ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0027

Study on the Phenomenon of Mud Water Inrush in Karst Tunnel Excavation

Zhongyi Sun, Longjian Lei

School of Urban Construction, Changjiang University, Jingzhou 434023, Hubei, China

Abstract

Tunnel water inrush disaster is a common geological disaster in tunnel construction, it is left in the tunnel surrounding rock by the historical evolution of groundwater, in the tunnel forward construction process, the ground water is formed through the structure fissures, construction blasting, drilling hole and so on, which has great potential danger to the tunnel construction. Based on the analysis of the cause of mud water inrush, this paper summarizes the research from the mechanism of water inrush, Prediction and prevention, treatment plan. At present, the main research direction of the outburst of mud and water in the excavation of tunnel or foundation pit is cause analysis, and the effect of prediction and prevention is achieved by monitoring and contrast through numerical simulation, and put forward the method of governance scheme according to the related research example.

Keywords

Tunnel Excavation; Mud Water Gushing; Numerical Simulation; Treatment Scheme.

1. Introduction

In the system of tunnel excavation, there are two kinds of geological conditions that cause water burst: Karst and water-rich structure, including faults and intrusive rock contact zone. The problem of tunnel gushing can also be divided into two types: karst gushing water and non-karst gushing water.

With the rapid development of our country's economy and society, the construction of large-scale projects such as transportation, Water Conservancy and hydropower has ushered in a new development, tunnel and other underground projects will face the challenge of"Complex structure, great difference in geological conditions", so how to do a good job of tunnel safety construction is particularly important, in order to reduce or eliminate the occurrence of similar accidents, we will protect the lives and property of the people. According to statistics, most of the major underground projects are located in high mountains and canyons, there is a potential risk of water burst disaster. It is obvious that the mud-water outburst caused by tunnel excavation has become one of the most costly geological disasters in tunnel construction, at present, the phenomenon of mud and water inrush in tunnel excavation has been paid much attention, and the mechanism of water inrush, simulation and prediction, and corresponding prevention and control scheme are the main contents of current research, it is of great significance for the construction and safety of tunnel and foundation pit to do well the correlation study of gushing flood.

2. Research Status

2.1 Surge Mechanism

Tunnel water inrush is mainly affected by surrounding rock lithology, geological environment and tunnel excavation mode and other factors. The essence is that tunnel excavation flexure destroys the original balanced geostress field, karst water storage and water transport system, which leads to the

ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0027

instantaneous release of groundwater accumulation energy. Tunnel rock mass is destroyed and gushing out of the tunnel excavation face in the state of fluid is a dynamic failure phenomenon. Ma Min[1] thinks that the water head of the karst cavity is highly related to the water inrush accident of the tunnel, and when the water head of the karst cavity exceeds the safety critical water head, the inrush accident will occur in the karst tunnel; through the mechanical analysis and derivation of the instability model, CHU Vietthuc[2] thinks that slip and instability will occur in the karst tunnel when the safety factor of the filling body is 0.46, resulting in mud outflow and groundwater inrush. Zhao Bojian [3] thinks that the thickness of inrush plate of karst tunnel is the key problem of inrush, and determining its safe thickness is the primary problem to ensure construction safety. Zhang Dingli et al.[4] through the analysis of water inrush events, three types of evolution of water inrush in subsea tunnel are found, that is, hydraulic fracturing structure, stratum collapse structure and interface slip structure. According to the characteristics of these types, the corresponding process control measures are given. Fu Helin[5] and others considered that the main cause of mud water inrush in the tunnel is the heterogeneity of surrounding rock, that is, there are discontinuities in different lithologic strata, resulting in the heterogeneity of permeability coefficient; through analysis, it is concluded that when the geological conditions are the same, the greater the permeability of rock mass, the more conducive to drainage and pressure reduction; on the contrary, it is more likely to produce seepage failure. A method to reduce the disturbance to rock and soil by tunnel excavation is put forward. The formulas of water inflow and water pressure outside the soil are derived by using the seepage equilibrium equation and Darcy's law. Fu Helin[6] and others also think that on the basis of the simplified calculation model and related theoretical calculation formula of water gushing in deep-buried tunnel, the sensitivity analysis of relevant characteristic parameters is carried out, and the influence mechanism of tunnel water gushing is discussed. the influence mechanism of each supporting structure and drainage system on tunnel water gushing is revealed. In-depth study of the evolution process and mechanism of tunnel inrush is of great significance for guiding tunnel construction and prevention and control of tunnel mud inrush.

