting in water serious waste which does not meet the current emphasis mine "green mining concept"[1-3]. Therefore, it is necessary to use water that is to ensure safe mining exploitation, while also ensuring the protection of groundwater resources, which need to be considered fully closed curtain grouting process, within the mining area will be a strong water-rich Ordovician limestone aquifer and the regional aquifer isolated, it will ensure the normal mine production safety, but also can save a lot of running costs (drainage costs), and effective protection of groundwater resources.

Curtain grouting in the tunnel (Lane) Road, wellbore construction process has been widely distributed applications [4-8]. [9] for the reliability of rock grouting has been analyzed; [10] for curtain grouting effects were also studied. But the problems in Zhong-guan Iron Ore are complicated hydrogeological conditions, larger water inflow in mine ore, all ore bodies buried under the water table, ordovician limestone aquifer in the system directly to the roof for the ore body. Need to consider the exploitation of large underwater mine safety program design long curtain grouting, grouting parameters of the analysis, so as to achieve the safe exploitation of water resources while minimizing the damage, this study is based on this idea, research mine green mining is expected to provide for similar ideas.

2. Project Overview

Surface mining is widely covered by Quaternary sediments from the gravel layer, gravel layer of loess, variegated sand and gravel and clay layer, gravel layer of ice accumulation, the total thickness is 70-130m, the underlying Carboniferous and Ordovician strata. Carboniferous strata is coal-bearing clastic sedimentary, dominated by interbedded sandstone and shale, thin limestone lenses during folds, local folds coal. The bottom is western iron and aluminum shale clay soil. Thickness of carboniferous strata in the mine and the residual is from a few meters to 100m, with underlying ordovician limestone was unconformity. Ordovician strata is composed of thick layered patchy limestone, dolomitic limestone, argillaceous limestone, brecciated limestone, lower part of the contact zone with magmatic rocks, altered to marble, contact metasomatic skarn-type magnetite. The largest thickness of the Ordovician stratigraphic region's 585m. Magmatic rocks in the mining area to a greater depth of buried rock, rock to - the basic diorite - monzonite, syenite series based, is a complex "layered" invasion in Austria Ordovician or Carboniferous, Permian, the lava rock to north east in general, tend to the South East.

Zhong-guan Iron Ore is belong to the iron ore deposits of contacting metasomatic skarn, which buried in the ground about 300m below, the ore body goes about 2000m, and the width is 300 ~ 1000m, the dip angle is generally 10° to 15° . There are four ore mine in all, which are NO. I, III, IV, V, respectively. The ore reserves of NO. I is 85.99 million ton, accounting for about 92% of total reserves of mine. The average grade of TFe is 45.84%, Sulfur is 1.58%, and Cobalt is 0.01%. The roof of deposit is middle limestone of the Ordovician, and the floor is diorite of the Yanshan period. The ore reserves which submitted to the approval of geology report are 93.4844 million ton. The first stage mining in southern curtain are above the middle within a range of 350 meters, the minable Ore reserves are 69.87 million ton, and the average grade of TFe is 46.01%, which can serves 26 years for a mine of 200 ton. The deposits occur under the Ordovician limestone, directly, the large flowing, and the conditions of the hydrogeological are very complex, which requires using the grouting curtain to hold up water before mining, and according to the engineering tests, it can block 80% of underground water inflow, after this the mine is of mining conditions.

3. The design analysis of curtain grouting

To ensure the safety mining under large water in Zhong-guan iron ore, the following factors should be considered: First, take a detailed investigation on the distribution of the buried grouting aquifer in Zhong-guan iron mining areas and the hydrogeological characteristics such as thickness, occurrence, the rate of karst fissures, permeability coefficient, contact characteristics, the position and performance of drain water body and other factors; Second, must ensure that the mining and the iron ore around cannot destruct and impact the curtain body after formed; after the curtain grouting, it can formed a closed circle in the horizontal direction, and in the vertical direction, it must be contact with the impermeable body (diorite), the curtain should go through in both the thinner direction of the aquifer and stable parts of the occurrence; simultaneously, it should design a reasonable pilot projects of curtain grouting and putting to use, and the curtain should avoid the villages and buildings as far as possible; finally, to make rational on economical, we should balance among the length of the curtain, the amount of drilling projects, the amount of grouting and the ore body in the circle.

Zhong-guan iron ore is in Han Dan, where the hydrological and geological conditions are very complex and larger water inflow, all the mine body are buried below the water table, the direct of the ore roof is limestone aquifer in the Ordovician. Water control program should be considered at first in the construction of the mine. With economic development, the environmental protection requirements are also rising in our country, especially that water conservation laws is being to use. At present, getting (drain) water has reached 320,000 m³ per day in this area artificially, resulting the water level dropped obviously in local limestone, the average cumulative decline 151.55 m compared to the year of 1974, has formed a hopper around the iron ore in Phoenix Mountains, which shows the Anti-supply trends in Northeast, if the iron ore is still chose the drainage dewatering program, the expansion of the funnel-shaped area is increase and the regional groundwater become worse, which is not allowed for the environmental friendly. So chose the southern tip of ore mining clusters, and using closed single-row ring-type curtain grouting plan, the biggest advantage of this program is to protect the groundwater resources and hydro-geological environment, meanwhile largely reduced drainage costs. The disadvantage is the much investment and requires the high quality drilling and small deflection.

