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Original Paper

Research on the Application of Slant Hole Grouting Process in the Undermining Hollow Area of Urban Main Road

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Abstract

China has a huge number of underground goaf, when the new city main road crosses the goaf, a large number of non-migratable buildings may be left on the ground due to economic problems, resulting in the goaf does not have the condition of vertical drilling and grouting, so the slant hole grouting technology is of great significance in research. In this paper, we take a city main road under construction in Changchun City as an example to study the application of slant hole drilling grouting in the hollow area, and hope that it can provide reference examples for similar projects.

Keywords

goaf, inclined hole grouting, urban main road

1. Introduction

China's coal mining is huge, China's coal production in 2021 was 4. 13 billion tons, a large number of coal resources mining caused a large number of mining voids left below the surface, according to preliminary statistics, as of the end of 2015, the national underground mine mining formed a total of 1. 28 billion m 3 of goaf, distributed in 28 provinces (cities and districts). Many of these mining voids, which are also known as air-mining zones, are distributed under the urban and suburban areas of cities. With the continuous expansion of China's urban scale, the road network is constantly encrypted, part of the new roads, housing and building routes will inevitably directly across the hollow area, increasing the load above the hollow area, so that the hollow area of the stress redistribution occurs, the hollow area of the overlying rock layer may produce deformation and displacement or even collapse, resulting in serious safety accidents. Generally, the treatment method for the hollow area is to carry out grouting and other processes before the new construction of the project to ensure the stability of the hollow area, and the grouting holes are generally vertical holes. When the new road crosses the hollow area is located in the suburbs or urban areas, there may be non-migratable buildings around, can not be vertical grouting

treatment of the hollow area, so explore the use of tilt grouting technology has an important significance of application.

2. Engineering Overview

2.1 Location of the Goaf

Southeast Lake Road project through the hollow area part of the starting point coordinates 125°27′6. 40″ East; end point coordinates 43°51′31. 72″, the planned road level for the city trunk road, the hollow area management adopts the point injection grouting program**,** due to the existence of residential villages and relocation difficulties above the hollow area, the project adopts the slant hole grouting process. The location of the road and hollow area is shown in Figure 1.

Figure 1. Schematic of the Location of the Road and the Mining Area

2.2 Extraction

The Shibeiling coal mine went into operation in 1970 and ceased production in 1988. After the closure of Shibieling Mine, the mine was re-mined by Sandao Coal Mine from 1994 to 2008. The coal mining method is long-wall mining, and the roof slab adopts the total collapse method. The overall distribution of the Goaf is characterized by local two-seam (3, 4) and three-seam (3, 4, 5), and other areas are 6, 7 single-seam mining type. The mining situation of each coal seam is shown in Table 1.

Table 1. Mining of Each Coal Seam

coal mine	quantity of coal mined	coal seam	Average mining depth	Maximum seam thickness	Mined-out area
	Ten thousand tons		m	m	m^2
Shibiling coal mine	96. 2	2	100-200	1. 18	158369
		4	100-200	0. 89	
		6	150-340	1. 25	555694
Sandao coal mine	170. 7	3	80-100	1. 43	/
		5	160	1. 10	44852
		7	240	3. 38	29420
add up the total	266. 9				788335

2.3 Surface Deformation Survey

The investigation of house cracks, ground cracks and surface collapse pits in areas where ground collapse may exist is one of the most important means of determining whether ground collapse exists in the area. The regular appearance of cracks in houses over a large area, a phenomenon that usually occurs at the edge of a ground collapse area, is accompanied by the appearance of ground cracks on the nearby surface. The results of the survey are shown in Figures 2 through 6.

