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Exploration of Flood Risk Cause Identification and Prevention and Control Strategy of Subway Underground Construction in Coastal Areas

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Abstract: This paper explores the identification of flood risk causes and prevention and control strategies for subway underground construction in coastal areas. With the backdrop of global climate change leading to increased frequency and intensity of extreme weather events, the construction of rail transit engineering, especially in coastal cities, faces significant challenges. The paper discusses the high-risk nature of subway construction due to the complex underground environment and the lower skill threshold of construction personnel. It reviews the current status of risk management research both domestically and internationally, highlighting advancements in risk identification, assessment methods, and intelligent construction management. The study emphasizes the need for a comprehensive approach to flood risk management, including risk identification, assessment, and disaster prevention planning, as well as the improvement of flood disaster prevention and control systems. The paper concludes by advocating for the optimization of engineering design, construction adjustments, and the establishment of a long-term monitoring and maintenance mechanism to enhance the resilience of coastal cities' subway construction against flood risks.

Keywords: Flood Risk Identification, Subway Underground Construction, Risk Management, Climate Change Impacts.

1. Introduction

1.1. Research Background

In recent years, the global climate change has led to an increasing frequency and intensity of extreme weather events. Taking China as an example, according to the data of the National Bureau of Statistics, various economic losses caused by typhoons and urban waterlogging in coastal cities have increased year by year in recent years. The above climate change also brings great challenges to the construction of rail transit engineering everywhere. In nearly 20 years of large-scale subway project construction process, due to the city subway through the urban area, surrounding densely populated, along the building foundation forms, underground pipelines, hydrogeological complex, at the same time the subway engineering survey, design and construction of human error, lead to subway engineering construction accidents.

Compared with general construction projects, subway projects not only have a large investment, but also have a high degree of construction risk. This is mainly due to the fact that the subway construction is constructed in the narrow underground space, and the hidden dangers are complex. However, the working threshold of the construction personnel in such projects is lower than that of the general construction industry. Such contradiction makes the accident rate of the subway construction stage, especially in the underground tunnel construction stage, is higher than that of the general construction projects. Construction safety accidents and disasters not only bring huge casualties and economic losses, but also make the construction activities are forced to interrupt, the resulting indirect property losses can not be ignored.

The climate challenge and the high risk of the project construction itself interweave, making the urban subway construction in the coastal areas become a new difficult problem in the engineering risk prevention and control.

1.2. Research Status at Home and Abroad

1.2.1. Current status of relevant foreign studies

In terms of theoretical research of risk management, developed countries in Europe and the United States started such research earlier. Among them, HH Einsetin first introduced the concept of engineering risk analysis into underground buildings. He introduced the concept into underground construction projects in 1970. In the 1990s, risk analysis was applied as a decision tool to three typical rock engineering applications: slope design, fissure medium and tunnel construction.

Subway construction safety risk identification and assessment, Ding, L. et al. (2012) introduces the automation process of subway construction safety risk identification, the research solved the by establishing automatic identification process and algorithm to achieve fast access to engineering parameters for risk identification, and the development of security risk identification system based on construction drawing identification (SRIS) the two key problems. Dharmapalan, V., Gambatese, J., Fradella, J., & Vahed, A. M. (2015) used the investigation and analysis method to quantify the absolute safety risks of construction activities and incorporate the relevant risk factors into the online tool called safety Design Risk Assessment Device (SliDeRulE) to realize the quantification of the correlation between specific design characteristics and construction safety risks. Kang Li et al. (2022) proposed a risk assessment model based on AHP (analysis level process) and FSE (fuzzy comprehensive evaluation) for the systematic analysis of shield construction safety and through the construction of evaluation index system and weight matrix.

In the aspect of metro construction risk management, Zhipeng Zhou, Qiming Li et al. (2011) proposed the application of multi-functional metro construction accident database (SCID) in the safety management of metro construction. Anders, K., Assmann, A., & Fritsch, K. (2016) explored the importance of building an operational model capable of real-time flood simulation in response to a flood crisis. A.G. Protosenya et al. (2016) proposed A method based on risk assessment to determine the safety plugging scheme when the subway tunnel is flooded.

In terms of flood control and disaster reduction in underground space, the main research results are mainly in numerical simulation, physical model construction and the formulation of flood control guidelines. In numerical simulation, Dutta (2003) and others used mathematical model to analyze the relationship between ground water depth and underground space inlet velocity, and Toda (2009) analyzed the flow evolution process in complex underground space during flood. In terms of physical model, Inoue (2003) in Japan studied the diffusion speed of flood in underground space and the corresponding water conditions through a large model of central Tokyo; Ishigaki (2005) used actual size stair model to find that the ground safety critical water depth that people can escape through stairs is m. In the formulation of flood control guidelines, the Irrigation Bureau of Malaysia has formulated clear flood control guidelines in order to ensure the safety of underground garages.

