Analysis Method in Prospecting Weak Zone of Mine Watertight Screen and Its Field Test

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Abstract

Construct the resistivity water curtain in the water-rich mine, the effects of watertight screen is seriously deteriorated because of its weakness. The weakness is inevitable owing to the complexity of hydrogeological conditions. The water storage and water conductivity characteristics can be analyzed with triple-medium theory. The research on the cause of weakness is based on hydrogeology. the flow field characteristics are discussed in three conditions include natural condition, ideal condition and in presence of weakness condition. In order to investigate the forming reason of the weakness, the structural characteristics of water channel, the conditions of recharging, flowing and discharging of groundwater are analyzed. The research on the groundwater flow field characteristics of the weakness area is usually through multi-level dewatering test, and the weakness criterion is put forward.

Keywords

Weak zone of curtain; Groundwater flow field characteristics; Multi-level dewatering test; Weakness criterion.

1. Introduction

To build a watertight screen is an effective method for flood control of karst water disaster in mine. The karst fissure of the aquifer is exposed by drilling, and the continuous underground wall is formed by grouting method. The stability and effectiveness of the curtain become an important safety barrier during the process of the mining [1]. The curtain weak zone is a key factor affecting the water resistance effect of watertight screen, It can be reflected by the characteristics of groundwater flow field.

The morphology of groundwater flow field is a comprehensive reflection of the hydrogeological conditions in the region [2]. The groundwater flow field of mine is influenced by hydrogeology and mining, from the initial steady state to the unsteady state, and to another steady state under the self adjustment. At present, the method of flow field analysis has become an important method to judge the characteristics of karst. Many scholars have done a lot of research in this area [3-7], Chen Yuesheng [8] analysis of the flow field of karst water in the mining area. Wu Zhenling [9] revealed the evolution of groundwater in Fengfeng mining area. Zhang Yan [10] expounded the application of the flow field analysis method in the determination of hydrogeological boundary. Solve the problem of hydraulic property of exploration boundary. Sun Hui study on the permeability characteristics of limestone grouting curtain body [11]. The present research is weak with less exploration curtain, curtain under the condition of the groundwater treatment of mine grouting process in mine mining, and according to the actual engineering, the flow analysis results directly reveal weak research with the curtain is still blank in china. However, the study of watertight screen in foreign countries is focused on the study of the

seepage performance of diaphragm wall in deep foundation pit[12], mainly for the porous medium, but there is little research on the fractured media, and the lack of practical engineering case analysis.

This paper analyzes the form and causes of weak zone curtain, using multi level drainage test, the flow field characteristics of Zhangmatun Iron Mine curtain, analyzes the spatial position of weak zone curtain and concentrated area, and the analysis results are verified by drilling, is of positive significance to the large curtain curtain grouting, we hope to provide a the reference for the similar engineering.

2. Background

The type of iron ore genesis belongs to Zhang Ma Tuen contact metasomatic iron deposit, ore roof or floor rock for karst fractured marble, karst water has been suffering from the threat of mining since, for the implementation of water blocking curtain grouting engineering community. Curtain Engineering points south, southwest, West, North four section, forming a "U" shape, almost includes west body whole, connected with the F1 fault with water resistance, groundwater intercepted in the scene, the scene in mining. The whole length of the watertight screen 1410m, the depth of 330~560m, the thickness of the grouting curtain design is 10m, the geological reserves of 1.578 ×107t in the curtain area.

