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Emergency Dewatering and Drainage Technology and Its Application in Urban Underground Space

Wang Bin

The Third Exploration Team of Shandong Coalfield Geology Bureau, Taian, China

Email: 402171806@qq.com

Abstract

To solve the garage damage caused by the excessive groundwater level, the geological and hydrological data of the project site were analyzed, an emergency dewatering and drainage scheme was prepared, and such parameters as the number, spacing, and depth of dewatering tube wells were optimized and adjusted. By carrying out emergency dewatering and drainage, the dangerous case in the garage was relieved rapidly and effectively, followed by dewatering and drainage management in the later stage to control the groundwater below a safety level. The applicability of the emergency dewatering and drainage technology to flood disaster control in underground space were verified.

Keywords: Tube well; emergency rescue; dewatering and drainage; operations management

1. INTRODUCTION

Under the new era, requirements have been proposed for the rural revitalization, and the urbanization process in China will be continuously accelerated. The development and utilization of underground spaces such as urban subways, underground shopping malls, and underground garages have effectively solved the traffic and surface environmental problems and brought people considerable convenience [1-3]. Meanwhile, underground space is also facing geological disasters, such as piping, water inrush, flood, and fire [4]. Zhengzhou 7·20 extraordinary rainstorm-induced waterlogging accident and Jinan Yinzuo Supermarket 7·18 flood accident all occurred in urban underground space, causing huge casualties and economic losses [5,6].

Wang Z and Li J L put forward the basic principles of emergency pumping and drainage in view of the sudden water inrush accident in the construction process, and introduced the detailed selection and layout of equipment, pipelines, pumping stations, power supply, and electrical systems during emergency pumping and drainage [7]; Cheng X B optimized the dewatering scheme by adjusting the depth and spacing of dewatering wells in underground stations [8]. Liu J and Ji Y A analyzed the water inrush accident of a foundation pit, and successfully solved the flood accident by strictly controlling the construction quality and equipment operation [9]. Wang Y, Liu X R, Zhou X H, and Guo X Y analyzed the disaster-causing factors of urban underground space by investigating the disaster caused by the Zhengzhou extraordinary rainstorm disaster, and put forward the conception of the prevention and control system [10].

Judging from the above accident cases and study results, urban underground space has become a gathering place of urban disasters. In this study, emergency rescue was implemented for the flood disaster in an underground parking garage by combining practical engineering, a detailed dewatering scheme was given, the garage was then subjected to dewatering and drainage, and the flood disaster in this garage was successfully solved.

2 ENGINEERING PROFILE

2.1 Brief Introduction of Undergrounding Parking Garage

On the plot C of Tai’an Bocheng Community, there are 18 residential buildings with 11-17 floors on the ground, the parking garage on the underground 1st floor is irregularly rectangular with an east-to-west length of 393.0 m, a south-to-north width of 220.0 m, a perimeter of 1700.0 m, an area of 49200.0 m2, a ground elevation of 126.1 m, and a floor height of 4.2 m. The garage is a frame structure, and an independent foundation with waterproof plates is adopted.

2.2 Engineering Geological and Hydrogeological Conditions of the Tite

(1) Engineering geological conditions

The landform type of the site is single, and the geomorphic unit belongs to the alluvial plain of Dawenhe River. The terrain is flat, and the ground elevation is 132.15-129.50 m. The strata revealed in the survey are successively ① cultivated soil, ①-1 miscellaneous fill, ② silty clay, ③ clay, ④ fully weathered muddy limestone, and ⑤ limestone, which did not penetrate the limestone layer during the investigation.

(2) Hydrogeological conditions

No groundwater was found during the investigation. The miscellaneous fill on the surface of the site is loose in structure, mixed with sand, gravel, etc. The eastern area of the garage is a backfilled abandoned limestone mine pit, and the backfill components are waste rock powder and mineral powder, with a large permeability coefficient, which is beneficial to the infiltration and enrichment of groundwater and becomes a water-bearing layer; in ④ fully weathered muddy limestone, pores, fractures, and solution cracks develop extremely, which can easily become good water conducting channels and water storage spaces under rainstorm conditions and facilitate the flow and enrichment of groundwater.

