Analysis of risk sources and protective measures for cable laying in built tunnels

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Abstract. For rational development and comprehensive utilization of urban underground space, improve the utilization rate of urban highway tunnel, it is considered to lay power cables on the basis of built tunnels. However, there are certain hidden risks. Therefore, the following research is carried out to identify and implement corresponding protection measures for risks: first, the structural composition of the cable tunnel is analyzed, meantime, the safety risk events of the historical cable tunnel are studied, and then the various risk sources existing in the laying of the power cable system using the built tunnel are identified. Based on this, the corresponding protective measures are put forward in order to improve the reliability of the cable laid in the existing tunnel.

Keywords: built tunnels, cable, risk sources, protective measures.

1. Introduction

With the continuous development of China's economy and the accelerated urbanization level, it is expected that the urbanization rate of China will reach an astonishing 80% by 2050 [1,2], which also leads to many related problems, such as intensified conflict between man and land, traffic congestion, and so on. In the current situation that the urban space can no longer meet the needs of human development, it is an inevitable trend of the world's urban development to migrate and expand the urban development space from the ground and upper space to the underground, which is also an effective way. As the main means of transportation of urban roads, underground traffic tunnel has a very positive significance to reduce the land use of urban roads and relieve the pressure of urban traffic. Moreover, the use of built underground traffic tunnel to lay power cables has been widely used in foreign countries. High voltage cable plays an important role in urban planning and development. The cable laying along with the highway tunnel broadens the way to implement the planning and construction of the power grid, meets the needs of the development of the power grid, promotes the innovation of ideas, methods and technologies, and fully reflects the construction idea of the power system compatible with the environment and saving land.

The research on laying cables in existing tunnels in China has just started. High voltage power cables in urban core areas are mostly laid in tunnels with high reliability, but the one-time investment is large, the construction cost is high, and they are vulnerable to the underground environment, which is not convenient for maintenance. Cao [3] developed a real-time monitoring system for the temperature of the power cable tunnel, which can timely warn and alarm the fire occurred on the cable. In addition to the risk of the cable itself, some scholars have also studied other parts of the cable tunnel. Based on the improved YOLOv3 algorithm, Song [4] proposed an automatic real-time detection method for cable support tilt detection; Tan [5] designed the deformation monitoring system of the old tunnel which is suitable for service in order to ensure the safety of the tunnel structure; Shi [6] studied the leakage of different types of lining, and developed a device for rapid detection of cable tunnel leakage using infrared thermal imaging technology.

However, most existing cable and tunnel risk studies only focus on a single risk source, which cannot systematically and comprehensively show the risks faced by cable tunnels. In addition, due to the lack of scientific and systematic risk management and analysis means, and the lack of information related to it, the operating unit did not have a comprehensive understanding of its risk status, nor could it grasp its distribution and actual situation in time. In addition, in some complex and unstable

underground environments, manual access to underground cable tunnels for overhaul and maintenance will not only consume human resources, but also may expose personnel to greater risks. Therefore, in order to effectively prevent the occurrence of cable operating fault and cable operating fault accidents caused by power grid, this paper analyzes the use of existing tunnel laying cable faces all kinds of risk source and affect the path, and put forward a series of are very important to the long-term and stable operation of the tunnel and cable protection measures, so as to effectively improve the efficiency of operations, Improve the safety and reliability of operation and maintenance.

2. Basic theory of risk source identification

In the late 19th century, the concept of risk was first introduced into western economics. At present, the method has been widely used in environmental science, safety science, economics, sociology and other fields. However, to date, there is no complete and unified concept of the concept of risk, and there are different definitions in various aspects [7]. For example, American economist Haynes J. defined Risk as a possible loss in his book Risk as an Economic Factor published in 1985 [8]. The American economist F.H. Knight made clear the difference between risk and uncertainty in his book Risk, Uncertainty and Profit in the early 1920s. The Risk Assessment Committee of the Landslide Research Group of the International Union of Geosciences and Sciences defines risk as the possibility and possible consequences of adverse effects on health, property and individuals, which can be expressed by the product of the possibility of occurrence and the possible results [9].

Risk identification refers to the process of systematically and continuously discovering risks and uncertainties through various methods before the occurrence of risks [10]. Risk identification includes risk decomposition, the existence of new risks, the identification of risk factors, the identification of risk events and results, the new risk decomposition, and the establishment of project risk list. The specific process of this study is shown in Figure 1. Risk source identification mainly includes brainstorming method, decomposition analysis method, Delphi method, checklist method and flow chart method [11].