Zhangmatun Iron mine hydrogeological unit belongs to hilly karst hydrogeological sub region in the middle and South hydrogeologic zone, become Ji'nan - Pingyin DC monoclinic structure. Sedimentary strata affected by tectonic movement. The fractures are very developed, and the karst is also developed in the karst. In the area of main aquifers in the Cambrian Ordovician under thin limestone, dolomitic limestone and Ordovician thick pure limestone karst fissure aquifer, the minor aquifer is Quaternary pore aquifer, the other rock with weak fissure water. The southern area of the hilly area, Northern Piedmont Plain, low-lying South high north. The southern mountain in Cambrian and Ordovician strata are exposed, directly recharged by precipitation, strata dipping to the north, in the plain area of V in the Quaternary, groundwater runoff from the south to the north, the upper Carboniferous and Permian sandstone shale and quaternary weak permeable soil layer, underground water with high pressure head, the northern block of gabbro after part of the groundwater gushing surface discharges in the form of a spring. In the middle of the mining area, the middle and lower Ordovician limestone has a large area of Iwade, and the groundwater is mainly supplied by meteoric water, and in addition, it has a large number of groundwater.

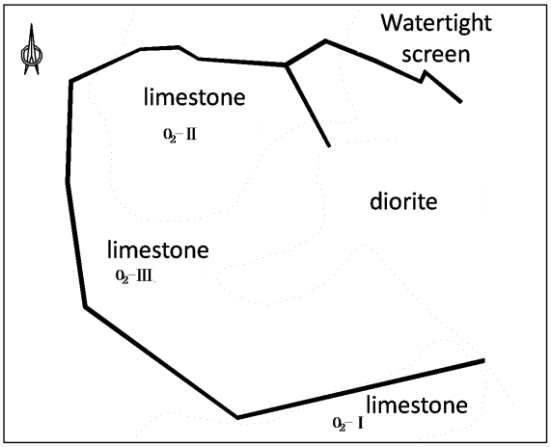

Fig.1 Plane of curtain

3. Causes and hazards of curtain weak zone

3.1 Dynamic characteristics of karst water

Karst water bearing medium is a complex composed of various kinds of voids. According to the effect of various voids on the karst water, the karst aquifer medium is considered as the three medium, that is, pore, fissure and karst pipeline. It is generally believed that the permeability coefficient is much smaller

than that of fracture and karst pipeline in the movement of groundwater, and it mainly plays the role of water storage and release. Karst fissures and pipelines are the main paths of groundwater transport[13].

The movement of groundwater movement follow different patterns in karst water three heavy medium in porous medium, the flow obeys the Darcy linear law, and mainly for water storage and water release effect; fractured media can be divided into micro cracks and large fractures according to the karst water dynamic effect of micro fissures in groundwater obeys Darcy linear law on the effect of water, large fractures, and the difference is that its pipeline fracture flow still obeys Darcy's law; karst groundwater medium is usually non Darcy flow, the permeability coefficient of the medium is variable[14] versus Reynolds coefficient.

3.2 Causes of curtain weak zone

The movement of groundwater is mainly laminar flow in northern limestone. The limestone karst in northern China is mainly composed of karst, karst and karst caves. The pipeline is only an individual phenomenon, and the karst groundwater is a kind of fracture network laminar flow[15]. According to the hydrogeological data of Zhangmatun Iron Mine water conducting structure for cracks in the actual research, the engineering geological body can be simplified to the generalized dual medium model, micro cracks and large fractures.

Ideally, the water curtain project after the completion of the curtain, the hydraulic connection is interrupted, with continuous pumping of groundwater surface, static reserve release, the curtain of the formation of isolated hydrogeological units, groundwater barrier in the curtain, but because the influence factors of subsurface geological conditions is complex and numerous water blocking curtain grouting effect, cannot to achieve the ideal state. According to the construction information, Zhangmatun Iron Mine in the process of building curtain grouting quantity and the area of karst fissures was proportional to the extent of. The karst fissure is strongly developed, the strong water flow takes away a large number of slurry to form the phenomenon of running slurry, increases the grouting quantity, and can not effectively seal the groundwater runoff channel.

In order to find out the causes of weak zone curtain has used the drilling method, analyzed that the weak zone of Zhangmatun curtain consists of the following 2 forms:

(1) After grouting watertight screen to wall part of the region has not been effectively closed fracture.