1.2.2. Domestic relevant research status

The research on subway construction risk in China started relatively late. It was not until the end of last century that Chinese scholars studied the safety risk management based on the existing foreign theoretical achievements and combined with the actual cases of subway project construction in China.

In terms of theoretical foundation construction, Xiao Wentao et al. (2019), based on the theory of resilient cities, believe that resilient cities are the strategic orientation and a new paradigm of urban security development under the background of today's risk society. Xu Qifan (2022) introduced the theory of organizational toughness to define the connotation of the toughness of subway construction organization. Through relevant research, it is believed that the influencing factors of construction organization toughness include five core categories, including prevention ability, preparation ability, response ability, recovery ability and external environment.

In terms of safety risk identification of tunnel and underground engineering, Qin Xiaoping (2019) identified the possible safety risks in various stages from construction preparation to shield tunnel exit through the expert empirical identification method, and established the corresponding risk assessment model. Cao Zhen (2013) in combination with the actual engineering case of the main factors of subway tunnel shield construction safety risk including engineering geology and hydrogeological factors, load factors, construction factors and external factors and four secondary factors, and using fuzzy mathematics and hierarchical analysis theory put forward the quantitative assessment of subway tunnel shield construction safety risk level of fuzzy comprehensive analysis.

(3) Construction safety risk assessment method

Wang Yongxiang et al. (2021) decomposed the safety risk structure of the subway shield construction stage, coupled the risk parts and risk factors, and constructed the risk evaluation index system. Later, the mutation stage method was applied to quantify the risk and determine the risk level.

Liu Yipeng et al. (2021) adopted WBS-RBS method to establish a whole-process risk index system, and applied dynamic Bayesian network (DBN) to the safety risk dynamic evolution analysis of underwater subway shield construction for the first time. At the same time, the probability change process of risk over time is combined to predict the dynamic evolution path of risk in different situations through forward and reverse inference.

Jiang Tingting et al. (2021) used the hierarchical analysis method and entropy weight method to determine the subjective and objective weight of each index, obtained the comprehensive weight of the index through the game theory combination empowerment, adopted the weighted average operator and the maximum membership principle, and established the fuzzy comprehensive evaluation method.

Li Cangsu (2023) using structural equation model (SEM) as the main research tool, the construction safety risk evaluation analysis, which provides a new quantitative method for risk management, while using the system dynamics model of risk factor weight validation, increased the reliability and practicability of the evaluation model.

(4) Waterlogging risk control of underground space construction

Ren Zhibo (2019) studied the risk of waterlogging prevention during the construction period of urban underground space, taking the large underground space during the construction period of Wuhan Optical Valley Central City as the research object, analyzed the waterlogging prevention risks of the underground space before and after the engineering measures, and evaluated the effectiveness of the scheme. He proposed that when studying and formulating the waterlogging prevention scheme of foundation pit during the construction of large underground space, the influence of regional waterlogging prevention capacity must be considered, and the waterlogging prevention countermeasures of large underground space during the construction period are mainly considered from the perspectives of engineering safety and flood control and drainage capacity of surrounding urban areas.

Shu-guang liu (2023) combined with underground space flood instance at home and abroad, from disaster factors, disasters and disaster prevention and mitigation ability discusses the main scientific problems facing urban underground space flood prevention and control, points out that the ground flood invasion underground space is mainly affected by the external flood environment and its defense ability, general urban underground space in planning and design did not fully consider the demand of flood control, makes it in response to flood show a variety of defects. At the same time, it is proposed that the flood risk management of urban underground space is not only related to the disaster prevention attribute of underground space, but also closely related to the surrounding urban environment. It is also affected by multiple complex factors such as the management level and the situation of the affected people. The obvious lack of attention and decision execution ability cause a lot of losses.

(5) Construction monitoring technology and intelligent construction management

Yin Dong (2022) proposed the intelligent site management method based on uav and computer vision, used uav technology to collect engineering information in an all-round way, and realized the refined three-dimensional model construction of the construction site based on inclined photography, so as to intelligently identify the safety risks of the construction site.

1.2.3. Review of relevant research status at home and abroad

The domestic and foreign related research situation in the field of subway construction risk management has made significant progress, the research content covers the definition of risk management, engineering construction risk identification, construction safety risk evaluation method, construction monitoring technology and intelligent construction management, and other aspects, have formed a relatively mature research system and methodology. And through the analysis of literature, construction safety risk management is gradually to the development in the direction of digital, intelligent this trend also attention, and the multidisciplinary approach in construction safety risk management also plays an important role, such as machine learning, complex network theory, BIM technology, etc., the application of these methods help to more comprehensive and accurate identification, prediction and evaluation of security risks in the process of construction.

