Monitoring and Prevention of Harmful Gases in Kunming Metro Station No.5 Line Dianchi Weicheng Station~Jinhai New District

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Abstract

In view of the fact that the release of harmful gases such as shallow underground biogas may have a great impact on the stability of the proposed project site, the construction process of the subway and the safety of the later operation, effective treatment of harmful gases is necessary for Kunming subway construction management. It is an important problem to be solved at present. This paper uses the static penetration method to investigate the biogas layer existing in the Dianchi Weicheng Station~Jinhai New Section of Kunming Metro Line 5, and analyze the stability of the construction site of harmful gas to the proposed project. Gas release evaluates the safety impact during construction and operation, and combines the experience of similar engineering harmful gas prevention and control, and proposes measures for safe gas emission measures.

Keywords

Harmful gases, static penetration, shield, foundation stability.

1. Introduction

During the project investigation, Kunming Rail Transit discovered toxic gases such as shallow biogas in the underground. The release of these toxic gases may cause huge economic losses to the safe construction of the project and surrounding buildings, and when the concentration of these toxic gases reaches a certain safety limit, the fire is encountered. An explosion will occur, which is a great hidden danger to the safety of construction workers and citizens. For example, in the exploration and construction process of the underground tunnel of Wuhan Metro Line 2-8, there are many toxic gases such as gas and gas, and the concentration value is high. In the early stage of construction of Hangzhou Bay Bridge [1], the survey personnel appeared in the survey process because of shallow The phenomenon of casualty caused by the burning of laminar gas caused huge economic losses; the toxic gas leakage occurred during the excavation of a foundation pit in Shanghai, causing the construction base to collapse and causing certain human and financial losses. These toxic gases appearing during the accident have seriously affected the safety of subway construction and operation. Therefore, in the early stage of construction of the Kunming subway station project, it is very important to investigate and deal with the occurrence of underground toxic gases.

2. Harmful gas regional environment

The main city of Kunming, from the west to the east, spans the central part of the Kunming Basin. The Kunming Basin is located in the watershed of the Jinsha River, Nanpanjiang River and Honghe River Basin. It is a Cenozoic basin formed after the fault zone along the Pudu River fault zone after the formation of the quasi-planetary in Yunnan at the end of the Miocene. It is a north-south narrow long waist shape. It is more than 70 kilometers long from north to south, 15 to 25 kilometers wide from east to west, and covers an area of about 1500 km^2. The southwestern part also holds about 340 km^2 of Dianchi water surface at an altitude of 1886 m. The basin is surrounded by mountains and the peaks are 2500-2800m above sea level. From the interior of the basin to the surrounding mountainous areas, there are many layers of flat landforms.

The project site is located in the Kunming Basin and is a Grade II terrace of Dianchi Lake. It belongs to the river delta and Huxiang sediments. The terrain is relatively flat and has little ups and downs. It is generally higher in the northwest and southeast, and lower in the northeast, central basin and southwest. The ground elevation is 1886.94~1890.28m, and the relative height difference is 3.34m. Now it is mainly for urban roads and buildings with convenient transportation.

2.1 Causes and formation conditions of harmful gases

For the shallow underground layer, the organic matter in the sediment can form methane-rich gas through the action of microorganisms, and can be aggregated on a large scale to form a biogas reservoir. This is the general principle of biogas production. In the strata exposed in the Kunming Basin, Quaternary sediments were deposited in this area. The organic matter in these loose sediments decomposed in biochemical action, forming gaseous products, which are stored in the surrounding soil layer or in their own pores. Set, form a shallow gas reservoir (the following formula)

$$\text{Organic matter + anaerobic bacteria} \xrightarrow{\text{Certain temperature and pressure}} CH_4+CO_2+CO+H_2S+H_2O$$

According to previous research results, the formation of shallow harmful gases requires at least three conditions: (1) rich organic matter (2) relatively closed geological environment (3) the formation has a certain storage space[2]. These shallow harmful gases are mainly methane type, with a high content of methane and a small amount of other components such as nitrogen, carbon monoxide, hydrogen sulfide, and carbon dioxide. In general, the thicker the peat-like angry layer, the thicker the dense clay cover of the roof, the more the gas volume, the greater the air pressure. The representative gas-bearing strata in the region include the sedimentary soil layers of the Jianghan Plain, the alluvial soil layers in the lower reaches of the Yangtze River, and the lacustrine sedimentary layers in the Yunguichuan area.