(2) The closed watertight screen is affected by the impact of groundwater or the dissolution of the water channel leading to the existence of.

Based on the analysis of hydrogeological data and construction data, it is considered that the formation of weak zone of watertight screen is caused by the following factors:

(1) The construction of curtain water blocking works in the middle of 90s of last century, by the grouting material, grouting equipment development level, the level of geological exploration and engineering design constraints.

(2)The construction of watertight screen through hole grouting, grouting depth is generally greater than 400m, double liquid grouting to operate, watertight screen construction using single liquid grouting slurry, the serious loss of the main water conducting structure of high pressure, large flow, single cement slurry cannot be effectively deposited on water conducting structure block.

(3) Karst fissure water bearing has the heterogeneity and anisotropy of rock mass, the hydraulic conductivity is mainly controlled by large fractures, can not guarantee the water watertight screen structure to guide the control action for comprehensive coverage.

(4) Limestone marble within the mining area of hard rock, the curtain cannot pass through the hydration hydrolysis with weak rock self sealing; mining area for water drainage area, the hydraulic gradient exists inside curtain, curtain of groundwater on water resistance of concrete and limestone weak zone near the impact effect and effect of cavitation, the curtain of weak zone by the corrosion of internal voids caused by weak connectivity zone is formed and enlarged.

3.3 Hazards of curtain weak zone

The prevention and control of groundwater disaster is the main problem in the mining process of the mining area, the existence of the weak zone of the water curtain brings a series of hazards to the operation of the mining area:

(1) The underground water is introduced into the curtain, which is easy to cause the water filling in the mine, which seriously threatens the life and property safety.

(2) It is harmful to the hydrogeological environment around the mine, the drainage and drainage in the mining area, the curtain of groundwater supply outside the curtain, leading to serious loss of surrounding groundwater.

(3) Because of water resources cannot be caused by mining. 4109 and 4208 rooms in Zhangmatun Iron Mine, because the flood threat resulted in 400 thousand tons of iron ore to mining.

(4) Increase the economic burden, the annual cost of nearly Zhangmatun Iron Mine Drainage 1400W, serious damage to the economic interests of enterprises.

4. Flow field characteristics Under different conditions

4.1 Natural flow field

The natural flow field of groundwater reflects the recharge and discharge of groundwater. The natural condition of underground water in mining area. The elevation of 16~26m mining area covered by Quaternary aquifer, but the middle thickness more than 130m diorite apart, no direct threat to deposit water filling. Mining area of the main aquifers in Middle Ordovician limestones, according to the space position, the hydraulic connection and buried layer, can be divided into O2- I and O2- II, O2- III three layer (Figure 1). O2- II and O2- III is located inside the limestone curtain, water contact more closely, and more for the seam roof and floor, is a major threat to deposit water filling.

According to the analysis of the exploration data before the construction of the block water blocking project, there are three main groundwater recharge channels in the mining area: the northern part of O2- II limestone, the western and southern part of O2- III. According to the local limestone layer pumping test results are summarized as following table.

Table 1. Parameters of water channel in limestone bed

position	length (m)	depth (m)	Unit water inflow (L/sm)	Water conductivity coefficient (m^2/d)
O_2- Ⅱ north	350	20~30	1.575	186
O_2-Ⅲwest	620	38~42	4.342	460
O_2-Ⅲsouth	175	35~40	3.817	438.9

In the construction of the mining area before mining, groundwater migration is mainly controlled by the geological structure, because the formation from south to north, tilt, north-south trending faults, the groundwater runoff from horizontal moving south to north, the northern region encountered. Stop a large number of igneous rock, the total flow of incomplete statistics up to 380 thousand m^3/d.

4.2 Flow field

The water resistance engineering curtain affects groundwater recharge, caused by the change of the groundwater flow field, building watertight screen caused by the water level difference inside and outside the curtain. Water blocking curtain body after the end of the project, the water curtain formed inside and outside the differences are in the south, southwest, West and North Section: 23m, 14m, 25m and 11m, the water level is higher than the tent curtains.