4. The technology study about curtain grouting of safety mining

4.1. Feasibility Analysis of curtain grouting

The aquifer of Zhong-guan Iron Ore is the O₂ limestone, which is a uniform water-bearing bodies, distribute in all the mining area and formed the roof of ore composition. The developed fault zone are F4, F5, F6 and the rock crushing of F1 (mine), F2 (mine), F3 (mine) and karst fissures, there are three groups of cracks; namely, a line parallel to the main structure, the other two groups are oblique cross fracture, which are usually tensor-shear and pressure-shear cracks. Most of the drill core area are broken, drilling collapse seriously, and 52 holes out of 65 water holes, the q flood is 1 L / s • m ~ 50 L / s • m, and q pumping is 2.63 L / s • m ~ 178.82 L / s • m. The hydraulic gradient is between 5.4 ‰ and 1.1 ‰, it reflects that the conduction pumping is faster when pumping up water in the mining hole, that is, it has affect in observation holes, which are within 2000 meters during 2 to 3 hours, the development of the karst fissure in this area are strong rich in water, so the aquifer of limestone mining area can be irrigated very well, and also shows that the mining area has the basic conditions for using the curtain grouting.

4.2. Confirm the parameters of the curtain

4.2.1 Confirm the location of the curtain line

In order to mining maximum amount of ore mine, according to the Hydro-geological conditions and the occurrence conditions of mine, it can be determined that the location of the curtain line south from 1 to 2 lines, north to -6 to 7 line, and the appropriate distance between north to south is 1090 meters. Using fill mining method, according to the principles of the dislocation line and the cross-line of +100 meters extrapolate 30 meters to determine the location of the curtain, and considered the mineral rights, the scope of coal mining areas, villages and other impacts, it can be determined that the largest curtain east-west width is 850 meters, formed a closed ring curtain on plane, and the length of the curtain line is 3303 meter, Table 1 shows the curtain line inflection point coordinates.

Table 1 Statistics of the curtain line inflection point coordinates

NO.	X Coordinate	Y Coordinate	NO.	X Coordinate	Y Coordinate
1	4083963.6981	522108.6521	7	4084745.8800	522774.0400
2	4083830.4205	522642.1070	8	4084910.3329	522794.9089
3	4083950.8071	522834.6608	9	4084969.8851	522548.0634
4	4084474.0585	522896.7375	10	4084689.8892	522146.6310
5	4084567.0000	522802.0000	11	4084602.0000	522107.2160
6	4084631.4085	522805.4331	12	4084140.5469	522005.4422

4.2.2 Determination on the depth of the curtain

Based on the burial conditions of the orebody and requirements on the depth of mining, combined with the Hydrogeology at mining area, referring to practical experience of the same type curtain projects, determine the depth of the curtain need to penetrate O₂ limestone, orebody, and 10m in diorite beneath. The depth should increase or decrease depending on the condition of construction to prevent the base of the curtain from penetration. Bottom boundary elevation of the curtain is at -96m~-568m, -292.15m in average. Elevation of drill hole is 523.92 m in average, 321 m at minimum, 810 m at maximum. The number of holes which depth more than 600m is about 30.8% over all

4.2.3 Determination on the top boundary elevation of the curtain and the length of grouting interval

The Lithology in curtain area is divided into 4 parts from upper to lower: thickness of quaternary is 37m~118m, thickness of carboniferous is 0m~82m, thickness of O₂ limestone (includes the orebody and skarn) 189m~620m, thickness of diorite is 10m. The Water Level of Zhongguan iron mine was measured +14m in 2004, most turn into phreatic in hydraulic properties, so the elevation of grouting top boundary can't based on carboniferous bottom board, neither use +14m as start point add the maximum amplitude of groundwater level at mining area is inappropriate. Because the current water level of Zhongguan iron mine, +14m, is under the background that displacement of all region O₂ limestone is 320000m³/d, which cannot represent the natural static water level of Zhongguan iron mine. With The analysis that water level of Zhongguan iron mine is +97 in 1994, when the displacement of all region is 79000m³/d in total .the displacement of mine nearby is 3500 m³/d, which has no effect on the water level of Zhongguan, on these reasons the grouting top boundary elevation of curtain is designed +100m, don't grout with pressure on the top. The length of grouting interval is from elevation at +100m to the bottom of the hole, the length of single hole in grouting interval is 385.5m in average. Which in limestone is 375.5m in average, 10m in diorite.

4.2.4 Grouting parameter selection

Grouting drilling of hole spacing ,in accordance with the curtain grouting engineering test overspending effect, preliminary design pitch is 12, local complex area can be appropriately to narrow. The effective diffusion radius of the slurry R acuity 7m. curtain thickness T, based on a single cement

slurry material can allow the penetration of the slope and the curtain can to the maximum head difference design curtain thickness T acuity 10m.