2.2 Numerical Simulation

At present, most numerical analysis methods such as finite element method, finite difference method, discrete element method and coupling method are used to study the problem of water inrush in karst tunnel. this paper mainly studies the evolution process and critical conditions of water inrush in karst tunnel.

Based on the principle of FLAC3D finite difference method and fluid-solid coupling analysis, Zhang Fujun[7] and others studied the effects of different treatment methods such as drainage, grouting and plugging combination on the water inflow and stability of the tunnel based on the principle of FLAC3D finite difference method and fluid-solid coupling analysis. The results show that when a large amount of water gushing occurs in the water-rich fault tunnel, the combined drainage and plugging measures of water diversion tunnel drainage and grouting can not only reduce the water gushing volume, but also ensure the stability of the surrounding rock; for C class water gushing tunnel, grouting measures can be taken; for D class and below water gushing tunnels, conventional pumping and drainage measures can be taken. Ma Min[1] and others established a generalized calculation model based on the spatial location and scale shape of water inrush in Jiudingshan karst tunnel of Chu-Da Expressway, simulated the process of tunnel roof failure and water inrush accident by discontinuous deformation analysis (DDA) method, and analyzed the failure mechanism of tunnel surrounding rock and the conditions of water inrush accident. The results show that the water head of the karst cavity is highly related to the occurrence of water inrush in the tunnel, and when the water head of the karst cavity exceeds the safety critical water head, the water inrush accident will occur in the karst tunnel. Based on the research background of CHU Vietthuc[2], the DEOCA tunnel project of Highway 1 located between the two provinces (Fu'an City and Qinghe Province) is selected. By means of field investigation, laboratory tests and theoretical modeling, it is found that there are 4 large karst cave groups in this area, of which 3 are super large karst caves or giant caves, and the karst

ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0027

water inrush process is a typical representative of this project. CHU calculates and analyzes the evolution process of water gushing and mud inrush, uses the real fracture process analysis program RFPA to simulate the microscopic evolution process of karst pipeline inrush, and uses the fast Lagrangian Flac3D program to simulate the macroscopic evolution process of karst pipeline mud inrush. The numerical results can better reflect the evolution process and mechanism of karst tunnel inrush. Li Chaoyang[8] uses Monte Carlo method and GA-BP neural network in reliability theory to analyze the occurrence probability and disaster consequences of water inrush in karst tunnel; the following conclusions can be drawn: (1) the disaster criterion caused by water inrush in karst tunnel is summarized, and the probability calculation is carried out by Monte Carlo method through MATLAB software, which greatly improves the calculation efficiency and accuracy. (2) BP neural network optimized by genetic algorithm is used to predict the consequences of water inrush disaster. Six indexes of cavity water pressure, hydraulic replenishment, burst type, filling condition, water-rich degree and cavity reserves are selected to describe the characteristics of the cavity in detail, and quantified. The disaster consequences are classified in accordance with the disaster classification standards in the specification, and the disaster consequences are described by multi-group percentile data, which overcomes the defect that the existing models can not accurately evaluate the consequences of water inrush disasters. Li Tieru[9] studied and simulated the types, causes and main distribution of water inrush in underground tunnel engineering based on ABAQUS finite element software. The numerical results show that the geological conditions of karst tunnel have a great influence on the displacement of lithology and strata, which leads to the expansion of zero water pressure area and significant change of water pressure in the tunnel. According to the specific situation of Pingyang Tunnel in Hubei Province, Ling Tao[10] and others adopted the treatment policy of "blocking mainly, limiting drainage, preventing outburst and preventing surge", and simulated and calculated the grouting (main control points) by using FLAC3D numerical simulation software FLAC3D. The study shows that the deformation of the roof before grouting is 87 mm, and that after grouting is only 27 mm. The test results show that the deformation can be controlled well after grouting. The existing numerical simulation calculation methods have been simplified to a certain extent, which can simulate the whole evolution process of karst pipeline inrush flood, but because of the complexity of the actual engineering situation, there is a certain error between the numerical analysis results and the actual situation, so it is difficult to make a quantitative comparison with the actual engineering situation.