3 DISASTER-CAUSING PROCESS OF RAINSTORM

3.1 Disaster-causing Factors

The short-term heavy rainfall in Culai Mountain area of Tai'an is the main cause of this flood accident. Driven by wind, a large amount of water vapor was lifted in Culai Mountain, resulting in an extreme rainfall, with the maximum rainfall exceeding 100 mm in a short period of time. The short-term rare rainstorm brought great challenges to the drainage capacity of the community.

The overall terrain of Bocheng community is high in the northwest and low in the southeast, and the C1 garage is located at the lowest terrain of the community. Because it is a newly built community, the ground sewage system, rainwater pipes, and other pipe network systems have not been laid, making it impossible to carry out normal drainage operations. Under the heavy rainfall, rainwater flew through the ground to low-lying places and penetrated into the ground through the topsoil. The community is about 2 km away from Dawen River, and the surrounding ditches are seriously blocked, resulting in the failure of water diversion and drainage. Therefore, the topographical and geomorphological conditions are also the disaster-causing factors of this accident.

Before the rainstorm, Tai'an meteorological department issued a meteorological and disaster warning, and the management, construction, and supervision personnel were not prepared enough. After the accident, the rescue work was not carried out in time, and the harm of this accident was also aggravated by human factors.

3.2 Disaster Situation

Before the accident, the aboveground and underground structures were completed, the ground was not completely covered with soil, and the construction of underground drainage facilities was not completed. Affected by various factors, rainwater was not discharged smoothly, and the water level rose sharply after it seeped into the ground. Groundwater was found at 0.5-1.0 m below the ground. The buoyancy borne by the garage increased, exceeding the limiting bearing capacity of the floor, and groundwater poured into the garage from the damage point of the floor, with an accumulated water depth of 0.8 m and an elevation of about 126.9 m. The load-bearing columns affected by the buoyancy were dislocated and broken, and cracks appeared in shear walls.

There is an abandoned mine pit in the south of the community, with a depth of about 5.0 m, an area of about 10000.0 m2, and a water surface elevation of 130.1 m, which leveled with the ground elevation at the site and exceeded the elevation of the garage roof. Because the backfill of the abandoned mine pit was mostly miscellaneous fill and slag, with strong water permeability, and it was less than 100 m from the C1 garage, it was then preliminarily judged that this water pit was hydraulically associated with the garage.

4 EMERGENCY DEWATERING AND DRAINAGE DCHEME

According to the characteristics of short dewatering time and large displacement at the site, the dewatering method combining tube well group dewatering with open-cut drainage of accumulated water was adopted to meet the requirement for rapidly lowering the groundwater level and relieving the danger.

4.1 Tube Well Group Dewatering Scheme

(1) Considering the influence of groundwater on the garage structure, the drawdown in a single well should be slightly greater than the existing safe water level of the underground garage, and the water level in the observation well was designed to drop to 1.0 m below the garage floor, that is, the safe water level was 124.5 m.

(2) The total displacement of the tube well group should be greater than the water inflow around the garage. According to the Technical Code for Groundwater Control in Building and Municipal Engineering (JGJ111-2016) and the water pumping and drilling situation in the early stage of emergency rescue, the water inflow of the garage was calculated by using the “large well method”. The total water inflow of the garage was about 16,000 m3/d, and the average water inflow of a single tube well was 510 m3/d. A total of 39 dewatering tube wells with a depth of 10-12 m and a spacing of 20 m were preliminarily designed. The main drain was arranged along the distribution route of dewatering wells, and water was discharged into the open channel outside the site.

4.2 Pumping and Drainage Scheme for the Garage and Water Pit

(1) Open-cut drainage was adopted to drain the water accumulated in the C1 garage, in which the water level reached 126.9 m, the water area was 49200.00 m2, and the estimated water volume was 42000.00 m3. A total of 4 non-blocking submersible sewage pumps with power of 7.5 Kw/h were used to pump the accumulated water in the garage to the main drain and finally discharge it into the open channel.

(2) The abandoned mine pit on the south side of the community was full of accumulated water, and 4-6 non-blocking submersible sewage pumps with power of 7.5 Kw/h were applied to directly discharge the accumulated water into the open channel.

5 DRAINAGE PROCESS AND RESULTS

5.1 Emergency Rescue Process

The emergency rescue lasted 16 days since the 1st dewatering well started dewatering and drainage on August 22 until the groundwater level was lowered to the safe water level on September 6.