2.2 Harmful gas characteristics and hazards

Shallow harmful gases are also called shallow biogas, the main component is methane, containing hydrogen sulfide, carbon monoxide and other components (Table 1 is the main harmful gas physicochemical properties), its main characteristics and hazards are as follows:

Table 1 Physical and chemical properties of major harmful gases

project	CH_4	CO_3	CO	H_2S	C_2H_6	C_3H_8
Molecular weight	16.042	44.01	28.01	34.08	30.07	44.09
density (kg/m^3)	0.7168	1.98	1.25	1.54	1.36	2
Density of air	0.5545	1.53	0.97	1.17	1.05	1.55
Boiling point(K) (101.3kPa)	111.3	194.5	83	211.2	184.7	230.8
Lower explosion limit (%)(293K,101.3kPa)	5		12.5	4.3	3	2.1
Upper explosion limit (%)(293K,101.3kPa)	15		74.2	45.5	12.5	9.35
Calorific value(MJ/m3,288K)	37.11		11.86	23.5	64.53	98.61
	33.38		11.86	21.63	58.93	88.96

2.2.1 Characteristics and hazards of methane

Methane is ubiquitous in organic soil layers or sand layers. It has strong permeability and is lighter than air. It is a colorless, odorless gas. When the reservoir sealing pressure is reduced, it will emerge from the soil layer. Point hazard:

1. When the methane concentration in the air of the underground project is high, the oxygen content in the air will be relatively reduced, causing people to suffocate and die.

2. When the methane concentration reaches a certain value, it will explode in case of fire, it will heat the surrounding air, and may cause the gas pressure to increase. The harmful gas such as carbon monoxide generated by methane explosion will cause poisoning and death.

3. When the concentration and pressure of methane in the rock layer is large, it may be released (outburst) in a sudden and violent form due to the influence of engineering activities, and at the same time bring out a large amount of sediment, which directly causes tunnel collapse and casualties. , destruction of equipment and facilities.

4. The large amount of gas released in a short time will greatly reduce the strength of the gas-bearing formation, causing significant changes in the physical and mechanical properties of the gas-bearing layer distribution area and the adjacent area, resulting in uneven settlement on the ground or underground engineering damage.

2.2.2 Characteristics and hazards of carbon monoxide

Carbon monoxide is a colorless, odorless, odorless, highly toxic inorganic compound gas that is slightly lighter than air, has a very low solubility in water, and is easily soluble in ammonia. Carbon monoxide is sucked into the lungs and combined with hemoglobin in the blood to form a stable carboxyhemoglobin, which competes with oxygen for hemoglobin, which causes blood oxygenation function to be impeded, causing acute hypoxia, mainly manifested by fatigue, headache and dizziness. Nausea and vomiting, blurred vision, collapse[3] and even convulsions and coma, severe poisoning if not treated in time may be life-threatening.

2.2.3 Characteristics and hazards of hydrogen sulfide

Hydrogen sulfide is a colorless gas with a special odor (smelly egg smell), soluble in water, and its specific gravity is larger than air; hydrogen sulfide is a kind of nerve poison, a certain concentration of gas, people can smell its odor, inhaling The higher the gas concentration of the human body, the greater the damage to the human body. The concentration of gas to be inhaled to the human body reaches a certain period of time, and the limit value is generally 1000 mg/m^3, which may cause death of human electric shock.

2.3 Hazardous gas occurrence status

The generation of harmful gases in the shallow underground layer is generally present in the groundwater of the sand layer or in the voids of the soil particles. When the local downforce is lowered or the temperature is raised, the solubility saturation of the gas will decrease, and a free gas will be formed. For example, methane is generally present in the cohesive soil with poor permeability and permeability above the sand layer, and most methane is compressed in the free portion[4] in the concave portion of the soil layer to form a balloon.

