Upward-pumping and downward-drainage water draining (UDWD) method and raised-bore drilling technology (CBT)

New techniques employed in shaft construction

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ABSTRACT

The joint employment of UDWD and CBT was introduced in constructing the auxiliary shaft, which measures 309m in depth and passes 52m thick alluvium sediment, in Jiaojia Zhai Mine of Xuangang Mining Bureau, Shanxi Province. This alluvium sediment characterizes in rich water reserve and high velocity of flow, so it's difficult to construct shaft by means of freezing, diaphragm-wall concreting, grouting or conventional drawdown method singly. Therefore, the water descending was exercised in the alluvium sediment. The residual water column was dredged downward through the laneway connecting hole. And the raised-bore drilling machine (CM) penetrated the bedrock, which was followed by enlarging excavation. It's proved that this method saves time and cost, enhances quality, and is a brand new technique in shaft construction.

KEYWORDS: water drawdown, raised-bore drilling, and new technique in shaft construction

FULL TEXT:

1. THE OUTLINE OF THE JIAOJIA ZHAI AUXILIARY SHAFT PROJECT (JZAS)

JZAS is a new shaft building project in the process of mine enlargement. Its proposed depth reaches 309m, which consists of 52m thick alluvium sediment, and 257m bedrock. The outside diameter of the well chamber measures 7.5m, and the inside 6.5m. The well wall is simply concrete lined of 500mm thickness.

2. PROJECT AND HYDROLOGIC GEOLOGICAL CONDITIONS

Yangwu river, a branch of the upstream Wutuo water system, flows through Jiaojia Zhai Mine, and JZAS is located right at the second terrace, where the alluvium is composed mainly of grit, and the lithology features in limestone primarily and sandstone secondly. Sands and soil at all granularities are filled in the high water containing scree and grit sediment. Scree and grit are distributed from the relatively small one (20-40mm in diameter) at the top to the larger (the rock core sample measures from 300 to 320mm, and the largest rock is 1m in diameter) in the middle (26 meters deep), and to the shrinking ones at the bottom (rang from 150 to 200mm in diameter).

Below the alluvium lies a slim mudstone and dark grey quartzitic rubble sediment of 0.45 in thickness. Beneath that is the 6.69m thick maroon and mottle grit like mudstone, then the 4.7m maroon powder like sandstone, and the 2.72m brown mudstone at the bottom.

According to the instruction offered by some staff from local mining bureau, there exists no water proof between the alluvium and bedrock within the heavily effloresced water containing sediment (WCS), but hydraulically connected.

The geological data of November, 1988, when the static level was 28.27m, indicated that below this lever, the grit sediment, the sand and gravel sediment, and the sand grit mix sediment could be treated as a WCS, and the rock weathering zone is the other one. Or we could look the sediment below static level and above stable bedrock as a WCS

Table 7-1. Data collected from the central inspection borehole in the JZAS auxiliary shaft

Static Level before Pumping (m)	**Thickness of WCS (m)**	**Height of Column (m)**	**Resumed Level after Pumping (m)**	**Depth of Laid down Submerge Pump (m)**
28.27	23.78	24.23	28.61	h1=42.93 h2=47.02