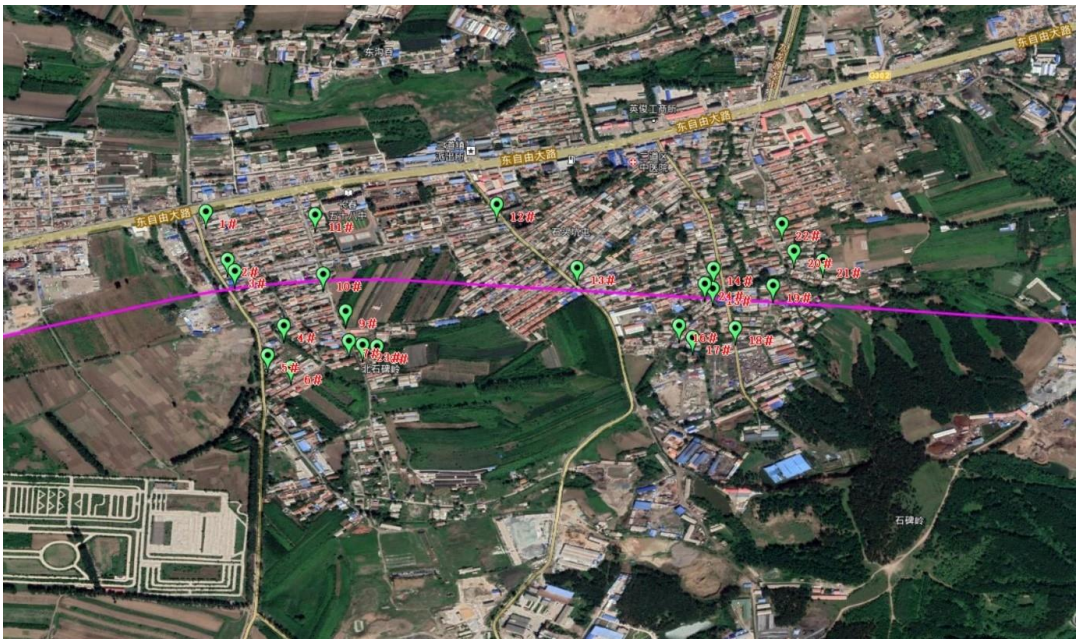

Figure 2. Distribution of Survey Points for Surface Deformation Traces

Figure 3. Cracks in the Exterior Wall of the House

Figure 4. Cracks in the Perimeter Wall

Figure 5. Interior Wall Cracks

Figure 6. Cracks at the Top of the Exterior Wall of the House

3. Design of Grouting Holes, Curtain Holes and Inspection Holes

3.1 Inclined Hole Design

According to the design and construction of the hollow area technical rules in the building construction area for the vertical hole layout design, calculate the vertical hole drilling point and grouting point coordinates, because the vertical hole drilling point in the residential building area, can not be constructed, so in the construction of the area can be selected to the appropriate slanting holes drilling point, through the calculation of the slanting holes to get the inclination of the hole, the length of the hole and other data, to slanting holes equivalent to the role of vertical holes, so as to achieve the purpose of the treatment. See Figure 7 for the design of equivalent slant hole.

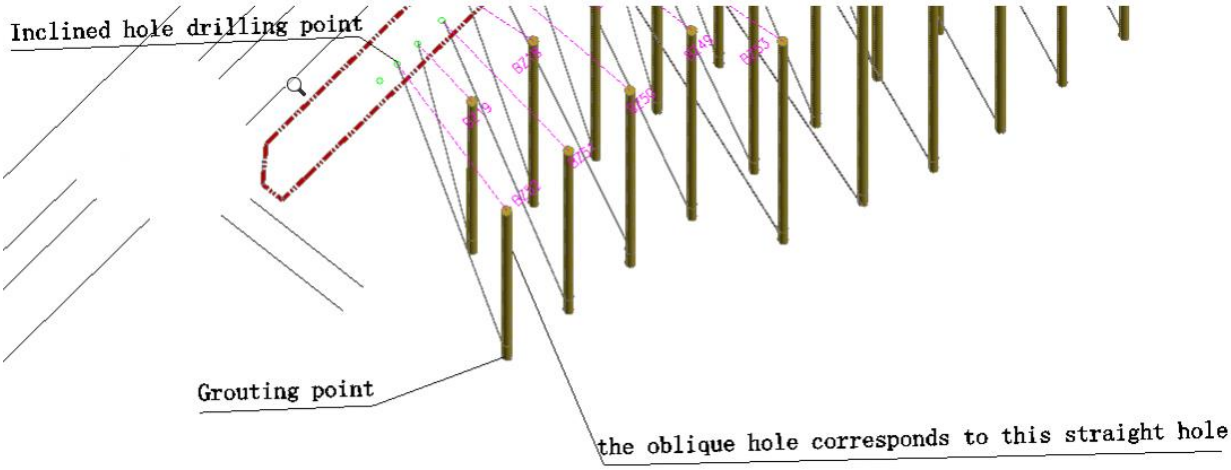

Figure 7. Schematic Diagram of Equivalent Slant Hole Design

3.2 Scope of Treatment

(1) Calculation parameters: according to the corresponding specifications and engineering geological conditions, the roadbed protection level is II, and the width of the enclosing belt is 10m; the movement angle of the loose layer is 45°, the movement angle of the bedrock is 70° in the direction of the direction of movement, and the movement angle of the bedrock is 70° in the direction of the direction of inclination.