In recent years, through relevant researches, it has been found that shallow harmful gases are generally present in layers of shallow layer gas, agglomerate (cystic) shallow gas, high pressure gas mass (capsule), and gas diapir. From the microscopic point of view, the state of gas phase in the soil is based on the positional relationship between the gas phase and the liquid phase in the soil void, the connectivity and the direct differential pressure relationship between the two phases and the saturation of the harmful gas in the shallow layer. The direct difference is that the gas phase morphology can be divided into four states: fully connected, partially connected, partially connected and completely closed. In general, the state of the gas phase in the soil can be determined according to the composition of the ejected material, for example, when the ejected material generates dry gas during the eruption process, a mixture of water, mud, sand, etc. occurs, and the gas phase of the process is in the soil. The state in the body is a dynamic process from complete closure to partial communication to complete communication

3. Survey construction layout

This harmful gas survey uses the “Drilling-Monitoring-Static Probe Vehicle Pressure Monitoring Special Pipe-Continuous Monitoring” method to conduct harmful gas concentration test, harmful gas top, bottom plate depth measurement, pressure and flow rate measurement. The LYLC large crawler static penetration test equipment[5] completes the gas survey work, the maximum pressure can reach 28MPa, the maximum detection depth can reach 150m, and the inner diameter of the probe tube is 26mm. Accurate determination of harmful gas components and content in the room. Figure 1 shows the LYLC large crawler static probe vehicle.

Figure 1 LYLC large crawler static test vehicle

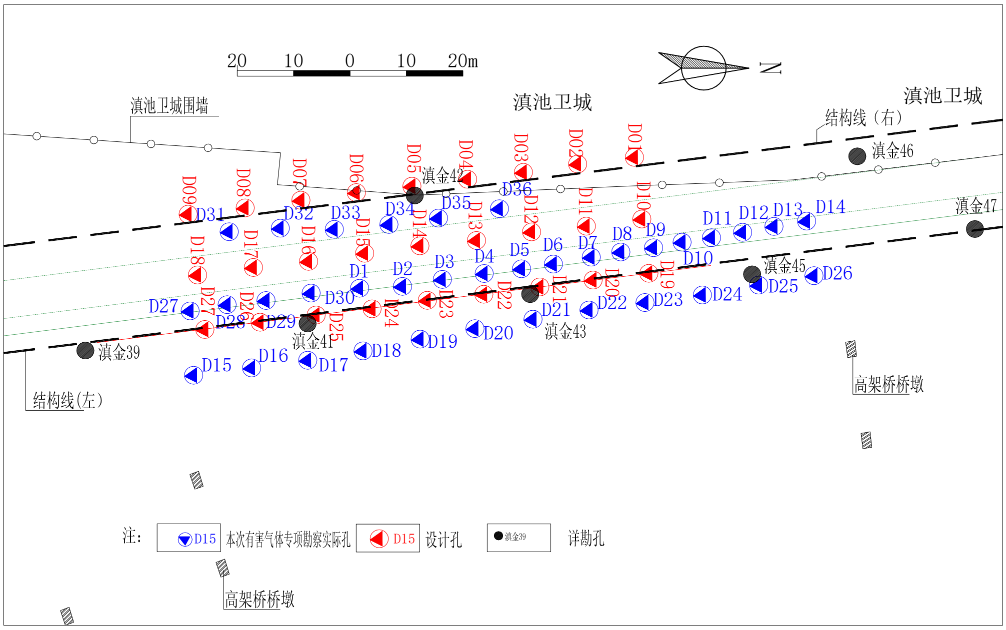

Fig. 2 Schematic diagram of the actual position of the survey hole in the dian-jin prospecting area

3.1 Exploration point layout and determination of hole depth

During the exploration of the tunnel section of the dian-Jin station, harmful gases were found in Jz-III16-dianjin-42 (mile DK20+426.47 right 5.63m). Because the interval between exploration points in this section is 20m~40m, this special survey is The Jz-III16-Jinjin 42 hole is the center, extending 40m to the large mileage and small mileage respectively. The hole pressure static contact hole is arranged in the middle of the left line, the right line and the left and right lines, and the parallel line position is according to the spacing of 10m. Arrangement.

Actual construction: Because the right line is inside the wall of Dianchi Weicheng Community, some of the right and middle holes are in the drainage ditch, and coordination cannot be carried out. Therefore, it is moved to the middle of the left and right lines and the east side of the left line. A total of 36 holes are arranged. The specific position is shown in Figure 2 below.

The construction time is from May 27th to June 11th, and from November 13th to 15th, 2017. A total of 36 holes are calculated for 1462.1m, and the hole depth is between 38.9~42.1m.