However, also should see, although the progress has been made in related research, but the underground space flood control and disaster reduction at home and abroad, more for static underground space such as large underground garage or has built the evolution of subway station water research, the flood risk of underground subway construction research is less. Scholars in the urban underground space construction period waterlogging risk research is more focused on the specific measures of flood control and drainage, for how to strengthen the flood control and drainage design and planning and establish less risk prevention and control system, in the urban subway construction underground construction flood risk prevention and control aspects can also further research and put forward specific measures, in order to better guarantee the safety of the subway construction.

1.3. Study Significance

Based on the above research blank, the main research significance of this paper is based on the real case to explore the subway construction environment and the resulting risk factors, to explore the effective flood prevention and control mechanism and measures, for the coastal city subway underground construction risk management theory system provides a new perspective and analysis framework, also to promote the development of the field management practice and perfect is of great value.

2. Analysis of Causes of Flood in Underground Construction in Coastal Areas

2.1. Analysis of External Factors

2.1.1. Geographical Conditions

Along the subway in coastal areas, there are various landforms such as mutual plains, denudative hills or low hills, including quaternary strata, Jurassic tuff, and Yanshanian granite, with rich groundwater and runoff, rainfall and seawater infiltration, with complex geological conditions and high disaster risk. Because the geological structure is mainly rich water sand, soft soil, high head is prone to subsidence, subsidence of rich water soft formation, so once the construction, improper hole backfill, precipitation Wells, foundation pit leakage, soil pressure is too large or too small, mud viscosity flow set improper operation, such as easy to make the surrounding soil settlement, uplift, subsidence, thus, the surrounding construction, structures cracking, tilt, subsidence, road cracking and subgrade subsidence, subsidence, pipeline damage, runoff unicom aggravate soil erosion, and so on and so forth.

If the relevant sites are located in low-lying areas, from a geographical point of view, the low-lying terrain is likely to lead to the convergence of water flows under natural conditions, but this feature is magnified under the influence of extreme weather. Under the action of heavy precipitation brought by typhoons, the collection speed and accumulation of water flow in the low-lying areas are far beyond the design load of the conventional drainage system, making the low-lying stations become the focus of water accumulation. In addition, if the municipal line related pipe network is not yet perfect and cannot timely and effectively dredge and discharge a large amount of water, it will further aggravate the severity of the flood disaster.

2.1.2. Climate factors

As a huge and complex project, subway construction has extremely high requirements for environmental conditions. The heavy rainfall brought by typhoons in coastal cities in summer and autumn brings severe challenges to the urban infrastructure construction. In the foundation pit excavation stage of the subway project, the large rainfall process will seriously affect the stability of the soil in the pit. Due to the infiltration of rainwater, the shear resistance of the soil will be reduced, which can easily lead to the longitudinal deformation or slip of the foundation pit. If such deformation or slip is not found in time or properly handled in time, it may cause catastrophic accidents, which will not only threaten the life safety of the construction personnel, but also may lead to the delay of the project and increase the construction cost.

In addition, if some stations of the subway line are built close to the river in the case of heavy rain, the rise of the river level may cause the river to pour back into the foundation pit, which will not only destroy the stability of the foundation pit, but also cause pollution to the surrounding environment. At the same time, the rise of water level outside the pit caused by a large amount of precipitation increases the pressure difference inside and outside the pit, especially in the formation conditions with strong water permeability such as silt and sand soil, the change of groundwater level is more likely to cause the leakage of the envelope structure, which increases the construction risk.

2.1.3. Impact of pipelines around the station

If the relevant subway station is a part of the new urban development area, the surrounding municipal pipe network and other infrastructure will be constructed simultaneously with the main project. This means that during the construction of the foundation and foundation works, the relevant municipal pipe network has not yet been completed, accepted and put into use. Therefore, in case of sudden precipitation or accident drainage, the foundation pit of the whole underground space project may temporarily become a large catchment area, and the water cannot be discharged immediately through the municipal pipe network, which brings some challenges to the construction safety and progress of the project.

2.2. Internal Factors

2.2.1. Insufficient identification and assessment of early flood risk

If the construction unit in the project safety risk assessment, the flood disaster risk estimation is insufficient, and often ignore the identification and assessment of flood risk. This kind of situation is caused by a variety of reasons, one is a lack of risk awareness, the construction unit may not fully realize the subway construction process may face the risk of flood, especially in the context of climate change and extreme weather events increasingly frequent background, which leads to decision makers failed to flood risk assessment as a necessary part of the subway construction project. Second, in the planning and design stage of subway projects, the flood risk assessment is ignored or simplified. Third, the regulations and policies are not perfect, and the lack of clear regulations or policies requires that the subway construction must carry out flood risk assessment.