The distribution of the groundwater level water level reflects the characteristics of the flow field. From the shape of the flow field, it can be seen that the formation of the underground water level platform.

The water level in northern mining area of line sparse relief, shows that the hydraulic smooth channel; western mining area level line is more lenient, indicated that the watertight screen effect, groundwater runoff is hindered; the southern area from east to West has a long narrow level platform area, the formation of dense water line level, shows that the hydraulic channel is not free. The groundwater recharge mainly from the north, West and southwest section of the curtain to the mining area, mining area groundwater discharge to surface drainage. Under the condition of curtain, the water level of the mining area is about -5~5m elevation, and the water level at the same time reflects the characteristics of karst development under the condition of curtain and water.

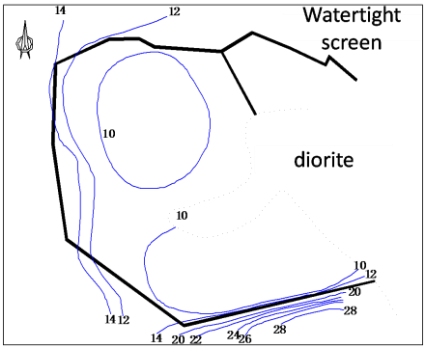

Fig.2 Initial water table field

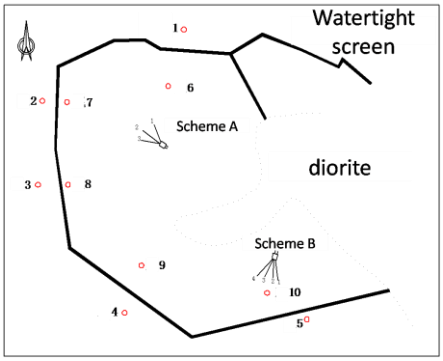

Fig.3 Location of dewatering holes and observational holes for dewatering test

5. Hydrological test

In the process of mine water inrush disaster prevention in weak zone curtain development position and scale is the key to carry out groundwater disaster management. How to obtain the orientation information of the weak zone of the curtain is a key technical problem to be solved in the design and construction of the underground water disaster. In order to find out the curtain of weak zone distribution region and the distribution of curtain weak zone permeability, launched a multi level experiment. Through the change of groundwater flow field morphology revealed weak zone permeability and distribution.

5.1 Experimental method

Zhangmatun Iron Mine arranged 8 water chamber and the water hole at the -324m level and -360m level, and -360m level in the construction of drainage capacity with 55000m3/d drilling, hydrological observation of a total of 10 for the curtain arrangement, and clear the 30 wells earlier layout, forming a surface observation network. The groundwater discharged by the drainage chamber discharged into the storage tank by the water level of -360m pumping station discharging to the surface for the surrounding industrial water.

Zhangmatun Iron mine dewatering test was carried out by -324m and -360m level in the water chamber, water test for each level of each discharge chamber is divided into three programs, test through the observation hole of hydrological data record.

Table 2. Distance between dewatering holes andobservational holes

number	Distance from A(m)	Distance from B(m)
1	263	548
2	287	627
3	293	554
4	386	359
5	508	158
6	131	450
7	234	579
8	229	490
9	275	299
10	406	83

5.2 Testing process

The water level observation, the water level test and the recovery water level observation were carried out before the multi level combined water discharge test was officially released.

The official release test includes A, B, C three programs:

(1)Scheme A: the -360m level of the water chamber, the water discharge test in the 4 drainage chamber open, lasting for 10 days.

(2) Scheme B: the -324m level of the water chamber, the water discharge test in the 4 drainage chamber open, lasting for 10 days.

(3) Scheme C: by the -324m level and -360m level drainage chamber implementation, waterproof test, the 8 water discharge chamber open, lasting for 10 days.