Table 2 List of drilling data in the dian-jin prospecting area

Number	depth（m）	time	Number	depth（m）	time	Number	depth（m）	time
D1	41.3	2017/11/6	D13	41.0	2017/4/6	D25	40.2	2017/28/5
D2	40.9	2017/10/6	D14	41.5	2017/5/6	D26	40.2	2017/28/5
D3	40.8	2017/10/6	D15	40.2	2017/4/6	D27	40.5	2017/26/5
D4	41.0	2017/9/6	D16	39.9	2017/3/6	D28	40.1	2017/11/6
D5	40.5	2017/8/6	D17	39.8	2017/3/6	D29	40.3	2017/11/6
D6	41.1	2017/8/6	D18	40.5	2017/1/6	D30	41.2	2017/11/6
D7	41.1	2017/6/6	D19	41.2	2017/8/6	D31	41.2	2017/13/11
D8	40.2	2017/5/6	D20	42.0	2017/8/6	D32	41.2	2017/14/11
D9	40.1	2017/8/6	D21	39.9	2017/31/5	D33	41.5	2017/14/11
D10	40.8	2017/7/6	D22	39.8	2017/30/5	D34	41.2	2017/15/11
D11	40.3	2017/7/6	D23	38.9	2017/30/5	D35	42.1	2017/15/11
D12	38.9	2017/7/6	D24	39.9	2017/29/5	D36	40.80	2017/15/11
36 hole/1462.1 m、average40.61m								

3.2 Survey hole construction and monitoring

At present, for the treatment of harmful gases in tunnels, the KDL-3 explosion-proof geological radar is used for advanced detection of the excavation surface, and the detected gas-bearing layer is drilled ahead with the ZY-150 drilling rig[6]. The holes emit harmful gases. For mountain road tunnels, drilling and blasting methods are often used[7]. However, most construction machines fail to meet the requirements of fire and explosion protection. The timely treatment of harmful gases is the most advantageous method to reduce construction risks.

Kunming Metro surveyors use the energy-sensing equipment to make use of its small disturbance to the formation, which can accurately obtain gas pressure, concentration and other parameters. The static penetration hole diameter is 32mm, the central hollow ventilation, the lower part is the flower tube, and the outer stainless steel wire filter network. The static probe probe is pressed in the pre-set hole position, and the parameters such as methane, carbon monoxide and hydrogen sulfide pressure are comprehensively detected every 2m, until the pressure is 40m. When extracting the drill pipe, various harmful gas concentration data and pressure data are detected every 2 m. At this time, the whole hole is pressed into the 32mm galvanized tube for monitoring, and the 32mm tube is assembled with a valve and a pressure gauge to form a monitoring system for monitoring 24 hours a day.

4. Exploration results and analysis

4.1 Project Overview

Dianchi Weicheng Station~Jinhai New District Station Section (referred to as dian-jin Area) starting point is DK20+019.362, the ending distance is DK21+070.565, and the line length is 1051.203m. The line is uphill on the slope of 2.0‰, and then descends 200m from the slope of 20.000‰, then downhill by 300m with a slope of 6.000‰, and then uphill by 590m with a slope of 15.102‰, followed by a slope of 20.000‰. Uphill 200m, and finally entered the Jinhai New District Station with a slope of 2.0‰. The left line line goes up the Weicheng Aicheng station with a slope of 2.0‰, and then descends 200m with a slope of 20.000‰, and then slopes down to 160m with a slope of 4.310‰, and then uphill for 350m with a slope of 7.997‰, followed by 9.000‰. The slope is 580m uphill, and then uphill by 200m with a slope of 20.001‰, and finally enters the Jinhai New District Station with a slope of 2.0‰. The right side of the survey area in this section is the residential area, the frame structure, the depth of the foundation is unknown, and the distance line is 8~15m. Figure 3 shows the location of the dian-jin prospecting area.

Figure 3 Schematic diagram of the location of the dian-jin prospecting area

The harmful gases present in the surrounding rock are generally excavated by the full-section method and the step method. The TSP technology is used to advance the lead detection, and the concentration of harmful gases is monitored by the grouting process[8]. The construction method of this section is shield method, shield The diameter of the structure is 6.20m. The geographical location is shown in Figure 3. The underground construction depth is shown in the table below.