2.2.2. Inadequate consideration of the engineering design

The design of subway engineering is vital and directly related to its ability to cope with natural disasters. If the flood risk is not accurately identified and assessed in the process of safety risk assessment of construction projects, or the assessment results are not fully paid enough attention to, the separated water retaining wall may not be included in the engineering design. This stems from the risk assessment may failing to take into account surrounding environmental changes and possible future developments, leading to a lack of prospective design.

2.2.3. Flood risk of large-scale underground space construction

In general, the subway interval between both ends of the tunnel and often station or wind shaft foundation pit connection, under normal circumstances, the interval of the mouth of the foundation pit surrounding set not less than 1m flood control wall fully closed, used in the channel before heavy rainfall to block, the tunnel of precipitation, only consider a single pit area with about 50KW pump, a single tunnel hole equipped with 1.5 meters high sandbags enough to deal with any degree of heavy rainfall.

But the local station and other underground space project construction at the same time, underground space interconnected, cannot do completely closed isolation, subway station foundation pit drainage capacity calculation if only consider the station foundation pit depth and area, will not be able to meet the requirements of flood drainage, encounter sudden rainstorm weather, is bound to cause a lot of water foundation pit water, resulting in floods.

2.2.4. Flood control measures are not in place

If the construction unit of extreme weather harm seriously enough, lead to the site of the conventional foundation pit flood control measures such as pumping and drainage pump, sandbags and high extreme rainstorm weather, likely unable to effectively cope with beyond the historical value of precipitation, especially in the grid power due to rising water tripping power distribution system can not work, may lead to the pump and other equipment cannot work, tend to further speed up the water flooding interval disaster.

2.2.5. Insufficient emergency capacity of the construction site

Flood rescue scene often appear in one of the problems is that the emergency equipment (mainly pump) basic rely on external power supply, so in the absence of independent standby power supply or generator, once the network power supply interruption, the key equipment cannot operate, this seriously weakened the efficiency of the emergency response, further exacerbated the water problem.

This situation reveals the possible problems in the underground construction site management of the subway project. First, construction workers may not receive sufficient emergency response training and lack the necessary experience and skills in how to effectively carry out emergency work in the case of flood disaster. Secondly, the construction site may not fail to carry out regular emergency drills, or the content and scope of the drills are not comprehensive enough to fully consider various potential emergencies. This leads to the strangeness of the implementation process of emergency measures and the inability to act quickly and effectively.

2.2.6. Lack of information and technology application

Although modern science and technology and information systems have powerful risk prediction and early warning functions, there are often cases where information resources are not fully utilized or technical means are not fully utilized, leading to the failure to successfully predict and prevent the risk of water backflow.

3. Risk Prevention and Control Countermeasures of Flood in Underground Construction in Coastal Areas

3.1. Implementation of Flood Risk Identification, Assessment and Disaster Prevention Planning

In the process of subway construction, risk assessment and disaster prevention planning are the key links to ensure the project safety and smooth urban traffic. Comprehensive risk identification and assessment can provide a solid foundation for the safety of subway construction; similarly, targeted disaster prevention planning based on the results of risk assessment is crucial.

3.1.1. Carry out flood risk identification and assessment

Risk identification and assessment are the premise and foundation of flood risk prevention and control. In the early construction of subway underground engineering, may be flooding to comprehensive risk identification and assessment of the area, including the geological conditions, hydrology, meteorological data and the subway line environment of further analysis, to accurately identify the area that may be affected by the flood, and assess the damage to these areas, so as to determine the potential risk points and weak links.

At this stage, it is necessary to carry a detailed investigation and analysis of the landform and hydrogeological conditions of the construction area. Before the flood, the model and direction of the municipal pipe network should be found, the pipe network around the foundation pit should be comprehensively investigated, and the position relationship between the pipeline and the foundation pit of the foundation should be clarified. Establish a scientific risk assessment model to simulate and analyze the potential impact of different flood scenarios in the construction area; collect and analyze the historical flood event data to predict the possible future risk trends. Based on these information, the construction party can assess the possible threat of flooding in the construction area, develop a targeted risk assessment report, and formulate corresponding flood control measures accordingly.

Each construction unit shall make a "one flood control map", clarify the category and location of flood control risk sources, the location of emergency materials reserve, emergency rescue procedures, etc., and post them in eye-catching positions on the site.