Hydrological observation including the drainage chamber hole discharge of water measuring and hydrological observation hole measurement, observation time since the formal water after 1,2,3,4,5,6,7,8,9,10,12,14,16,18,20,25,30,40,50,60,70,80,90100110120 minutes were observed, then the observation frequency is two times an hour, after 600min observation frequency change to 1 hours at a time, 1000min observation frequency changed to 2 hours at a time, until the end of the experiment. The content of the observation is the groundwater drawdown, the change of groundwater level and the observation of the recovery water level.

5.3 Result

(1)Test result of scheme A:

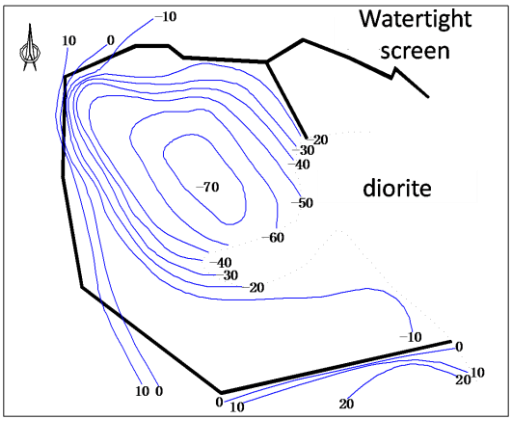

Fig.4 Water table of releasing water test in scheme A

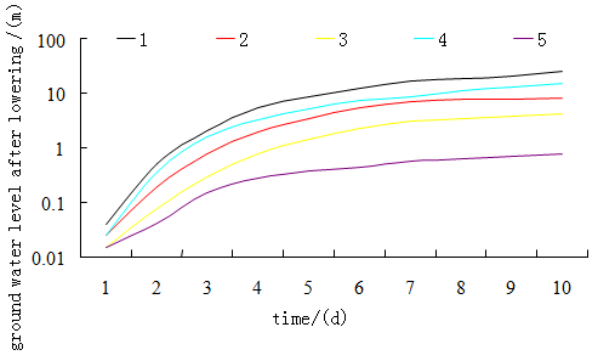

Fig.5 Change of drawdown with time logarithm outside of curtain in scheme A

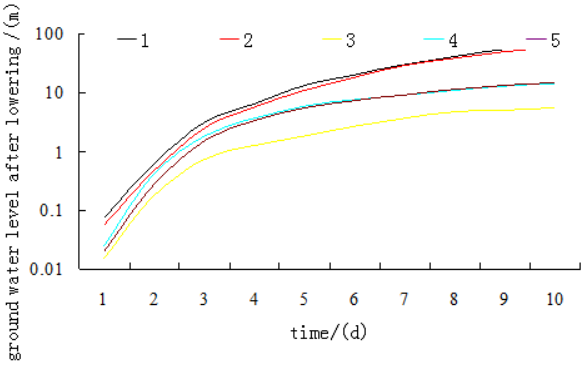

Fig.6 Change of drawdown with time logarithm inside of curtain in scheme A

(2) Test result of scheme B:

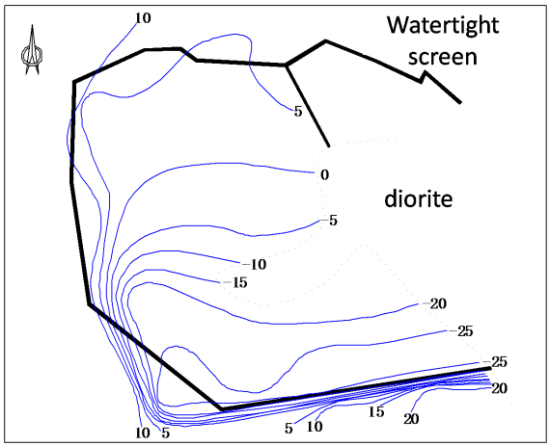

Fig.7 Water table of releasing water test in scheme B

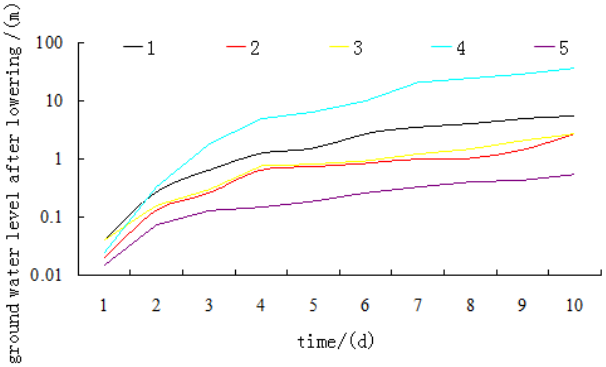

Fig.8 Change of drawdown with time logarithm outside of curtain in scheme B

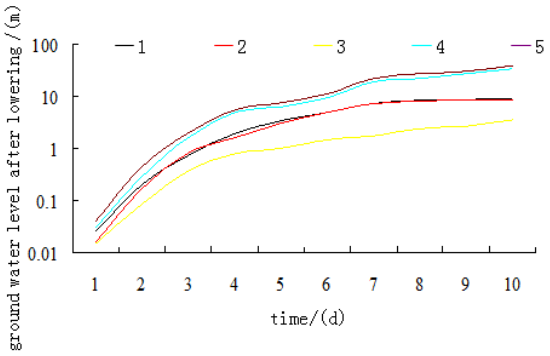

Fig.9 Change of drawdown with time logarithm inside of curtain in scheme B

(3) Test result of scheme C:

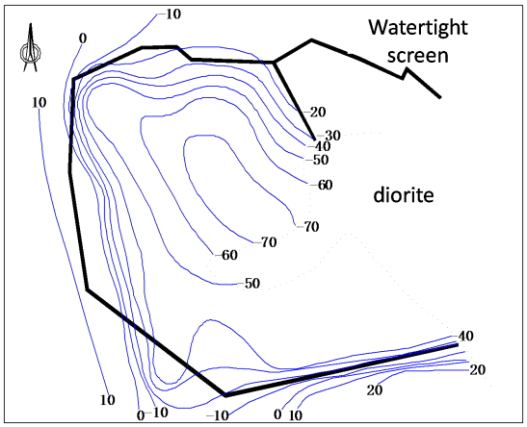

Fig.10 Water table of releasing water test in scheme C

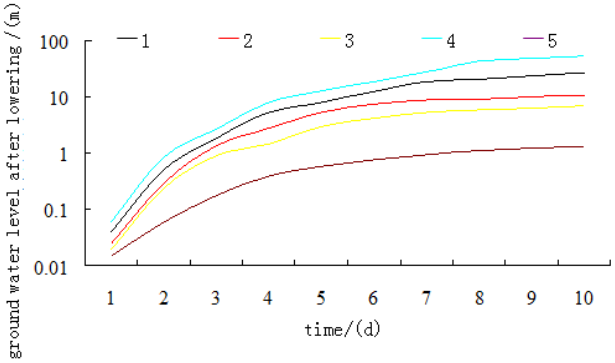

Fig.11 Change of drawdown with time logarithm outside of curtain in scheme C

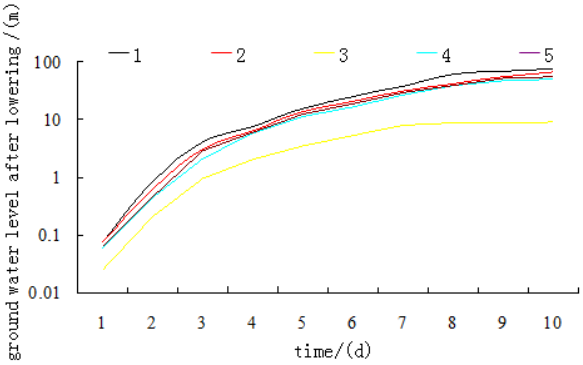

Fig.12 Change of drawdown with time logarithm inside of curtain in scheme C

5.4 Analysis report

The water discharge test shows the connection of water between the observation hole and the drainage hole, which fully reveals the response rule of the groundwater flow field under the condition of large curtain.