Table 3 List of buried depths of underground works in the dian-jin prospecting area

Underground engineering category		station	Interval
Buried depth（m）	maximum	26.1	31.1
	Minimum	4.5	8.6

4.2 Engineering Geology Profile

According to the detailed exploration and drilling, the depth of the survey can be divided into the Quaternary fill (Q_4^{ml}) and the Quaternary Holocene Lake (Q_4^{al+l}) two stratum units from top to bottom. The lithology and other characteristics are shown in Figure 4. The formation of the section shield and station construction is (2) 2-2, (3) 2-3, (3) 1-2, (3) 1-3, (3) 3-3, (4) 2- 3. (4) 3-3. The ejection hole of the dian-jin hole No.42 hole is 22.7～27.2m peat soil layer (3)1-3, lasting for 5 hours, the discharge height is about 1m, and the ejection position is 0.8m below the outer structure line, the sheet metal In the No.42 hole (3) 1-3, a 0.3m thick silty clay layer is sandwiched and this interlayer is also present in the adjacent borehole.

4.3 Monitoring situation

The long-term monitoring peak data of each survey hole in the dian-jin section is as follows:

Table 4 Summary of peak data of hazardous gas field test in the dian-jin interval

Exploration hole number	CH_4 concentration(%)	CO (ppm)	H_2S (ppm)	Flow (m3)	Gas pressure(MP_a)
D1	5	12	0	/	/
D2	44	278	7.5	/	/
D3	6	35	0	/	/
D4	26	127	3.5	/	/
D5	8	152	3.7	/	/
D6	90	37	0	/	/
D7	62	0.7	0	/	/
D8	91	1.3	0	/	/
D9	25	269	6.2	/	/
D10	55	499	6.8	/	/
D11	4	86	0		/
D12	34	0	0	/	/
D13	5	142	2.7	/	/
D14	12	286	1.6	/	/
D15	4	0	0	/	/
D16	50	219	3.3	/	/
D17	54	199	4.4	/	/
D18	32	128	1.5	/	/
D19	14	102	3	/	/
D20	9	85	0	/	/
D21	5	95	0	/	/
D22	14	105	1.9	/	/
D23	7	185	0	/	/
D24	26	115	2.9	/	/
D25	38	128	0.9	/	/
D26	25	112	4.8	/	/
D27	44	499	0	/	/
D28	10	77	1.2	/	/
D29	12	2	0	/	/
D30	2.6	16	0	/	/
D31	26	232	0	/	/
D32	31	402	0	/	/
D33	44	499	0	/	/
D34	41	499	0	/	/
D35	34	312	0	/	/
D36	39	347	0	/	/

As can be seen from the above table data, the content of hydrogen sulfide is small, and harmful gases are widely distributed in the soil layer. The concentration varies depending on the permeability of the soil layer and the amount of harmful gases in the formation itself.

Typical on-site monitoring data is analyzed as follows:

In the long-term (15 days) monitoring data, the methane concentration value is more stable at around 10%, and does not tend to zero, indicating that the soil layer in this area is a free hazardous gas migration layer, and there is continuous monitoring of harmful gas migration and penetration. In the tube. Under certain conditions, the migration is temporarily stopped, and then there is a phenomenon of migration again, as shown in Figures4, 5, and 6.