(1) Preparation for emergency rescue

In the early stage of emergency rescue, an emergency dewatering and drainage scheme was formulated through field reconnaissance and analysis of surrounding geological, hydrological, and environmental conditions. Relief supplies, mechanical equipment, and materials were deployed, and technicians were organized to immediately enter the site of the accident to carry out rescue work.

(2) Positioning of tube wells

According to the rescue plan and dewatering design drawing, the well location, well spacing, and well depth of the tube wells were determined, and the measurement error of the well location was≤50 mm. Avoidance measures were taken for the underground pipelines, and the well location was adjusted in real time as needed.

(3) Drilling rig-aided well completion

The site was equipped with two crawler drilling rigs, which were kept steady without skewness during normal drilling process. Permanent casing pipes were buried in special weak strata, which were drilled to the design elevation. The well diameter was 273 mm, and φ200 mmPVC-U plastic pipes were put into the well after well completion to prevent rainwater accumulation or other sundries from falling into the well. The well wall was 40 cm higher above the ground.

(4) Filling of the water filtering layer

After the completion of tube wells, permeable materials were backfilled at the periphery of the tube wall, and the gravel with a particle size of about 5 mm was symmetrically filled to prevent the tube from tilting.

(5) Well flushing

Water flushing was conducted by means of air-lifting reverse circulation after drilling to the design elevation. This method could move the residual sediments and debris in tube wells up to the ground to reach the goal of fast sand bailing.

(6) Installation and debugging of submersible pumps

Submersible pumps with a flow rate of 5 m3/h and a lift of not less than 30 m were lowered into each well at a depth of 0.5 m above the well bottom and fixed with steel wire ropes. Trial pumping was then implemented, and water pumps were adjusted depending on the field pumping situation.

(7) Installation of main drain

After the completion of the tube wells, the main drain was arranged 1 m along the outer side of the tube wells. Because there were many precipitation wells on the site, the precipitation was large and the transportation distance was too long, water recovery wells were evenly arranged on the ground while ensuring the pipe laying slope according to the site terrain. Water was collected through such wells and finally discharged through the main drain. The main drains were DN300 mm double-wall corrugated pipes, which were laid along the tube well route in north-east-south order with a slope no less than 0.5% and a length of about 1000.0 m.

39 dewatering wells were completed by August 31. After pumping, it was found that the groundwater level in the east and west tube wells had a small decline, failing to meet the requirement of quickly eliminating the danger. Considering that most of the eastern and western sections were low-lying areas, the backfill in garage foundation pit excavation was mostly mineral sand, the stratum permeability coefficient was large, and a large amount of rainwater was collected underground, so the tube wells on the east and west sides were densely arranged with a distance of 10-15 m and a well depth of 15 m. After adjustment, 49 dewatering tube wells and 3 observation wells were arranged. See Table 1 for the number of tube wells and various parameters.

Table 1 Comparison of tube well parameters

Item	East side	West side	South side	North side	Total number of tube wells/unit	Well depth/m	Well spacing/m
Before adjustment	6	4	20	9	39	8-10 m	20-25 m
After adjustment	13	7	20	9	49	8-10 m 12-15 m	20-25 m 10-15 m

5.2 Normal Dewatering Stage

After the early 16-day emergency dewatering and drainage stage, the water level of all tube wells dropped to about 1.0 m below the garage floor, which achieved the goal of eliminating the danger. Then, the normal precipitation stage was welcomed. According to the preset dewatering scheme, underground dewatering was continued to provide a dry environment for the garage floor repair in the later stage, which totally lasted 104 days from September 7 to December 19.

5.3 Dewatering Results

After dewatering and drainage in the early emergency rescue stage and the later normal dewatering stage, the groundwater level dropped to a safe level of 124.5 m, and all the accumulated water in the C1 garage and the abandoned mine pit on the south side was drained. During the emergency dewatering and drainage period, the water level of the tube wells was observed, and the initial observation frequency was twice/day, which was gradually changed with the precipitation. On the 1-8 d of emergency rescue, a total of 39 dewatering wells were arranged at the site for dewatering. The average water level dropped from 128.15 m to 127.70 m with a dewatering depth of 0.45 m, indicating an unobvious dewatering effect. In the later stage, the tube wells were densified, the well depth was increased, the water level in tube wells decreased from 127.70 m to 124.30 m with a dewatering depth of 3.4 m, and the total dewatering depth reached 3.85 m in the emergency rescue stage. The reason was that with the increase of the number of tube wells, the decrease of well spacing, and the increase of well depth, the groundwater displacement in the garage and surrounding areas increased, and the average groundwater depth increased. See Figure 1 for the average underground dewatering depth before and after adjusting the number of tube wells.