4.2.5 Curtain seepage control requirements and the determination of grouting pressure

The seepage control requirements, in accordance with the hydrogeology numerical method the thickness of the curtain is 10 m, and to achieve the design requirements of water rate 80%, the unit bibulous rate of the curtain should be less than 5 Lu (LvRong q value), curtain $k \leq 0.08$ m/d. According to the grouting curtain test project summary report, 7, 8 inspection hole, $q = 0.4Lu \sim 0.8 Lu$, $k = 0.03$ m/d, explain the water shutoff curtain water shutoff rate can achieve above 80%. The curtain grouting pressure determined primarily for head pressure twice. The curtain grouting test project summary report indicates that because of the underground water level burial depth is bigger, the pressure of cement grout weight can achieve 1.125Mpa to 1.8Mpa, can appear cement grout self-respect pressure is greater than the design pressure ,so grouting pressure control principle can be divided into two kind of situations: when grout self-respect pressure is less than 2 times of hydrostatic pressure, according to 2 times of hydrostatic pressure as grouting pressure value; When grout self-respect pressure is greater than static pressure water twice, the surface pressure gauge the readings should be controlled in 0.5Mpa to 1.0Mpa.

4.3. Curtain grouting requirements

4.3.1 The technical requirements for curtain grouting

(1) Aperture: when the elevation is above 100 m, it is grouting without pressure, and the aperture and the drilling structure is considered by the construction unit itself, but when below the 100 m, the aperture must be guaranteed to be larger than 75 mm at least in the grouting section. The grouting holes should be constructed according to the orders.

(2) The oblique of the hole: the oblique of the hole should be measured per 30 m in the whole hole; the Offset distance of any drilling holes' depth should not exceed the maximum depth of 6 ‰ meters. The oblique of the hole is the most critical technical issue in the curtain grouting project of Zhongguan iron ore, and we need carry out some curtain grouting trials, so as to ensure the horizontal offset distance of the final hole of grouting holes reasonably.

(3) Drilling hole washing: all Drilling Holes should be washed out with large flow and high pressure water before grouting, the thickness of sediment remaining in the hole shall not exceed 20 cm.

(4) Water pressure test: it should be carried out by stages, and the Lugeon value should be calculated according to the Standardization.

(5) The standard of grouting results. The speed of grouting is not more than 30 L / min, with persisting to grout for 30 min.

(6) Grouting method: Grouting is designed to use down going method.

(7) Hole sealing: the pressure sealing means is applied to seal the hole, the hole should be sealed twice, at last, checking the sealing quality randomly.

(8) Checking the quality of curtain project: the quality of curtain grouting should be mainly checked by the method of water pressure test, then giving a comprehensive assessment combining with the analysis of completion data and test results. The number of holes checked occupy 12% of the total number of grouting holes, checking should be conducted strictly in accordance with segmented water pressure test.

4.3.2 Curtain grouting materials

The curtain grouting materials of Zhongguan iron mine mainly consists of Single cement slurry, but it can be added in some certain amount of admixture when comes across special terrain. Label: no. 425 by cement ordinary Portland cement. The square-pore sieve with the size of eighty microns is usually employed to test the fineness of cement, and it will be better if the tested result of retained amount is not higher than five percent. The sand in the admixture can be hard natural sand or artificial sand, of which

the practical size should be shorter than 2.5mm, fineness modulus be smaller than 2, SO₃ content should be less than 1%, mud content be less than 3%, the organic content should be no more than 3%, the plasticity index of the cohesive soil should be bigger than 14, the content of the clay that shorter than 0.005mm should not less than 25%, and the sand content be less than 5%. The fly ash used should be special selected which should not be thicker than the cement used at the same time. Loss on ignition of the fly ash should be less than 8%, SO₃ content should be less than 3%. The modulus of water glass should be between 2.4 and 3.0 and density between 30 and 45 baume degree.

4.4. The method to control the quality of curtain grouting

The curtain of the principal part of the project for the curtain single line about 3303 m total, Grouting hole design for 276, deep in 523.9 in average. Considering that the curtain line is long and deep, the hydrogeology and the geological engineering condition are complex and so on, increase 13% grouting holes to ensure the quality of grouting and design inspection holes at the same time. The curtain grouting quality should be evaluated mainly according to the result of hole pressure and other information of completed projects as well as Pit water drainage experiments should be consulted. The inspection holes should be placed along the center line of curtain lines, on the position where karst develops and structure breaks, the position where grouting more or the position where drills decline too much. Check the number of holes, due to the complexity of the curtain conditions considered by 12%, or 34 holes. Check the water pressure test the quality of grouting sections pass rate should be more than 90% failure rate of permeable section shall not exceed the design value of 100% of specified value, and not concentrated, the quality of grouting can be considered qualified. For the observed changes in groundwater levels inside and outside the check curtain water shut-off effect, and the need to set long-term observation wells. Design considerations within the screen 10 holes, hole depth 500 m, outside the screen 20 holes, hole depth 500 m. Also using geophysical tests, mainly radio waves Perspective drilling, wells television law.

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