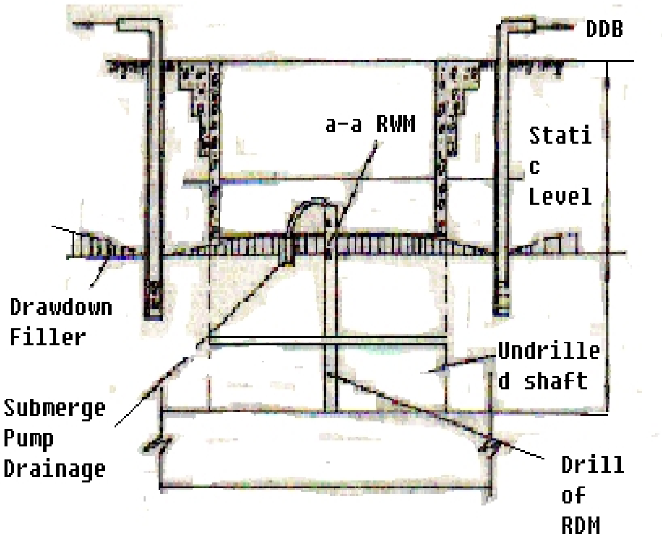
Pumping Time (min)	**Water Level Descended (m)**	**Water Influx (m^3/h)**	**Permeability Coefficient**	**Infection Radius (m)**
t1=1150 t2=650	S1=11.63 S2=15.79	Q1=56.97 Q2=54.60	K1=1.46 K2=1.40	R1=25 R2=25

The estimated water influx is Q_1 =56.97m³/h and Q_2 =54.60m³/h based on the data of Table 7-1.

3. THE CONCEPT OF THE NEW SHAFT CONSTRUCTION TECHNIQUE- UDWD AND CBT

The biggest challenge when deploying drawdown (DD) shaft construction method is the existence of residual water column at the late stage of DD process. It directly relates to the project's success. One way used was to pierce more descending holes, however, except increasing cost, it only reduced the height of column but not eliminated it. Another way, deeper the holes, didn't work either.

The only feasibility is to drain it to areas beneath the well through the holes at the well center, but the premise is the existence of under-mine laneway. The concept is quite simple, that is dredging influx on the working space into well cannulla by means of siphon or submerge pump. (Refer to Graph 7-1)



Graph 7-1: Sketch map of the shaft side section lining and excavation at the Alluvium sediment

So it's possible to dig a dry well when excavating at the alluvium sediment by means of water descending. Compared to other techniques, it's simpler, less equipment involved, cost-saving, shorter time consumed, less labor and energy cost, etc.

The water dredging holes could also be used as the guiding holes for raised-bore drilling at the bedrock excavation process, hence increase efficiency and reducing cost.

JZAS is old mine technical renovation project. It has several advantages over other new mines, for instance, the laneways do pass under the proposed shaft, and there're under mine water chambers and pump stations which are equipped with sufficient pumping capacity. Fully taking advantage of all these facilities makes it possible to burrow a dry shaft if employing UDWD and CBT.

4. PARAMETERS CONCERNED IN DD WORK

a. Number of drawdown boreholes
   It should be three based on the hydrological data collected by center inspection holes (CIH).
b. Proposed diameter of drill borehole
   Since the excavated diameter is 7.5m large, the possible small particles erosion during drilling and pumping may cause inanition around the boreholes, which may result in slice band in the process of excavation and lining.

To isolate the inanition and the excavated diameter, avoid disturbance between the headframes of excavation and drill during excavation process, and guarantee simultaneous work on drainage and excavation, the proposed diameter of drill borehole should be Φ27m (circle the well center). Three drawdown boreholes were arranged along this circle, one lay on the upstream facing flow, the other two stood by its sides.

c. Diameter of the DD boreholes
It should facilitate the operation of Φ216mm and Φ254mm submerge pump, and meet the demand of air-pressure pumping, so the filter pipe of drawdown boreholes ought to be Φ273mm in diameter.

d. Depth of the DD boreholes
The geographic data indicated that the alluvium and effloresced bedrock could be treated as a WCS with 66.61m thick effloresced bedrock soleplate. In view of the inflow height of submerge pumps and rock power deposition at the bore bottom, the depth of the DD boreholes should reach 75m.

5. NEW DATA COLLECTED IN THE WORK

Comparison between the results of drill cores from the three DD boreholes (DDB) and the data collected by center inspection holes revealed that there was little change in the alluvium's thickness, but the lithology varied a lot (see graph 7-2), and the particle diameter distributed quite unevenly. These are the features of quarternary period deposit at the river valley among mountains.