(2) The width of the treatment of the mining airspace B: the width of the mining airspace overburden rock movement impact, for the mining airspace of the flat ore layer can be calculated according to the following formula:

$$B=D+2d+D` \quad (1)$$

$$D'=2(h\cot\varphi+H\cos\delta) \quad (2)$$

Where: D-roadbed or bridge and tunnel width (m), roadbed take the width of the top of the rift valley or the foot of the embankment; d-maintenance zone width (m), roadbed take 10m, bridge take 20m; D'-the width of the impact of the movement of the rock overlaying the hollow area (m); h-the surface thickness of the loose (m); H-the thickness of the rock overlaying the hollow area (m); φ-the angle of the movement of the loose layer (°) δ- angle of influence of movement of overlying rock layer in the direction of strike direction of the air-mining zone.

(3) The length of the treatment of the hollow area L: the length of the treatment of the hollow area of the highway (along the route in the direction of the center line) L should be the actual length of the road underneath the hollow area and overlying rock movement and influence range, can be calculated according to the following formula:

$$L=L_0+2h\cot\varphi+H_1\cot\beta+H_2\cot\gamma \quad (3)$$

Where: H1, H2-the thickness of the overlying rock layer on the upper and lower mountain boundaries of the air-mining zone (m); β-the angle of influence of the movement of the overlying rock layer in the direction of the lower mountain of the air-mining zone (°); γ-the angle of influence of the movement of

the overlying rock layer in the direction of the upper mountain of the air-mining zone (°); L_0-the length of the air-mining zone in the direction of the center line of the road (m).

(4) The depth of treatment of the hollow area h:when the treatment scope is located within the boundary of the hollow area, the depth of treatment shall be 1m below the ground to the bottom plate of the hollow area.

3.3 Grouting Hole and Curtain Hole Placement

Curtain holes in the treatment range of the goaf are restricted by the residential houses on both sides of the line, and are laid at the boundary of the roadbed land, with a hole spacing of 15m; grouting holes are laid in rows along the road axes with the centerline of the design as the center outward, with a row spacing of 15m and a hole spacing of 20m within the range of the roadbed, and with the outer side of the roadbed to the boundary of the treatment, based on the geology, mining and other engineering geological conditions, with a row spacing of 20m and a hole spacing of 25m, respectively.

Four inspection holes are set up in the treatment area, and the length of the inspection holes is from the original ground to 1m below the bottom plate of the hollow area. 48 curtain holes are laid, with an average depth of 206. 1m; 66 roadbed grouting holes, with an average depth of 221. 2m;107 general grouting holes, with an average depth of 233. 22m, and the general grouting holes contain 13 straight holes and 94 inclined holes. The arrangement of holes is shown in Figure 8 nd Figure 9.