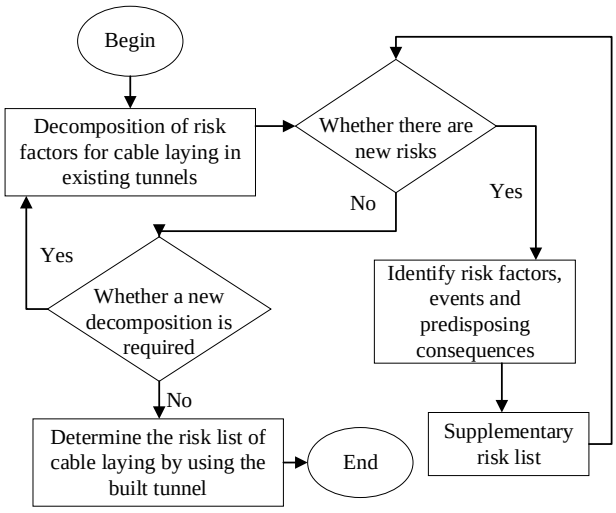


Figure 1. Risk identification process diagram

3. Identification of risk sources using existing tunnel cables

3.1. Identification of Risk Sources

Based on the experience of actual operation and maintenance, and the analysis of the safety risk events of cable tunnels found in the past operation and maintenance process, it is found that the risks mainly exist in the indicators such as cables and supports, power supply system, lighting system,

ventilation system, drainage system, inspection and maintenance, and environmental factors [12-14], as shown in Table 1.

Table 1. Ladder index system of risk sources for cable laying in built tunnels

The first layer	The second layer	The third layer
Risk source of cable laying in built tunnel	Tunnel structure	Water leakage; Cracking damage; Lining corrosion; Structural deformation;
	Cable and support	Partial short circuit of cable; Connector explodes; The steel structure is rusted and corroded;
	Power supply system	Distribution line corrosion; Short circuit of power supply line;
	Lighting system	Failure of lighting circuit and lamps;
	Ventilation system	When the air temperature is too high, the current carrying capacity of the cable decreases; Excessive humidity will aggravate corrosion and affect cable life; Small animals invade;
	Drainage system	Poor drainage results in ponding; Water is poured backward in flood season;
	Patrol and inspection	Harmful gas; Harmful factors of internal environment.; Get an electric shock;
	Environmental factors	Tunnel frost damage; Earthquake disaster; Landslides;
	Other	Traffic accident; Man-made destruction;

3.2. Analysis of Risk Sources

3.2.1. Risk source analysis of tunnel structure

Water leakage. In power cable tunnels, leakage is a common high frequency water damage. According to the water flow and leakage location, it can be divided into top and side drip, leakage, water injection, leakage and other types [15]. Once leakage occurs in the tunnel, it will affect the normal use of electronic equipment, the smooth progress of maintenance work, the stability of the internal structure, and more seriously, it may affect the normal operation of the power cable tunnel.

Cracking damage. The cracking of tunnel structure is caused by the failure of geotechnical investigation, which leads to the destruction of the designed bearing capacity of tunnel. In addition, the selected lining mode will also have a certain impact on the quality of the tunnel structure. At present, the most common structural cracks are mainly transverse cracks, longitudinal cracks and oblique cracks, which are very adverse to the overall safety of tunnel structure.

Lining corrosion. When there are corrosive substances in the environment around the power cable tunnel, the underground water will leak with the structural cracks and leakage, and then corrode the structure, causing lining corrosion problems. At the same time, cement quality and concrete material problems may also lead to tunnel lining corrosion, environmental water with corrosive substances will leak into the structure. If the lining corrodes in the tunnel, the soil will become loose, the strength of the soil layer will be weakened, and the bearing capacity of the lining will be affected.

Landslides. There are many reasons for tunnel collapse, which are characterized by external induction, timely protrusion and multi-stage occurrence. Once there is a collapse, the impact is very huge. It not only seriously threatens the life safety of workers, but also leads to the extension of the construction period, the increase of investment cost, the serious damage of machinery and equipment, and the decline of construction quality. Landslide is a kind of high incidence area, high risk area, it not only brings great danger to the project construction, but also brings bad influence to the society.

Structural deformation. When the tunnel section deformation is too large, it will lead to excessive expansion of the inner joint of the top arch, cracking of the cover beam, and waterproofing failure caused by extrusion of the transverse inner joint.

3.2.2. Risk source analysis of cable and support

The connector explodes. The middle joint of the cable junction box is not crimped and welded loosely; Or due to the unreasonable material of the joint, the joint is oxidized, heated and stuck in operation; In the manufacture of cable intermediate junction box, because the insulation material quality of the intermediate junction box is not up to standard; When pouring the insulating agent, there are air holes in the box, and the cable box is poorly sealed, damaged and leaked. The above factors can lead to insulation breakdown, short circuit, cable explosion and fire.