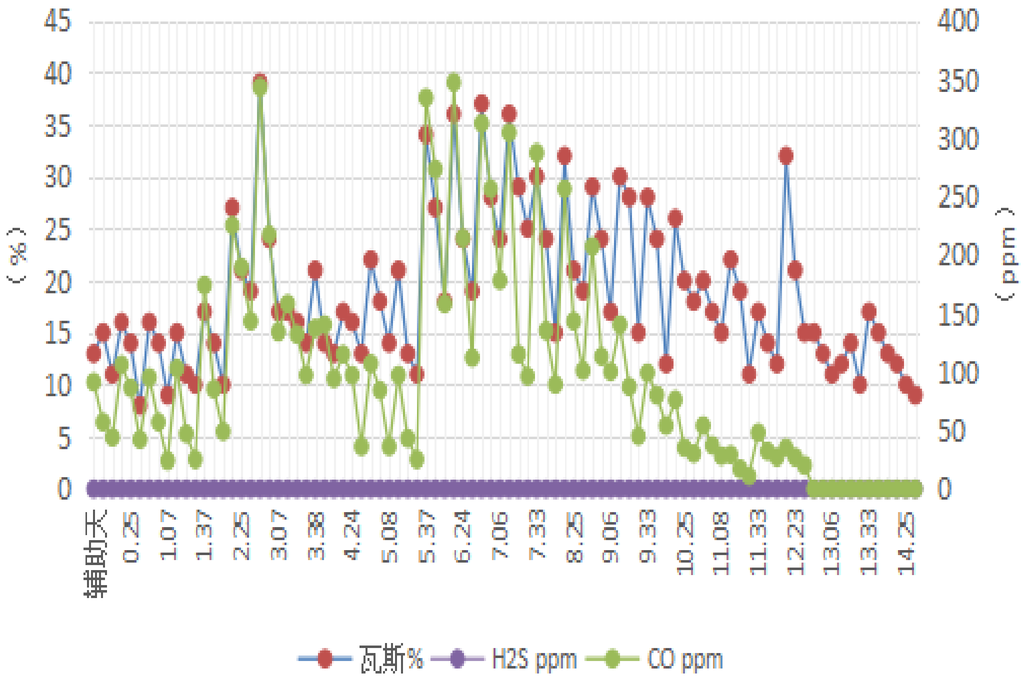

Figure 4 D36 hole harmful gas on-site monitoring concentration change with time

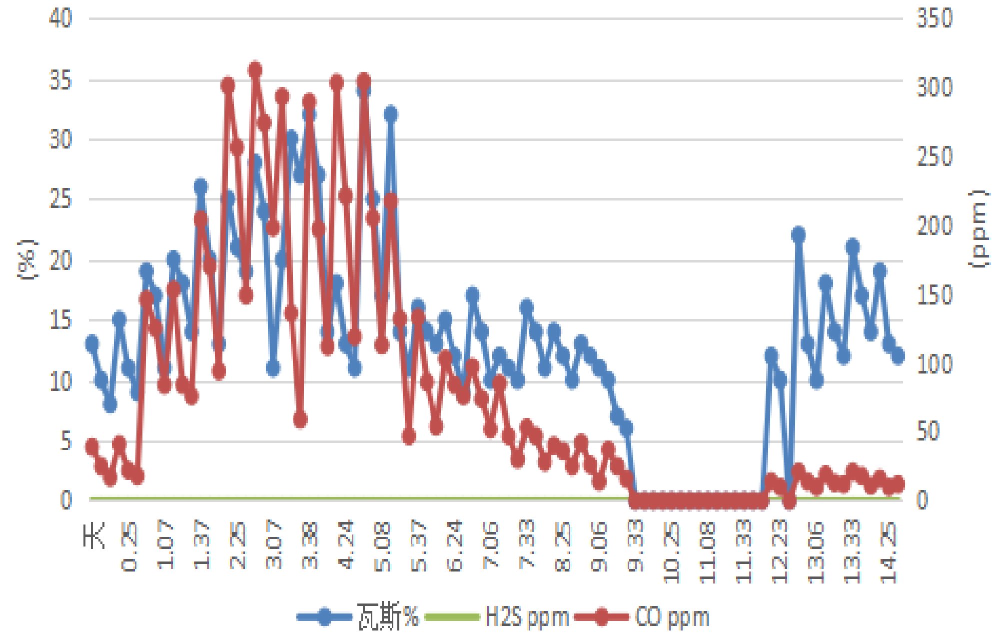

Figure 5 D35 hole harmful gas on-site monitoring concentration change with time

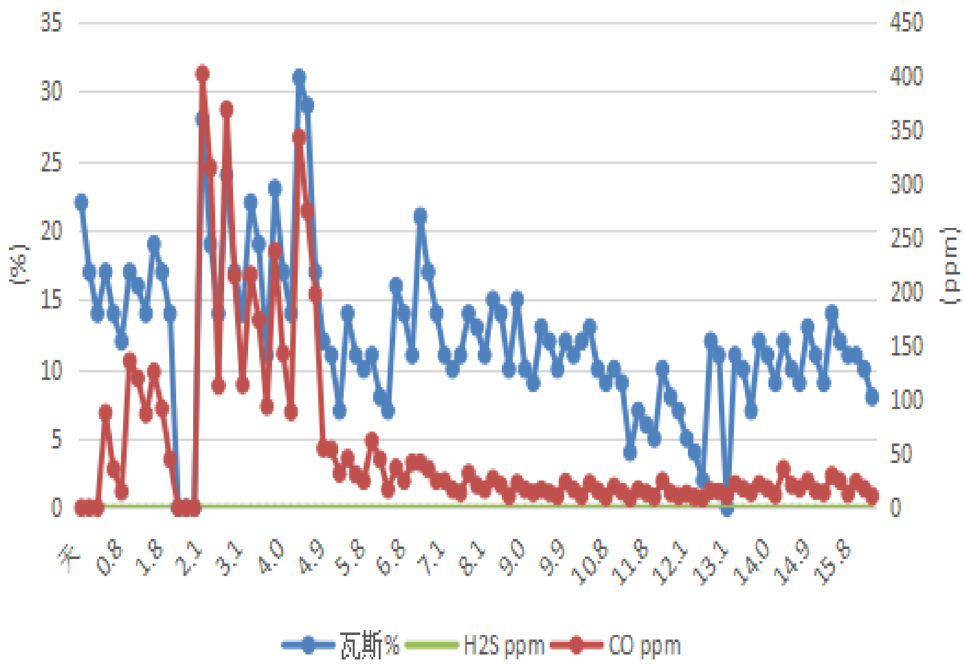

Figure 6 D32 hole harmful gas on-site monitoring concentration change with time

4.4 Harmful gas occurrence characteristics

The survey area originally contained a layer of pressure gas layer, and the rest existed in the pores of the soil layer in a dispersed free state. It was formed from shallow peat soil and stored in lenticular sticky silt and peat soil interlayer. Here, a small trap is formed. After the layer is covered by the sheet metal 42 hole (detailed hole), the release of harmful gases is completed. In the subsequent special investigation of harmful gases, no harmful gas is collected and replenished. .

Table 5 Characteristics of harmful gases in the dian-jin interval

category	Storage medium	Cover	Source type	Macroscopic features
Small medium pressure airbag	Peat soil, silty clay interlayer	Self-enclosed	Self-storing	Large gas volume, poor permeability of the reservoir, long discharge time, no remelting and replenishment, uneven distribution
Dispersed free state	Soil pores	/	Off-site migration, Self-storing	No pressure, no flow, diffuse infiltration

5. Harmful gases harmful to underground engineering structures

Soil layers containing harmful gases often have serious impacts on the construction of foundation works, which may lead to major and particularly serious safety incidents, and may even affect the safety of the engineering structure. Therefore, the impact and harmfulness of underground harmful gases on underground construction should be given sufficient attention. As the project belongs to the shield section of the subway project, it is found through investigation that the harmful gas accumulation area in the special survey section belongs to small low- and medium-pressure airbags, and the release of harmful gases to the later construction of the construction project and the existing buildings (structures) The impact is less likely to have a significant impact.