2.3 Governance Plan

With the sustained and rapid development of underground tunnel engineering in China, the prevention and control of tunnel karst water inrush disaster has become the primary problem to face and overcome. The prevention and control of water inrush in tunnel mainly includes predicting bad geology in advance, mechanism and evolution simulation of water inrush, scientific prevention and control means and decision-making and so on.

Combined with the example of the wind shaft project in Nanhu section, Li Cong[11] introduced the construction technology characteristics and application scope of "tunnel before well". By monitoring the effect of underground grouting and surface sleeve valve grouting, the "pressure relief guide grouting method" is creatively used to ensure the grouting in the confined space. This has a certain guiding significance for the inrush and leakage plugging of the deep foundation pit, and has a certain reference significance for the construction of similar projects in the future. Ma Jiazhi[12] and others also analyzed the causes of water gushing and sand gushing after the excavation of ultra-deep foundation pit in water-rich sand layer and several problems needing attention in emergency treatment. At the same time, the treatment method of "bottom hole reverse pressure + bottom hole water level + peripheral grouting" is scientifically formulated, which effectively solves the problem of sudden surge in ultra-deep foundation pit excavation in water-rich sand layer and ensures the safety of engineering construction. Han Xuegang[13] analyzed the cause of water gushing from the process of tunnel excavation, that is, the amount of water gushing in the process of tunneling and the

ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0027

geotechnical properties of the strata. at the same time, according to the local ecological environment, it is suggested to adopt the treatment method of "plugging mainly and supplemented by drainage". Through the treatment of tunnel structure, groundwater and surface vegetation and other factors, a better treatment effect has been achieved. Hu Diyong[14] in view of the complex geological environment in the western karst area and the geological disasters such as water gushing and mud outburst in tunnel construction, through on-site monitoring and numerical simulation, it is found that the change of groundwater seepage field due to the influence of construction environment is the root cause of the above problems. The deformation and failure of surrounding rock is mainly concentrated in the range of about 5m in front of the face, and has obvious lag. From the point of view of disaster source, water inrush is divided into four types, such as crack type. It is put forward that the prevention and control scheme of fissure water inrush should be mainly grouting reinforcement, and the combination of drainage, plugging and grouting should be adopted, and the grouting filling, blocking and drainage of cavern water inrush should be based on water storage structure. Qian Fulin[15] after studying and analyzing the mechanism of water inrush in practical engineering tunnel, according to the characteristics of inrush flow, the corresponding grouting treatment scheme is put forward, and according to the principle of "combination of plugging and drainage", overflow detection and water inrush prevention are combined to ensure the safety and progress of tunnel construction. The research method adopted by Liu Zhaowei[16] is the combination of on-the-spot investigation, numerical simulation and theoretical analysis to study the causes of water inrush in the actual karst tunnel of Yuanliangshan tunnel and analyze its prevention technology. through the comprehensive evaluation of the geological conditions of the tunnel, it is determined that the key area is class IV surrounding rock section. The corresponding treatment measures are taken according to different conditions to ensure the safety and stability during the construction and operation of the project. Finally, the relevant conclusions are given. Under the guidance of the above principles, the fundamental purpose of safe and high-quality construction of tunnel excavation under complex karst is achieved, the life and property safety of construction personnel is guaranteed, and good technical and economic benefits are achieved.