The steel structure is rusted and corroded. Rust will reduce the bearing capacity, structural instability, maintenance costs and shorten the life of the structure. If the steel structure is not regularly maintained and timely treated, rust spots and scale will increase the corrosion and rust rate of the steel structure, which will not only affect the service life of the steel structure, but also cause potential safety hazards.

3.2.3. Risk source analysis of power supply system

Distribution line corrosion. When groundwater and rainwater leak in the rock soil layer, some corrosive salts will be brought into the power cable tunnel. These salts will cause certain corrosion to the cable lines in the power cable tunnel and damage the power cable channel structure.

3.2.4. Risk source analysis of lighting system

Faulty lighting lines and lamps. The lighting system is damaged and cannot meet the normal and accident conditions, which affects the inspection, maintenance and operation of operators and the monitoring system.

3.2.5. Risk source analysis of ventilation system

When the air temperature is too high, the current carrying capacity of the cable is weakened. Because the heat generated by the cable in use can not be dissipated in time, the temperature in the pipeline increases, the carrying current decreases, so that the cable can not work at full load, resulting in direct transmission losses. At the same time, the high temperature inside the cable trench will cause fire. Some cable tunnels also lay communication, gas and heating pipelines. The rise of temperature in the tunnel has adverse effects on the safe and stable operation of various pipelines, and may even cause various pipeline failures.

Excessive humidity will aggravate corrosion and affect cable life. When the humidity in the tunnel is too high, on the one hand, it will increase the number of ionized gas in the working environment, thus reducing its own thermal insulation performance; In addition, because the temperature is too high, the insulation resistance of the cable itself will be reduced, and the moisture on the cable will also reduce the surface insulation resistance of the cable. These factors will greatly increase the leakage current when the cable fails, and even lead to insulation breakdown, resulting in very serious consequences.

Small animals invade. Since small animals have very little resistance, they can easily short-circuit equipment when they enter the cable tunnel. At the same time, the voltage fluctuation of the whole electrical system will be very violent, leading to secondary accidents, even fire and explosion. In addition, small animals may bite wires and cables, resulting in misoperation or refusal to operate the protection switch. If it is serious, it may lead to safety accidents such as grounding of DC system and open circuit of AC current circuit.

3.2.6. Risk source analysis of drainage system

Poor drainage results in ponding. Due to structural leakage, local outdoor rainfall and other factors, cable tunnel and cable trench large area of water. If this water is not drained in time, the cable can easily become submerged in the tunnel. Long term exposure to moisture will lead to serious corrosion

of cable supports, which may shorten the service life of tunnels and cables due to failure to repair and maintain, or affect the safety of users and staff.

Water is poured backward in flood season. When water seeps into the cable trench, moisture will be generated. If the outer sheath of the cable is broken due to various reasons, the electrical insulation of the cable will be damaged, causing water to enter the cable, leading to cable explosion. Moreover, long-term immersion in water will erode the outer protective layer of the cable, making its phase line contact with water, causing three-phase or three-phase grounding failure.

3.2.7. Risk source analysis of inspection and maintenance

The harmful gas [16]. As a typical closed underground building, the cable tunnel has reduced the oxygen concentration in the tunnel, deteriorated the air quality in the tunnel and increased the harmful gases due to the activities of a large number of exhaust gases, human beings and microorganisms. Moreover, due to the flammability of wires in the tunnel, a large amount of smoke and toxic gas will be generated after combustion, which will worsen the air environment in the tunnel. Long and narrow tunnels will gather high temperature and heat, which will not only corrode cable equipment, but also do great harm to human body.

Harmful factors of internal environment. The internal environment is mainly caused by unreasonable design, unreasonable construction quality, unreasonable later maintenance, terrain change and settlement. When climbing the ladder of Dagong shaft and cable tunnel with deep burial depth to get in and out of the tunnel, the ladder will rust and fall. The wet road surface in the tunnel may slip, scratch the sharp corner of the cable support, and suffocate in the poorly ventilated tunnel.

Get an electric shock. In the tunnel, there are various high and low voltage power supplies, control power supplies, lighting, water pump and fan power supplies. If water leakage and seepage occur due to the quality problems of tunnel construction, the tunnel will be wet and conductive dust, increasing the risk of electric shock.

3.2.8. Risk source analysis of environmental factors

Tunnel frost damage. Frost damage often occurs in tunnels in cold regions. Under low temperature conditions, the water accumulated in the tunnel is easy to freeze, causing equipment icing. At the same time, due to the change of object shape, the surrounding rock will experience frost heaving, which will not only affect the stability and safety of the internal structure of the tunnel, but also hinder the normal function of the cable equipment, causing subsequent safety accidents.