5.1 Influence of harmful gas release on shield structure

The harmful gas in the shallow underground layer forms a gas flow due to the sudden drop of pressure in the gas-bearing layer. The airflow sweeps the soil layer extensively, causing severe disturbance to the overlying or underburden. The longer the time, the soil layer will occur. Settling will result in uneven air pressure. Therefore, uneven deposition is often caused during the gas release process, which in turn causes severe deformation of the segment structure and even fracture damage. When the emission of harmful gases reaches a certain level, an explosion will occur in the event of an open fire, which will cause tunnel collapse and serious injury to construction workers.

5.2 Influence of harmful gas release on foundation stability

Evaluation of the impact of harmful gas release on the stability of the foundation There are currently no authoritative norms and standards in China. According to the successful experience of harmful gas exploration and prevention at home and abroad, the effects of underground harmful gas release on the stability of the foundation are mainly in the following forms:

1. A large amount of high-pressure gas is suddenly released, taking away the sediment particles in the gas-bearing formation, resulting in a significant decrease in the strength of the gas-bearing formation, causing collapse of the side wall of the foundation pit or the top and side walls of the tunnel;
2. When the gas layer of the harmful gas is distributed below the proposed structure (structure), the gas release will increase the porosity of the gas-bearing formation, decrease the bearing capacity of the formation, and increase the settlement under a certain load. It causes uneven settlement of the foundation of the building and seriously threatens the safety of the building. According to the special survey, it is found that the presence of harmful gases in the survey area are high pressure and small gas accumulation areas. Measures should be taken to eliminate the impact.