3.1.2. Implement subway disaster prevention planning to improve urban resilience

The disaster prevention planning of subway construction is not only related to the safety of the project itself, but also an important part of the urban resilience governance theory. Resilience governance emphasizes that urban systems should be able to adapt, absorb and recover quickly in the face of disasters and challenges. In subway projects, this means not only assessing the risk of flooding, but also improving the resilience of the entire city's transportation network through scientific planning and design.

On the basis of flood risk assessment, the planning suggests that the concept of resilience management should be integrated to enhance the ability of the subway system to withstand natural disasters such as floods. Land use planning should avoid the construction of subway facilities in high-flood risk areas, while planning buffer zones or green infrastructure, such as rainwater gardens and wetland parks, which not only improve the natural flood storage capacity, but also increase the diversity of ecosystems and green space in the city.

Urban construction planning should ensure that the subway construction is coordinated with the urban drainage system, and that the toughness of key parts such as subway entrances and ventilation Wells can be improved by setting up flood control measures such as waterproof doors and automatic pumping system. Drainage system planning should take into account the additional water flow during and after the operation of the subway, and design efficient drainage schemes to ensure that water can be effectively removed in extreme weather conditions and reduce the impact on urban operation.

In addition, subway construction disaster prevention planning should also include the formulation of emergency plans, such as evacuation plans during flood warning, emergency material reserves and the allocation of rescue teams. These measures can help improve the response speed and resilience of cities in the face of flood disasters, ensure the safety of subway projects and smooth urban traffic, so as to protect the safety of people's lives and property, promote the sustainable development of the city, and improve the overall resilience of the city and the ability to respond to natural disasters.

3.2. Improve the Flood Disaster Prevention and Control System

Based on the results of subway project risk assessment, a complete set of flood risk prevention and control system should be established, including early warning mechanism, responsibility system, emergency plan and material support.

3.2.1. Establish a comprehensive monitoring and early warning network

The subway construction project needs to establish a comprehensive comprehensive monitoring and early warning network, which should integrate real-time meteorological data, hydrological monitoring information and geological changes.

Through sensors and monitoring equipment installed in the construction site and surrounding areas, such as rain gauge, water level monitoring station and water seepage detection system, key indicators such as rainfall, groundwater level and soil humidity can be continuously monitored; infrared night vision probe should be set in the foundation pit near the river (ditch), and the pumping equipment shall follow up synchronously. In addition, the construction unit works closely with the local meteorological departments to access the advanced weather forecast models, which can predict the extreme weather events in advance and provide valuable early warning time for the construction party. The establishment of such a monitoring and early warning network can not only find out the potential flood risk in time, but also provide scientific data support for the construction party, so as to formulate effective countermeasures.

3.2.2. Implement the responsibility system for flood control and drainage

The construction unit shall implement the guarantee system of key flood control sites, and each flood control site shall assign special personnel to monitor them in real time. Each supervision unit should establish a hidden trouble investigation mechanism, and establish a problem database for the hidden trouble found before flood and flood season, track and close. Each general contractor shall establish a linkage mechanism of each construction unit in flood season, and unify the emergency team and material deployment. All construction units shall establish a joint prevention mechanism with pipe network property rights units, river management units, line operation units, etc. All units shall be equipped with a full-time flood control commissioner in the flood season. Each commissioner is responsible for the investigation and treatment of hidden dangers in flood season, information reporting and emergency response in flood season.

3.2.3. Formulate emergency plans for flood disasters

The preparation of the emergency plan is the core of the emergency preparation for the flood disaster in the subway construction. According to the risk assessment results, detailed emergency plans shall be formulated, which shall include the classification of flood disaster, early warning mechanism, emergency response process, personnel evacuation plan and resource allocation strategy. In the preparation of contingency plans, specific measures should be taken into account in different flood disasters, such as the foundation pit flooding, tunnel water, equipment damage, etc. The plan should also specify the responsibilities and tasks of personnel at all levels to ensure that they can be implemented quickly and effectively in an emergency. In addition, the emergency plan should be updated and rehearsed regularly to adapt to the changes of the construction progress and the external environment, and the flood control drill should be carried out at least once before the flood season every year.

3.2.4. Reserve of emergency supplies and equipment

In order to deal with the possible flood disaster, the subway construction site should reserve the necessary emergency materials and equipment according to the emergency plan. This includes but is not limited to sandbags, tarps, mobile pump stations, emergency generators, life jackets and first aid kits, among which the mobile pump station must be high power and high lift. According to the depth of the foundation pit and the area of the underground space project, the head and pumping capacity of the pumps are calculated in advance to ensure that the number of power meters equipped with pumps meets the drainage requirements in flood season.