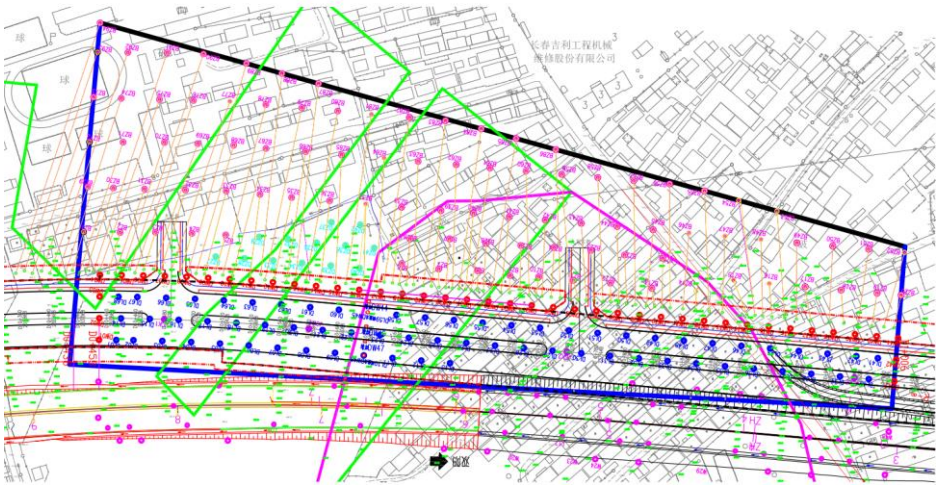

Figure 8. Planar Hole Layout

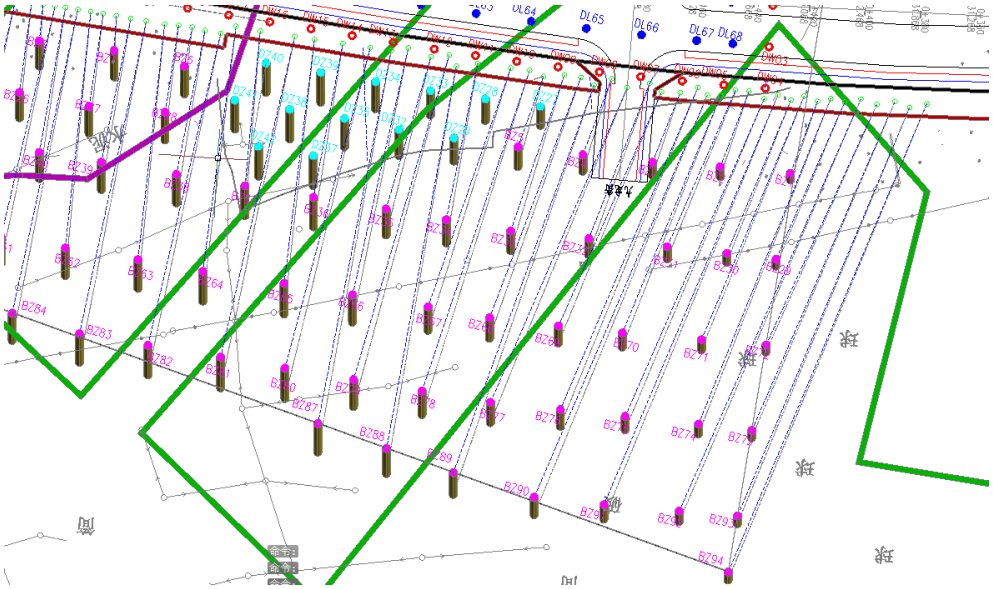

Figure 9. Artially Drilled Three-dimensional Layout of Holes

4. Grouting Construction Process

4.1 Slurry Material Proportioning Test

4.1.1 Slurry Material

Slurry material mainly consists of water, cement, fly ash, water glass, etc.

Water: local water, in line with national standards for drinking water can be used directly as grouting water, the quality of other water sources should be in line with the "Highway Bridge and Culvert Concrete Construction Specification" (JTTTF50-2011) 6. 5 provisions, before use, take water samples, in accordance with the "Highway Engineering Water Quality Analysis Practice" (JTJ056-84) requirements for the test.

Cement: use P. 042. 5R compound silicate cement or ordinary silicate cement, the quality of which should be in line with the national GB175-92 standard, and the cement should be re-sampled and inspected when it is damp or stored for more than 3 months.

Fly ash: It conforms to Class II standard of Fly Ash Used in Cement and Concrete (GB1596-2005).

Quick-setting agent (water glass): additives selected modulus of 2. 4 ~ 3. 4 water glass solution, the concentration is greater than 50 °, to meet the national standard GB/T4209-2008 liquid-2 indicator requirements.

Grouting slurry needs to meet a variety of performance requirements such as fluidity, stability, stone compressive strength, setting time and so on. Therefore, after the completion of the slurry need to carry out a variety of tests to determine its performance indicators to ensure the quality of the project. Slurry performance index test methods are as follows:

(1) Mobility

Under undisturbed conditions, the maximum diffusion diameter of the free flow of grouting material and its diameter in the direction of perpendicularity were determined by using a truncated cone prototype, and its average value was calculated.

(2) Stone rate

The newly configured slurry was filled into a measuring cylinder and left to stand. The volume of water precipitated from the 2h slurry was recorded. The percentage of the slurry stone volume to the total volume of the slurry is the stone rate.

(3) Specific gravity

The ratio of the mass of a slurry to its volume. The density of the slurry was determined using a slurry hydrometer.

(4) Stone compressive strength

The compressive strength of the stones at the age of 28d was determined by using 70. 7mm×70. 7mm×70. 7mm molding test specimens, curing in water at 20°C±5°C or standard curing, and the average value was measured by taking 3 pieces from each group.

Figure 10. Stone Compressive Strength Test

Figure 11. Stone Compressive Strength Test

The test results of the mix ratio are shown in Table 2.