The measured static level of underground water also altered at different construction time of these three boreholes. This difference affected the thickness of WCS, and its water character as well, which caused difficulties in hydrologic and geological analysis on pumping test results.

Table 7-2. Pumping test results on DDB 1

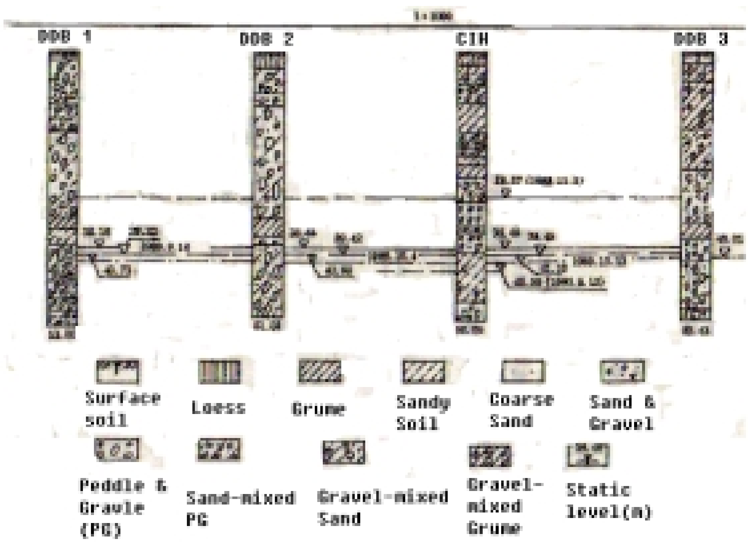
WCS	**Depth of Static level (m)**		**Pumping Result**		
Depth of Burial(m)/Thickness (m)	Pre-pumping	Pro-pumping	Water Level Descended S(m)	Water Influx Q (L/s)	Water Influx per Unit q(L/s m)
38.16~53.00/ 14.84	38.16	39.1	14.84	22.58	1.522

Inspection Hole Data			
No. of DDB	Static Level pre-pumping (m)	Water Level Descended S (m)	Distance to Pumping Hole L(m)
DDB 2	38.44	1.43	24.219
CIH	38.46	1.54	13.85

Table 7-3. Pumping test results on DDB 2

WCS	**Depth of Static level (m)**		**Pumping Result**		
Depth of Burial(m)/Thickness (m)	Pre-pumping	Pro-pumping	Water Level Descended S(m)	Water Influx Q (L/s)	Water Influx per Unit q(L/s m)
39.42~51.58/ 12.16	39.42	40.16	12.16	15.72	1.293

Inspection Hole Data			
No. of DDB	Static Level pre-pumping (m)	Water Level Descended S (m)	Distance to Pumping Hole L(m)
DDB 1	39.23	0.5	24.219
CIH	39.48	0.57	13.586



Graph 7-2. Alluvium lithology comparison between DDB and CIH in JZAS auxiliary shaft

Table 7-4: Interference pumping experiments on three DDBs

No. of Borehole	WCS	Depth of Static level (m)
	Depth of Burial(m)/ Thickness (m)	Pre-pumping
DDB1	40.73~53.00/12.27	40.73
DDB2	40.98~51.58/10.60	40.98
DDB3	41.01~52.43/11.42	41.01
CIH	41.10~52.05/10.95	41.1

Pumping Result				**Inspection Hole Data**
Water Level Descended S(m)	Water Influx Q (L/s)	Water Influx per Unit q(L/s m)	3 DDBs' Average Water Influx per Unit qcp(m)	Distance to Pumping Hole L(m)
12.27	11.24	0.916	0.954	13.85
10.6	5.13	0.484		13.586
11.42	16.68	1.461		14.062
3.6				

6. MEASURING THE WATER INFLUX IN SHAFT

a. Computing the drawndown water amount

Pumping test on DDB 1 and 2 discovered that their water influx q=1.522~1.293L/sm was much more than the primary construction designed q= 0.293L/sm. Further interference pumping experiments in a comparatively longer time on those three DDB found that when water level went down close to the soleplate of WCS, the total amount at a relatively stable level was 33.05L/s (118.98m³/h), the static level in the shaft lowered by 3.6m, and the WCS measured 10.95m in thickness.