The distribution law of the weak zone of the watertight screen and the response rule of the groundwater level line follows the following criteria:

(1) The ground water level line shape is very slow, which is the strong runoff zone[16].

(2) The strong runoff area near the curtain watertight screen for weak zone of intensive development zone.

(3) There is a close hydraulic relationship between the observation time and the drainage area.

According to the static water level line:

$$J_{AB} = \frac{H_A - H_B}{AB} \tag{1}$$

According to the structural characteristics of the water stopping curtain, watertight screen is divided into North, West, southwest, northwest section and South sections, with (1) analysis of the data type, available curtain hydraulic gradient table.

Table 3. Hydraulic gradient in research area

Scheme	Position	Hydraulic Gradient
A	north	80.22
	northwest	347.48
	west	299
	southwest	32.35
	south	482.65
B	north	93.26
	northwest	332.81
	west	285.7
	southwest	58.82
	south	597.63
C	north	71.79
	northwest	328.54
	west	262
	southwest	70.86
	south	477.44

Based on the above criteria and data analysis results can be seen.

(1) Water curtain construction, for drill pipe grouting hole construction is long, there is a certain flexibility, deviation of pre grouting area, leading to the curtain curtain layout and underground section

of the curtain line there are some errors, but can be clearly seen from Figure 10 the existence of watertight screen.

(2) O2- II and III O2- limestone limestone edge isohath intensive, shows that the two layer limestone water channel is not smooth, the A scheme is applicable to the analysis of water blocking curtain in North and northwest, the B scheme is applicable to the analysis of the west, southwest and South sections of water blocking curtain.

(3) Watertight screen north, southwest section isohath sparse wide slow, low hydraulic gradients, and the curtain drop fast response, here is the curtain weak zone mainly developed area, is the main area of curtain weak zone governance.

(4) The water level water blocking curtain, west northwest section of the line is more intensive, the hydraulic gradient is higher, and the curtain drop slow response rate, there is weak zone, but not significantly, should strengthen the monitoring of regional curtain.

(5) The southern section of watertight screen water line is extremely dense, hydraulic gradient is very high, and the curtain drop response rate is very slow, the curtain of weak zone is not developed, good water resisting property.

(6) In the direction of groundwater runoff for the regional center of limestone from the north, southwest section curtain to O2- II, O2- III collection. After the completion of the curtain, the key to restrict the flow of underground water to the mining area is not the karst fissure of the aquifer, but the waterproof watertight screen itself.

5.5 Hydraulic gradient and flow field

Theis formula is the basic formula for determining aquifer parameters in unsteady flow pumping test. In the hydrological experiment, the drainage mode of the hydrogeological body and the chamber drainage pipe can satisfy the hydrogeological conditions of the Theis model, and the analysis of the hydraulic gradient and the deep field can be approximately expressed by the Theis formula of the bearing water well:

$$T = \frac{Q}{4\pi S} \tag{2}$$

It can be seen in the experiment period, the flow field in the quasi steady state in the curtain, the water conduction coefficient is a key factor affecting down deep, and the curtain inside and outside the hydrological response observation hole drawdown between response rate and water channel is smooth there is a direct relationship between the characterization of curtain weak zone development degree. From the data analysis results can be seen, the hydraulic gradient, drawdown value in the direction of the water conduction coefficient is small, and narrow the area of dense water level, groundwater runoff is not smooth, the hydraulic gradient is small, drop small value direction, the water conduction coefficient is larger, as the curtain of weak zone of intensive development area. From (6) to each watertight screen water conduction coefficient as follows.