Table 2. Slurry Material Mix Ratio Test Results

serial number	Cement varieties	Cement 28d measured strength kg/m3	water consumption kg/m3	Amount of cement used kg/m3	Fly ash dosage	specifications	fruiting rate	mobility mm	Standardized 7d compressive strength Mpa	Standardized 28d compressive strength Mpa
1	P· O 42. 5	51. 5	714	107	607	1:1. 0	87%	280	0. 8	1. 2
2	P· O 42. 5	51. 5	693	114	648	1:1. 1	88%	280	0. 8	1. 2
3	P· O 42. 5	51. 5	674	121	687	1:1. 2	88%	270	0. 8	1. 3
4	P· O 42. 5	51. 5	656	128	725	1:1. 3	88%	270	0. 9	1. 3
5	P· O 42. 5	51. 5	632	133	752	1. 4	90%	260	0. 9	1. 4

4.2 Slant Hole Grouting Construction Process

(1) Determine the inclination angle and fix the drilling rod: use measuring instruments to accurately sample the drilling hole position, after the completion of leveling the drilling site, use cast-in-place concrete to fix the base of the drilling rig, align the holes, fix the drilling rig, debug the drilling rig rotator, and set and debug the angle and azimuth according to the calculated data, and then fix the equipment and prepare for drilling after the on-site geologic and surveying technician confirms that it meets the requirements.

(2) Forming holes and casting orifice pipe: based on the characteristics of the hollow area, the grouting process of the treatment project adopts one-time gyratory hole formation, drilling holes to form orifices, casting orifice pipe, then lowering Φ76 grouting pipe (wall thickness of 4. 5mm) to about 5m below the fissure zone, and grouting to the part from bottom up, and the grouting pipe will not be reused again. After the grouting in this section, unscrew the grouting pipe in the hole and the site grouting pipe at the hole mouth, and connect the site grouting pipe with the orifice pipe with a reducer screw, and carry out the second grouting from the hole mouth until the end.

Adopt high-precision angle measuring instrument and measure the angle once every 50. 0-100. 0m during drilling. According to the tilt measurement data, do a good job of analyzing and predicting, and adjust

the drilling parameters in time. Equip 2 sets of instruments on site to compare and review the test data and prevent measurement errors and drilling inclination.

(3) Preparation of slurry:curtain grouting holes grouting:water:solid (cement:fly ash) ratio of 1:1. 2; roadbed grouting holes grouting:water:solid (cement:fly ash) ratio of 1:1. 3; general grouting holes grouting:water:solid (cement:fly ash) ratio of 1:1. 2. Cement:fly ash ratio:15:85 for curtain holes, 15:85 for general grouting holes. quicklime:the weight of the cement is added 2% of the weight of the curtain holes quicklime. 2% of quick-setting agent. Grouting holes when the grouting volume is large, in the slurry mixed with cement weight 2%.

Slurry mixing time control to disperse, mix the grouting material, to obtain the mobility and stability of qualified stable slurry as a principle. According to the grouting test, when the rotational speed of 60 ~ 80 rpm, the mixing time is not less than 6 min. the time from the beginning of the preparation of the slurry to the end of the slurry should be less than 4 h. And the slurry storage tank slurry should be used for the second time before grouting.

(4) Grouting system and configuration requirements:material yard, primary mixing tank (machine), secondary mixing tank (machine), water supply system, grouting pump, grouting pipe, orifice pipe, orifice device, hole sealing device and other components.

The mixer and mixing pool should have a mixing volume of more than 2. 0m³ at one time; the rated discharge of the grouting pump is not less than 250L/min, and the pressure of the grouting pump should be more than 1. 5 times of the maximum design pressure of the grouting and not less than 3MPa; the maximum index of the pressure gauge used for the grouting should be less than 10MPa;

Table 3. Table of Machinery and Equipment

serial number	name (of a thing)	model number	unit (of measure)	quantities
1	core drilling machine	XY-44A	classifier for heavy objects, such as machines, TVs, computers; theater performances	1
2	core drilling machine	XY-4	classifier for heavy objects, such as machines,	1

			TVs, computers; theater performances	
3	water well drilling rig	GJ279-125	classifier for heavy objects, such as machines, TVs, computers; theater performances	1
4	water well drilling rig	HL600	classifier for heavy objects, such as machines, TVs, computers; theater performances	1
5	food mixer	CH-8600	classifier for heavy objects, such as machines, TVs, computers; theater performances	1
6	grouting pump	YZB-100G	classifier for heavy objects, such as machines, TVs, computers; theater performances	4

7	High Precision Angle Measuring Instrument	WD	classifier for heavy objects, such as machines, TVs, computers; theater performances	1

5. Conclusion

In this paper, through CAD three-dimensional modeling, slant holes instead of grouting straight holes are grouted to treat the undermined hollow area of the main road in the city, which solves the unfavorable influence of ground building obstacles on grouting treatment; corresponding research and exploration of slurry ratio and slant holes grouting construction process solves the construction problems of this project. The feasibility of the program is verified by engineering examples, which provides reference for similar projects and researches.

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