Two ways could be taken in computing water amount:

First, when q=f(s) curve slid down, Q=Q $_0 \dfrac{(2H-S)\cdot S}{(2H-S_{0)})\cdot S_0}$

Q: total water discharge amount (m³/h)

H: WCS thickness

S: water level reduced when constructing dry well

So $_0$: water level reduced in pumping test

Q $_0$: water discharge amount in pumping test

The result is Q=216.54 m³/h.

Second, when q=f(s) curve fell down, Q=Q $_0 \dfrac{S}{S_0}$

The result is Q=361.9 m³/h.

The arithmetic average of these two results is 289.22 m³/h. That means to construct a dry well need a totally 289.22 m³/h water discharge capacity of those three DDBs, which exceeds the operating capacity of submerge pumps. If merely relied on DDBs drainage, three more of them were required.

UDWD works in a different way. The residual water would be drained to the under mine through laneway connecting holes. Therefore, turn the dry well construction into reality.

b. Computing water discharge amount

A pumping test on the center inspection hole was also taken during interference discharge experiments on DDBs. When pumped amount reached 10 m^3/h, water level was reduced by 1m. Using above mentioned two functions, the worked out arithmetic average was 56.47 m^3/h. So the drawdown capacity, 120 m^3/h, of those three DDBs around the shaft plus the drainage capacity, 56.47 m^3/h, of drainage holes in shafts could meet the requirement to construct dry well at the alluvium and effloresced bedrock sediment.

7. CONSTRUCTION AT THE BEDROCK SEDIMENT IN THE SHAFT

a. Geological and hydrologic conditions

The bedrock discovered in JZAS is up and down SHIHEZI group stratum of Dias. Its upper part falls in discontinuous conjunction with the pebble in the alluvium of quaternary sediments.

The drill core proved that the obliquity at the bedrock stratum was gentle, between 7° ~ 15°. The main lithology was mudstone and sandy mudstone, which accounted to 60%, and the second was fine, medium and coarse particles of sandstone, 37.7%, between which lay three levels of coal, and the second level measured 5.8m in thickness. The main element of sandstone was quartz, most of which was muddily glued, compact and hard.

The examination of the uncovered bedrock in the established main sliding shaft concluded that the way from stable bedrock to the shaft bottom measured 234m long, and no water contained.

In view of JZAS' characters, drawdown method was introduced in constructions at the alluvium sediment, the residual water was drained down to under mine, and no water was there. Under these conditions, raised-bore drilling was the best way to drill and enlarge holes. It was proved by practice that this method processed fast, with high quality and safe. The water dredging holes in the shaft could also be used as the guiding holes for raised-bore drilling at the bedrock excavation process, hence increase efficiency and reducing cost.

b. Features of CM

LM-200 CM is developed by Beijing Construction and Shaft Research Unit of China Coal Research Institute. It integrates the advantages of similar domestic and international products, features in compact structure, reliable performance, and sound techniques, and represents a new generation of entirely hydraulic pressure and explosion proof CM. It consists of two major parts, main body and drilling tools. The technical specifications of the borer are as follows:

Diameter of Guiding Holes	216mm
Diameter of Enlarge Holes	1400mm, 2000mm
Depth of boreholes	250m, 200m
Obliquity	50º~90º
Rotating Speed of Aiguilles	0~9 (I), 0~18 (II), 0~36 (III)
Torque	40,20,10 (kN· m)
Total Power	82.5kW
Main Body Weight	8277kg
Thrust	350kN
Pull	850kN

c. Feasibility of using CM to drill and enlarge holes
It's feasible to adopt raised-bore drilling technique in drill and enlarging work in view of JZAS' characters and relevant geological and hydrologic conditions, and the capacity, structure and size of CM.