Table 4. Transmissibility in research area

Position	Coefficient of Hydraulic Conductivity（m^2/D）
north	646.8
northwest	87.5
west	109.8
southwest	594.3
south	3.2

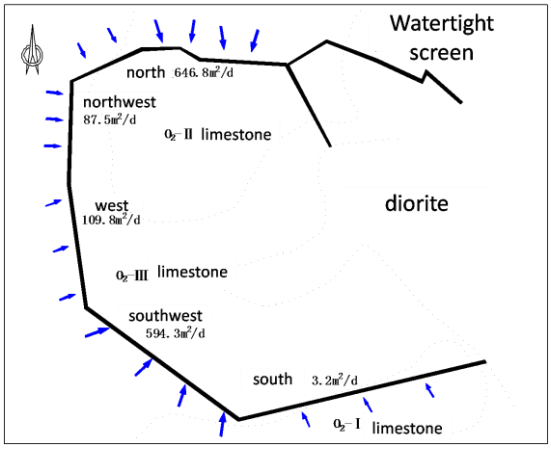

Fig.13 Runoff and transmissibility

6. Verification

In order to verify the accuracy of the analysis results of the dewatering test, drilling verification in two curtain dewatering test identified the weak zone region, as shown in the two section of weak zone near the roadway curtain curtain construction direction anisotropic bore 2, fan-shaped distribution, Kong Shen 66m.

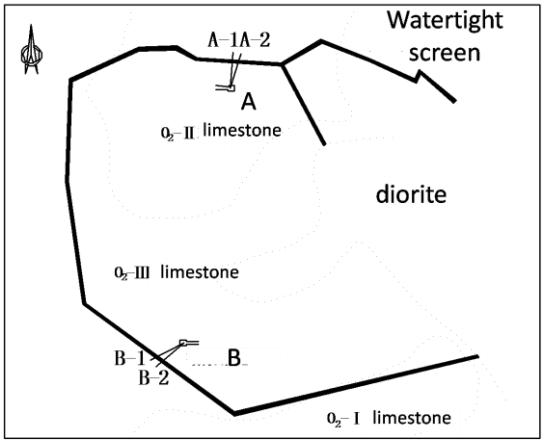

Fig.14 Location of exploration drilling

Take the typical drilling A-2 catalog as follows.

Table 5. Drill core logging from exploration drilling

Stratum	Layer depth (m)	depth of stratum (m)	Water depth (m)	Water inflow (m^3/h)	hydraulic pressure (MPa)
δ	17	17			
SK	19.4	2.4	18	5	2
Fe	23.2	3.8			
SK	25.5	2.3	24.5	17	2.8
δ	36	10.5			
O_2	58.6	22.6	37.5	80	3.1
			45.7	4	3.7
			54	60	4
δ	66	7.4			

Table 5 shows the exploration drilling in the zone near the curtain to expose fissures and gushing water, and water is large, verified here for the weak zones of curtain.

7. Conclusion

(1) From the perspective of hydrogeological analysis shows that the application of grouting method to build a watertight screen in karst strata, due to many complex geological conditions and grouting effect influence factors, leading to weak water blocking curtain with guide area, weak zone because of the existence of underground water curtain inside and outside the field of property that is different, is the basic analysis on the basis of the curtain weak zones.

(2) Shows that the flow field characteristics of natural groundwater flow and the characteristics of mine curtain under the condition of water blocking curtain construction changed the original flow, curtain formed hydrogeological unit new, recharge source for limestone groundwater runoff channels mainly for the weak zone region wide curtain crack direction for roadway curtain and excretion mine.

(3) Multi level discharge test based on the characteristics of flow field based on the analysis of the use of hydraulic conductivity and hydraulic gradient as the weak zone analysis criterion, get the curtain weak zone development degree distribution, the degree of influence on each curtain weak zone of mine section.

(4) The Theis formula is used to analyze the flow field of the water discharge test, and the influence of the hydraulic conductivity and the falling depth on the weak zone of the curtain is pointed out.

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