These materials and equipment shall be stored at the emergency supplies deployment point, easy to obtain and regularly inspected and maintained, to ensure that they are in good working condition. These supplies and equipment should be quickly deployed to critical locations so that they can be used immediately when a flood occurs.

Through the implementation of the above measures, the subway construction's ability of dealing with the flood disaster in the face of the flood disaster can be significantly improved, and the impact of the disaster on the construction safety and the project progress can be reduced. The construction party should fully realize the importance of emergency preparedness, and take it as an important part of the construction management, to ensure the smooth progress of the subway project and the safety of the surrounding communities.

3.3. Optimize the Engineering Design and Construction Adjustment and Prevention

In the process of engineering design and construction, the flood risk should be fully considered, and the corresponding design and construction adjustment and preventive measures should be taken.

3.3.1. Optimize the engineering waterlogging prevention design

In the design stage, the risk of flood should be considered, and the adaptable design should be adopted, such as setting enough drainage facilities, raising the standard of foundation pit water resistance, and designing a removable temporary water retaining structure, etc. The flood control design should be considered in multiple stages during the construction of the station foundation pit and the construction of adjacent sections. Design measures should also be treated in different levels, local measures with high risks should be strengthened, and local measures with small risks should be weakened.

(1) Flood control design during the construction stage of the main foundation pit

It is mainly to prevent surface rainwater backflow and groundwater outside the envelope into the foundation pit. The depth of surface water can be determined according to the survey report. In the preliminary design stage, we will often go to the site, and the survey is basically carried out in sunny days. It is suggested that we can go to the site in rainy season to provide reliable basis for the design. According to the depth of water, determine the height of the retaining wall on the pile top above the ground. Of course, the higher the retaining wall, the better. Because of the surface terrain fluctuation, the thickness of the water around the foundation pit will not reach a certain height and then continue to rise and flow to other areas, so it is not recommended to increase the height of the concrete retaining wall indefinitely.

During the construction of the main structure, a separate water retaining wall should be set up in the construction stage of the main project and ancillary works, to form an independent space inside the station and outside the station, and 400mm high brick retaining block should be set around the reserved holes of the upper stairs, so as to prevent rainwater water from entering the next floor of the subway.

(2) Flood control design during the construction period of the adjacent sections

The surface water is mainly the height of the shield hole and the retaining wall of the excavated hole, and the groundwater is mainly the opening of the side wall of the main structure at the interface between the main body and the auxiliary body. According to the severity of surface water, engineering hydrogeology, drainage pipes and retaining piles, it is suggested that the flood control measures in local areas of the station should be divided into three grades from strong to weak. If the flood control level is level 1, the retaining wall of the ground structure should be appropriately raised according to the ground water height in previous years; 250mm thick retaining wall should be added at the interface between the auxiliary and the main structure, and the concrete strength grade is C30. If the flood control level is level II, the retaining wall of the ground structure should be raised according to the ground water height in previous years; and 100mm thick concrete should be added at the opening between the auxiliary and the main structure. The flood control level is three areas, the design does not need additional strengthening.

3.3.2. Take engineering adjustment measures when necessary

Long-term countermeasures focus on fundamentally reducing the risk of flood, of which engineering adjustment measures are an important part. Project adjustment measures include improving the drainage system, strengthening the dredging and regulation of river channels, and building flood storage areas. These measures can effectively improve the regional flood resistance capacity and reduce the impact of flood disaster.

If there are many rivers or lakes (Jin'an River, Wulong River, etc.) near the stations of the line, there is more possibility that flood disaster will occur after a large amount of precipitation in the rainy season, causing foundation pit backfilling accidents. Therefore, the construction unit should take into account the possibility of this risk before carrying out the scheme and site leveling construction.

At the same time, during the construction process, the construction plan and methods should be adjusted in time according to the meteorological changes to avoid the key construction during the high flood season.

3.3.3. Take effective waterlogging prevention construction measures

During the construction process, a series of effective waterlogging prevention measures should be taken to reduce the impact of flood disaster. First of all, the design of the flood control needs should be taken into account, such as setting up enough drainage facilities, improving the waterproof standard of the foundation pit, and designing a removable temporary water retaining structure. In the excavation stage of the foundation pit, the stability of the retaining structure should be strengthened to prevent the structural damage due to the flood impact. At the same time, the construction site should be set up with intercepting ditches and water collection Wells, to ensure that the rainwater can be discharged quickly and effectively.