THE REASONS ARE:

a. The depth CM can reach meets the construction demand
The total depth of JZAS is 309m, drawdown construction area 75m, and the left bedrock part 234m. The maximum drilling and enlarging capacity of CM is 250m, deeper than the bedrock part.

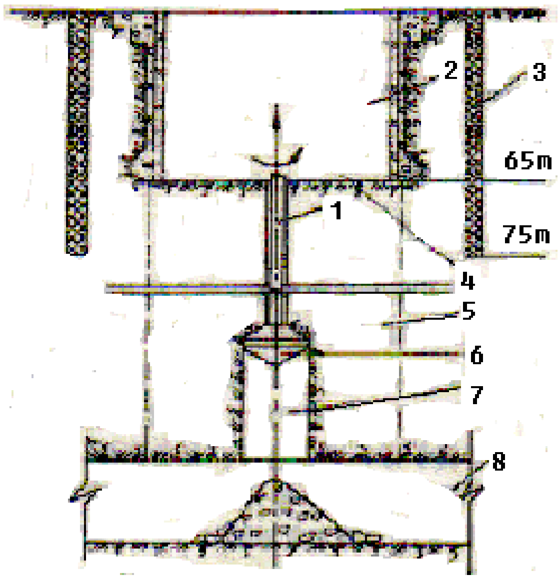
b. The largest section of CM can pass through the bell-mouthed hole of cradle
After dissembling, the largest part of CM is the main body, whose geometric size can go through the bell-mouthed hole, hence making it possible to descend CM to the shaft bottom.

c. The operating surface is spacious to contain CM
The inner diameter of JZAS is 6.5m, and the section area 28.26m², which offers spacious room for all the equipments, including the main body, drilling cramp, operating table, and pumping machine, and the operators may easily run them as well.

d. The stratum spreads gently and unbroken, and contains no big segment of expansile mudstone, so long time drainage through drainage holes and drill by raised-bore drilling machine (RDM) would not cause large scale snakes in hole and neck-down dimension.

e. No water contained at the bedrock sediment
The bedrock sediment where the auxiliary shaft passes contains no water. That means, after drilling through to the laneway, and fixing casing tube at the alluvium, not much amount of water would be dredged to the under mine area since no water contained at the bedrock sediment. And when lining and excavating at the alluvium sediment, only 50-60 m³/h water would flows down to under mine. So it would not shoulder much burden on under-mine water discharge.

In a word, it's environmentally feasible, technically reasonable, and safe and reliable to run LM-200 raised-bore drilling machine on the operating surface when working at the bedrock sediment in JZAS project. For techniques, refer to graph 7-3:



Graph 7-3. Sketch map of the construction plan at the bedrock sediment in JZAS

1. RDM drill stem	2. Excavated shaft	3. Sealed pumping boreholes
4. Working surface in shaft	5. Unexcavated shaft	6. RDM aiguille
7. RDM boreholes	8. Excavated laneway	

8. THE PROCESS OF UDWD WORK

a. Preparation

Includes analysis on the geological and hydrologic collected from drill core result and study the feasibility of this method.

b. Computing drawdown construction parameters

Based on above data, figure out number of drawdown boreholes, proposed diameter of drill borehole, and setting, diameter and depth of the DD boreholes, and compute corresponding discharge amount, and choose pumping style and submerge pump model accordingly.

c. Construct drainage holes at the shaft center (raised-bore drilling drill hole)

Drainage holes center the shaft, and measure 325mm in diameter at the alluvium sediment. Use DZJ-500/1000 freeze-grouting borer to drill coreless with mud. When it reaches 65m, install Φ273mm casing tube, which is cement sealed. Below this 65m line is the bedrock, where the drill hole should be 216mm in diameter. Still drill in coreless with mud model. To make sure the boreholes are vertical straight, measure gradient for every 20m progress by means of turbinate clinometer, and rectify deviation as long as it is detected. The gradient tolerance should be less than 5‰. It penetrates through to the laneway at 309m deep.