5.3 Influence of harmful gas release on surrounding buildings (structures)

According to the research results of related harmful gases at home and abroad, in areas where ground buildings (structures) are relatively concentrated, the release of harmful gases in large quantities may cause damage to surrounding buildings (structures). The influence mechanism and the long-term large-scale drainage of groundwater have basically the same influence on the ground building (structure). The release of a large amount of high-pressure gas destroys the gas-bearing stratum structure, the bearing capacity is obviously reduced, the compressibility is increased, and the overlying strata or construction is Settlement occurs under the load of the structure. Due to the uneven thickness and extent of the gas-bearing layer, uneven ground subsidence leads to cracking and deformation of the building (structure). In the construction process of Wuhan Metro Line 2 Fanhu-Hankou Railway Station, harmful gases were exposed. The high-pressure gas eruption height reached more than 10 m, lasting for several days, causing collapse of many places in the nearby ground and damage to the house.

The influence of harmful gas release on ground buildings is positively related to gas storage and pressure, that is, the greater the gas pressure and reserves, the greater the possibility of damage to the ground building (structure) during release, and the more damage severe.

6. Treatment measures for harmful gases

During the construction process, the construction work surface is unstable due to the presence of shallow underground harmful gas, and the disturbance of the surrounding soil layer is quickly triggered. The large amount of mud, water and gas swells out, making normal construction impossible, causing large deformation to produce open cut The destruction of the body itself and surrounding structures may cause damage to construction machinery and casualties. Therefore, in the open excavation construction process, it is first necessary to further and accurately identify the buried depth and pressure of the harmful gas within the scope of the project. Based on the mechanical parameters of the geotechnical layer, the preliminary judgment is made through analysis and calculation. The blowout and the possibility of disturbance to the soil, the key parts and duration of gas escape. Here are some suggestions:

(1) Deflating and decompression drilling. Before the shield is pushed forward, the drill holes are arranged in the harmful gas range for advanced controllable pre-deflation. From the perspective of connectivity, the left line should be arranged at a distance of 10m in the middle of the original special survey, and the right line should be used at a distance of 5m.

(2) Strengthen monitoring and improve ventilation conditions. Design and install a special real-time monitoring and alarm system for harmful gases, carry out safety monitoring on the whole process of subway tunnel construction, and immediately start the emergency ventilation system when the concentration of harmful gases exceeds the standard, evacuate personnel, and strengthen ventilation to ensure construction safety.

(3) Shield equipment. The gas alarm power-off device must be installed on the shield machine. When the gas concentration reaches 0.5%, it must be automatically alarmed, and the power supply is cut off, and the work is stopped and processed.

(4) In response to the gas emission from the construction period, measures are taken to reduce the operating stray current value and strengthen the stray current detection in operation.

(5) During the operation, measures should be taken to prevent static hazards. Workers are prohibited from wearing clothing that is easy to generate static electricity, and all personnel entering the tunnel must carry out safety education such as prevention of harmful gases and firefighting.

(6) For a communication channel in a region with high pressure harmful gas, it is generally necessary to adjust the original pure freezing passage construction scheme, and use the rotary jet reinforcement to strengthen and passively deflate before the shield is propelled. At the same time, it is required that the soil is uniform and has no hard core after reinforcement, and does not affect the construction of the freezing method. After the soil is strengthened, the gas layer is destroyed, which can reduce the generation and accumulation of harmful gases in the future.

7. Conclusion

Through this special investigation of harmful gases, the following conclusions can be drawn:

1. The special exploration section is a small low- and medium-pressure shallow biogas with gas (methane) as the main component, accompanied by toxic gases such as CO, H2S and CO2.

2. The harmful gases are widely distributed in the pores of the soil layer and exist in the free state and the adsorbed state. The tunnel construction of the proposed tunnel section will be carried out in the soil containing harmful gas, and the future tunnel project shall be managed according to the gas tunnel.

3. The accumulation of harmful gases is a lithologic trap.

4. The source of harmful gases includes the formation of organic soil layers in the shallow part, and the deep dissipative movement to the shallow part.

5. The release of harmful gases has little possibility and significant influence on the construction of shields, surrounding buildings (structures) and the later operation of the project. The release of gas will affect the strength of the gas-bearing layer and reduce its bearing capacity. When the layer is within the influence range of the foundation foundation stress deformation, it will have an impact on the foundation settlement.

6. Due to the complexity of the accumulation of harmful gases, the special investigation holes of harmful gases still find small high-pressure gas fields between the unexposed gas holes of the original prospecting holes, and the possibility of small high-pressure gas fields in the survey area or surrounding areas is not excluded

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