In the flood season construction, all the gaps and the entrance of the tunnel section are blocked by the "hard flood control baffle + color strip cloth cover + sandbag plugging" way, the three are indispensable, forming a barrier of water, color strip cloth seepage prevention, sandbag plugging trinity waterproof barrier. Reserve a pumping pump after the barrier to draw out the remaining water. The height of the flood control body should not be less than 2 meters. Flood control baffle, color strip cloth and sufficient number of sandbags must be stored in the flood control gap and the interval hole in advance. In addition, for the construction of underground space, the emergency drainage system and waterproof partition should be considered to prevent flood irrigation.

3.3.4. Consider the extreme rainstorm weather, and take preventive measures in advance

In the process of urban subway construction, because the station is uncapped and there is a gap, it will become a water gushing channel, and the water will pour into the interval tunnel. The flooding of the interval tunnel often means that the equipment and facilities in the tunnel soak water. Before the extreme rainstorm event, although the rainstorm warning is issued, when the precipitation exceeds a certain threshold, the traditional flood control measures will no longer be effective, which requires the construction party to have more advanced and efficient emergency measures.

For the underground large space project, referring to the actual situation of the coastal express line project, two kinds of holes can be adopted at the receiving end of the shield tunnel.

Method one, the rear cover of the steel sleeve to cover the tunnel hole is completely closed, and the rear cover is pressed on the pipe piece with the crane + excavator to do the support and sealing work. The position of the tunnel entrance for the flood control wall is used to prevent the tunnel flooding under bad weather conditions, and the rear cover is installed and supported.

The sealing effect of this method is reliable, which can maximize the tunnel flooding under extreme weather conditions, but the cycle is long, it usually takes a day to perform, the time is slightly urgent, and the tunnel needs to be removed after the flood crossing, which has certain limitations.

Method two, in order to be more efficient and safe to achieve the purpose of the hole flooding, through the flood prevention wall can meet the convenient, fast and safe flood control purpose. That is, the reinforced concrete structure is poured to prevent the flooded retaining wall at the entrance of the cave, and the idea of connecting the safety door of the passage is used, and the sealed safety door is installed. Normal construction operations can be carried out before extreme severe weather. Before the rainstorm comes, you can quickly close the safety door, and the requirements for manpower and material resources are minimized.

After the completion of the construction of the flood control wall, it can eliminate the impact of severe weather such as typhoon and heavy rainfall on the tunnel to the maximum extent. It is easy to operate and complete the closure of the flood control door to close the tunnel and prevent any heavy rainfall invasion. However, due to the reduction of ventilation area at the tunnel entrance, it is necessary to consider the construction ventilation in the tunnel and strengthen the installation of ventilation facilities in the tunnel, especially the heat dissipation of the freezing station in the construction stage of the contact channel, so as to prevent the equipment failure from affecting the freezing effect of the contact channel.

3.4. Establish a Long-Term Monitoring and Maintenance Mechanism

In the risk prevention and control of flood in subway construction, the establishment of long-term monitoring and maintenance mechanism is an important guarantee to ensure the effective operation of flood control and drainage facilities. Through continuous monitoring and timely maintenance, the potential problems can be found and solved in time, so as to effectively prevent and reduce the occurrence of flood disasters.

3.4.1. Regular inspection and maintenance to ensure the normal operation of the flood control and drainage system

Regular inspection and maintenance of key facilities such as levee and drainage system are the basis to ensure their normal operation. Special inspection should be organized before the flood season and every typhoon flood warning, including evaluating the structural integrity and functional performance of the facilities, and timely find and repair the damaged or aging parts. Regular inspections can ensure that facilities can play their intended role in the face of extreme weather and floods, preventing floods from breaking into the subway system. At the same time, the maintenance work should also take into account the daily operation of the facilities to ensure that the drainage system is unimpeded and avoid waterlogging caused by blockage and other problems.

3.4.2. Dynamic monitoring of hydrogeology

Monitoring surrounding water and geological changes is critical to timely detection of potential risks. Through the monitoring of hydrological conditions such as groundwater level, river water level and rainfall, as well as the observation of geological conditions such as geological stability and soil humidity, the risk of flood can be assessed and early warned. Environmental monitoring is not only helpful to predict possible flood disasters, but also to guide flood control and drainage measures in subway construction and operation.

3.4.3. Apply advanced technology to improve the efficiency of flood monitoring and early warning

The introduction of advanced monitoring technology and equipment can significantly improve the accuracy and timeliness of monitoring and early warning. For example, the use of remote sensing technology, intelligent sensors, automatic water level monitoring system, UAV inspection, etc., can achieve real-time monitoring of flood control and drainage facilities and the surrounding environment. These technologies can provide high-precision data to help managers quickly respond to flood risks and take timely response measures. At the same time, the technology update also means that big data analysis, artificial intelligence and other means can be used to conduct in-depth analysis of the monitoring data, so as to more accurately predict the occurrence and development trend of flood disasters.