d. Construct drawdown holes
Use Φ426mm anguille and coreless drill 75m deep, then embed Φ273mm water-purify casing tube. Fill in Φ5~10mm riverbed gravel as filter around it to ensure that the four series WCS underground water can enter it smoothly. After filling it, clean the shaft with strong force until water turns in limpidity, WCS is unobstructed, less sand contained, and water inflow increased and recovered to the original level.

e. Install pump to descend
Install submerge pump at the drawdown boreholes which are constructed in step D. After digging down 20m and standing up the cradle, pump water simultaneously from those three drawdown boreholes at the beginning of formally lining and excavating the shaft, which go on continuously along with the lowering of static level.

f. Line and excavate at the alluvium sediment
Blast is strictly prohibited, but pickaxe should be used for excavation. Along with the shaft's extending, cut off casing tube at the center. When meet the remained water column (RWC), dig a provisional sump at working surface, then dredg influx on the working space into well cannulla by means of siphon or submerge pump and down to the under mine. In this way, dry well could be build at the alluvium sediment.

g. Set up raised-bore drilling machine and operate it
When line and excavate till 75m deep, namely pass through alluvium and effloresced bedrock sediment, and enter stable bedrock, set up wall crab. Then lay down basis for raised-bore drilling machine, assemble the machine and adjust it. The next step is to put down the drill stem through the drainage holes to the laneway connecting point, mount it on the aiguille, and start enlarging the holes thoroughly. When finished, dissemble raised-bore drilling machine into section and send back to the ground.

h. Ream shaft chamber with drill and blast method
When the raised-bore drilling machine enlarged the hole to Φ1200mm, workers hold the borer in their arm and drill shot holes for conventional drill-blast ream work. The existence of boreholes widens the open area for blast, so no sump holes are needed any longer, and the blast efficiency got enhanced as well. After blasting, most of the waste rock slid down to under mine, the left was moved into the boreholes manually. Then they were loaded into tramcar by scraper loaders, and shipped to the ground through main declining shaft.

9. CONCLUSION

The UDWD and CBT technique is a new thing in old mine expansion and shaft construction, which combines the conventional drawdown method and the newly developed raised-bore drilling technology. It saves time and cost, enhances quality, operates safely and easily, and initiates world widely.

It turns drainage at the shaft center into reality, and eliminate RWC, so dry well can be built throughout the whole process, hence speed up construction, guarantee the quality of wall. Drainage at the shaft center, no matter how much the influx amount is (as long as it does not exceed the under-mine dredging capacity), not only eliminates RWC, but reduces the number of drawdown boreholes from previous 8~12 to 3~4. Less boreholes results in less construction cost and quicker completion naturally.

Employing raised-bore drilling technology in lining and excavation at the bedrock sediment reduces demand for water drainage system and ventilation system in the shaft, and simplifies the suspending system to a large extent. No need for lifting waste rock in barrels saves grasping equipments, and loading time. This also enhance efficiency and construction speed.

Raised-bore drilling is a new technology developed since 1980's. It can build up vertical shaft quickly, safely and inexpensively. Installing it on the working surface in the shaft and using drilling and enlarging technology to line and excavate at the bedrock sediment can fully take all of its advantages.

Boreholes centered at the shaft could be used as drainage holes during the lining and excavation process at WCS of the alluvium sediment, and dredge the RWC down to the under mine. It could be used the guiding holes for raised-bore drilling machine. One hole for two usages.

The UDWD and CBT technique could be employed under certain conditions. Along with the development of national economy and the structural adjustment of the coal mining industry, old mine renovation and expansion projects will emerge more and more and demand wide application of this technique, so it will enjoy a large and promising market.