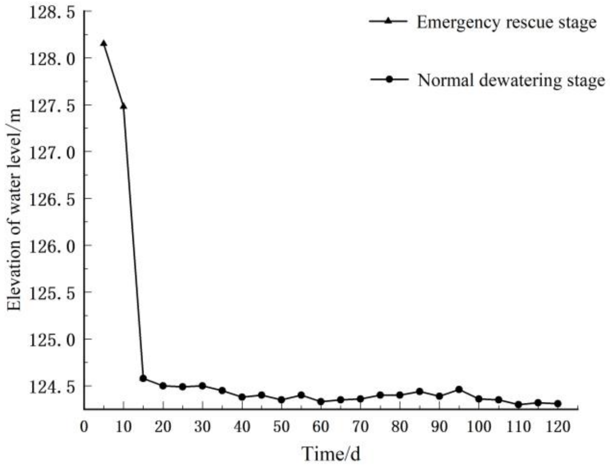

Figure 1 Comparison diagram of underground dewatering depth

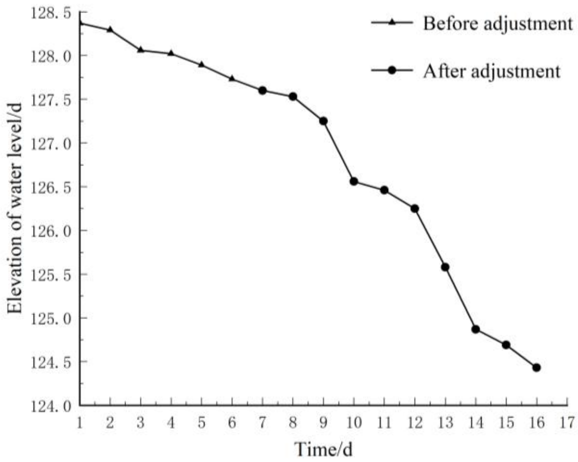

Figure 2 Tendency chart of groundwater level change

Group wells operated during the dewatering period in the garage. As the groundwater level declined, the group well effect was gradually evident. In the later stage, the single-well water pumping capacity presented a declining trend due to the reduction of groundwater volume, submersible pumps no longer operated in full load, and the single-well water discharge was a variable value. To ensure that groundwater was kept a stable safe level, therefore, the pumping capacity was controlled by controlling the electrified pulse delay of water pumps. The water pumps were started every 4 h (for 0.5 h each time), effectively preventing the burnt-out phenomenon of water pumps due to divorcement from the water surface and their idle running for a too long time, improving the dewatering efficiency, and saving the cost. During the normal dewatering period, the groundwater level was kept under a dynamic balance, the groundwater level was observed for 2-3 times per week and changed within 124.3 m-124.5 m, and the dewatering depth changed less in comparison with that in the emergency rescue stage, not exceeding the safe water level of 124.5 m. The change in the groundwater level is exhibited in Figure 2.

6 CONCLUSIONS

This project aims at an underground garage water inrush and water accumulation accident caused by special weather due to the insufficient attention to emergency rescue and dewatering and drainage in the early stage. After the accident, the key to this project lies in formulating an emergency dewatering and drainage scheme, carrying out emergency rescue work quickly, and minimizing the losses caused by floods. In the emergency dewatering and drainage stage, by adjusting the parameters such as the number, spacing, and depth of tube wells, the groundwater level is quickly reduced and the danger is relieved. In the normal drainage stage, the groundwater level is controlled at a reasonable depth by adjusting the pumping time of the water pumps, which meets the requirements of the later garage repair construction. This emergency dewatering scheme is reasonable and feasible, and the emergency rescue stage only lasts 16 days, saving time and labor costs, which can be used for reference.

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