To sum up, through the establishment of long-term monitoring and maintenance mechanism, the flood control and drainage facilities in the subway construction can always be in a good operation state, and effectively prevent and reduce the occurrence of flood disasters. This is not only of great significance to ensuring the safety of subway projects and the smooth flow of urban traffic, but also plays a positive role in improving the city's ability to cope with natural disasters.

4. Conclusion

The exploration of flood risk cause identification and prevention strategies for subway underground construction in coastal areas reveals the complex challenges faced by urban infrastructure development in the era of climate change. This study highlights the critical importance of adopting a comprehensive approach to flood risk management in subway construction projects, particularly in vulnerable coastal regions. Key findings and recommendations include:

(1) The need for thorough flood risk identification and assessment in the early stages of project planning, considering

both external factors (such as geographical conditions and climate) and internal factors (like design inadequacies and insufficient risk awareness).

(2) The importance of implementing robust flood disaster prevention and control systems, including comprehensive monitoring and early warning networks, clear responsibility systems, and well-prepared emergency plans.

(3) The necessity of optimizing engineering design and construction methods to enhance flood resilience, including adaptive design strategies and the implementation of effective water-logging prevention measures.

The crucial role of establishing long-term monitoring and maintenance mechanisms to ensure the continued effectiveness of flood control and drainage systems.

These strategies not only contribute to the safety and reliability of subway systems but also play a significant role in enhancing overall urban resilience. By integrating advanced technologies, interdisciplinary approaches, and forward-thinking planning, cities can better prepare for and mitigate the impacts of flood risks associated with subway construction and operation.

The findings of this study have broader implications for urban development and sustainability. As cities continue to expand and modernize their transportation infrastructure, the lessons learned from flood risk management in subway construction can inform wider urban planning and disaster preparedness strategies. This holistic approach to risk management is essential for creating resilient, sustainable cities capable of withstanding the challenges posed by climate change and extreme weather events.

In conclusion, effective flood risk management in coastal subway construction requires a multifaceted, proactive approach that combines thorough risk assessment, innovative engineering solutions, and ongoing monitoring and maintenance. By adopting these strategies, cities can not only ensure the safety and efficiency of their subway systems but also contribute to the overall resilience and sustainability of urban environments in the face of evolving climate challenges.

References

[1] Dutta D, Takamura H, Herath S. Understanding flood behavior in underground facilities for urban flood risk management [J]. New Technologies for Urban Safety of Mega Cities in Asia, 2003(10):201-212.

[2] Inoue K, Toda K, Nakai T. Simulation on the inundation process in the underground space [J]. Annual Report of Disaster Prevention Research Institute, Kyoto University, 2003(46B): 275-286.

[3] Ishigaki T, Toda K, Baba Y. Experimental study on evacuation from underground space by using real size models [J]. Annual Report of Disaster Prevention Research Institute, Kyoto University, 2005(48B):639-646.

[4] Jabatan Pengairan dan Saliran Malaysia.Guideline on flood prevention for basement car parks [R]. Malaysia: JPS, 2006.

[5] Toda K, Kawaike K, Yoneyama N, et al. Underground inundation analysis by integrated urban flood model [M]. Advances in Water Resources and Hydraulic Engineering, Springer Berlin Heidelberg, 2009.

[6] Lind, N.C., Pandey, M.D., & Nathwani, J. (2009). Assessing and affording the control of flood risk.Structural Safety, (2), 143-147. https://doi.org/10.1016/j.strusafe.2008.06.013

[7] Ding, L., Yu, H., Li, H., Zhou, C., Wu, X., & Yu, M. Safety risk identification system for metro construction on the basis of construction drawings. Automation in Construction, Volume 27, pages 120-137. (2012).

[8] Dharmapalan, V., Gambatese, J., Fradella, J., & Vahed, A.M. (2015). Quantification and assessment of safety risk in the design of multistory buildings [J]. Journal of Construction Engineering and Management, 141(4).

[9] A.G.Protosenya et al. Justification of safe plugging options for subway tunnels flooded in an accident based on risk assessment [J]. Applied Engineering Research. 2016,11(12). pp 7897-7906

[10] Edwar Forero-Ortiz et al. Flood Risk Assessment in an Underground Railway System under the Impact of Climate Change—A Case Study of the Barcelona Metro [J]. Sustainability. 2020, 12,5291

[11] Zheng Wan et al. Overview of technical research on safety monitoring, early warning, and risk assessment for underground structural engineering construction [J]. Emergency Management Science and Technology. 2023, 3:18