3. Summary and Prospect

Different geological conditions lead to different causes and mechanisms of mud-water inrush, according to different geological conditions and specific engineering status, through numerical simulation to achieve the effect of monitoring and prevention; at the same time, in the accident of water inrush, taking correct emergency measures and treatment plan will save the loss of life and property caused by the accident to a great extent. Nowadays, the problem of mud-water inrush is still an important issue that we need to pay attention to and study. The more we know about the inrush mechanism and the more abundant the means of simulation monitoring, we believe that we can deal with and avoid the inrush accident in the project very well.

References

[1] Ma Guomin, Zhang Xiuli, Yang Huaqing. Study on water inrush mechanism and safety critical condition of karst tunnel[J].Safety and Environmental Engineering, 20221,29(2):64-70.

[2] CHU Vietthuc.Numerical analysis of disaster mechanism and evolution process of water inrush in karst pipeline filled with highway tunnel[J].Journal of Central South University(Natural Science Edition), 2016,47(12):4173-4180.

[3] Zhao Bojian.Analysis of safe thickness of anti-inrush rock plate in karst tunnel[J].Sichuan cement, 2021(2):324,325.

[4] Zhang Dingli, Sun Zhenyu, Song Haoran & Fang Huangcheng.(2020).Evolution mechanism and process control method of water inrush in subsea tunnel.Journal of Rock Mechanics and Engineering(4),649-667.

[5] Fu Helin, an Pengtao, Li Kai, Cheng Guowen, Li Jie, Yu Xiaohui.Analysis of the influence of surrounding rock heterogeneity on tunnel water inrush[J].Rock and soil Mechanics,2021,42 (6):1519-1528.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202308_9(8).0027

[6] Fu Helin, an Pengtao, Wu Yimin, Cheng Guowen.Analysis of tunnel water inrush when considering drainage system[J/OL].Journal of Railway Science and Engineering:1-9[2022-04-27].

[7] Zhang Fujun, Hu Jun, Duan Yu, Zhu Caihui.Optimization analysis and engineering application of water gushing control scheme in a water-rich fault tunnel[J/OL].Modern tunnel technology: 1-10[2022-04-27].

[8] Li Chaoyang.Study on risk assessment and early warning of water inrush in karst tunnel based on data learning[D].China University of Mining and Technology,2020.

[9] Li Tieru.Study on karst water inrush in tunnel engineering[J].North Traffic,2020 (9):89-91.

[10] Ling Tao, Tang Yu, Peng Xuejun, etc.Analysis on the effect of grouting in the treatment of sudden mud gushing in a tunnel[J].Project Construction,2022,54(2):29-33.

[11] Li Cong, Liao Zhengen, Ma Jiazhi.Anti-inrush treatment technology of circumferential joint of segments constructed by"tunnel before well"method[J].Modern Tunnel Technology,2021, 558(S2):154-159.

[12] Ma Jiazhi, Liao Zhengen, Li Cong.Emergency treatment technology of inrush in ultra-deep foundation pit excavation in water-rich sand layer[J].Modern Tunnel Technology,2021,558 (S2):160-164.

[13] Han Xuegang, Fu Xiaojian, Lian Xiaoxing.Treatment technology of water inrush in working face of highway tunnel passing through water-rich fault zone[J].Municipal Technology,2020, 38(3):165-167.

[14] Hu Diyong, Xu Zhong, Wang Kunyun, Yang Zhu, Wang Mengfei, Huang Zhenpu.Analysis on disaster source types and disaster prevention of water inrush in karst tunnel[J].Resource Information and Engineering, 2021 Magi 36 (1):74-76+81.

[15] Qian Fulin.Mechanism analysis and treatment technology of water inrush in Guanjiao tunnel [C]. Proceedings of the symposium on engineering construction technology of Sichuan-Tibet railway. [publisher unknown], 2019,246-252.

[16] Liu Zhaowei, he Manchao, Wang Shuren.Study on Mechanism and Prevention Countermeasures of Karst Water inrush in Yuanliangshan Tunnel [J].Rock and soil Mechanics, 2006 (2): 228-232+246.