Earthquake disaster. Earthquake is a common natural disaster that can cause destructive impact on concrete structures. Although the earthquake damage degree of underground structures such as tunnels is not as great as that of surface buildings, some expressway and railway tunnels will also suffer from serious damage such as landslide burial, tunnel portal deformation, lining cracking and falling off. Once damaged, it is very difficult to repair. Due to the serious consequences of the earthquake, as the lifeline of the city, the safety of the power tunnel deserves great attention, and corresponding preventive measures should be taken.

4. Prevention Measures for Risk Sources of Cable Tunnel

For cable tunnels, any risk source will affect the safe operation of cable lines and power equipment, and even cause the entire cable tunnel system to break down when the impact is large. In addition, there is a certain contradiction between cable power supply and risk source prevention and control, and risk source prevention and control is imminent. Once the progress of prevention and control is delayed, the hazard level of the risk source will increase. But in the risk source control work, the power cable tunnel can not operate normally. In view of this situation, engineers should have a comprehensive understanding of the risk sources of cable tunnels, take risk elimination as the key work, and take risk source prevention and control as the key work in the project planning and design phase, in order to minimize the probability of risk occurrence. At the same time, engineers also need

to identify the cause and specific location of the risk source, in order to use reasonable means to control the risk source.

4.1. Strengthen Structure Inspection and Reinforcement

Establish a systematic structure detection mechanism, including: routine inspection focusing on observation; Carry out targeted special structural tests regularly. With the help of professional testing institutions, carry out structural stability tests on key cable tunnels, and evaluate the bearing capacity, structural strength, surrounding soil structure and function [17].

4.2. Strengthen the Application of Monitoring Technology

Various types of monitoring sensors shall be added in the tunnel to realize real-time monitoring of tunnel temperature, humidity, tunnel structure deformation, key crack width, ponding and other risk sources, and establish a tunnel danger early warning system [18]. Ensure that the monitoring data can be automatically input into the database, or other collected data can be supplemented and improved manually. After analyzing and processing the data, 3D interactive visual expression is carried out. At the same time, the system also adopts the virtual 3D technology. Through the central monitoring platform, it can intuitively observe all the monitoring information in the 3D state, and realize the 3D interactive function at any time, so as to realize the network remote data access. By setting up the data server, employees can log in to the Internet using their employee accounts to check the tunnel monitoring data and tunnel safety level in real time. When the structural safety risk of a building reaches a certain level, an alarm will be issued.

4.3. Standardized Management of Power Cable Tunnel

Environmental assessment shall be carried out for cable lines, basic data of equipment shall be sorted out, and coordinates, terminals, trenches and well photos shall be collected. Formulate standardized operation management system, including equipment operation analysis, basic data, standing book, etc; Improve the data analysis at each stage, record the operation process and fault status in the report, reflect the operation and fault conditions at each stage in the report, and timely handle key problems. Supervise the site standard operation, carry out field inspection from time to time, further promote the implementation of lean management and cable operation standard system.

4.4. Lean Management of Cable Practitioners

The problems such as unbalanced construction quality and local quality decline are becoming more and more prominent as the power cable operation team becomes larger and larger. Some cable engineering enterprises have insufficient understanding of the quality management and safety of the line, and even allow unqualified personnel to participate in the construction during the peak period, resulting in more and more faults in the line operation. Due to the lack of technical personnel, power cable industry caused great impact on the quality of cable equipment, so should enhance the training of the cable industry, and the relevant experts theory lecture, continuous upgrading of the technical level of workers, to ensure that personnel engaged in power cable engineering can smoothly through the inspection, so as to increase the number of professionals. In addition, it is also necessary to assign responsibilities to specific people and conduct irregular spot checks to further ensure the construction quality of power cables.

4.5. Pay Attention to the Theory and Technology Research of Risk Source Prevention

Due to the variety of tunnel diseases, causes and influencing factors, it is difficult to conduct a systematic theoretical discussion. However, theoretical and mechanism research is the basis of tunnel disease treatment. Taking the leakage of tunnel lining as an example, the causes of leakage and the influence of other factors are analyzed, which can be prevented from the source and effectively improve the reliability of tunnel structure. Therefore, it is necessary to systematically summarize the causes, influencing factors and laws of different types of cable tunnel hazard sources, and

scientifically discuss them theoretically. Through this method, a complete set of risk prevention theory can be gradually established, which plays a great role in risk prevention. At the same time, we should constantly introduce new scientific and technological materials and technologies to provide richer management techniques and means.

5. Conclusion

This paper considers the use of existing tunnels to lay cables, which can not only save ground space, beautify the city appearance, but also improve transmission efficiency. In addition, it is less affected by the outside world, so the power supply is safe, reliable and green. By using the common risk sources of the cable structure laid in the built tunnel, it can be divided into tunnel structure, cable and support, power supply system, lighting system, ventilation system, drainage system, patrol and inspection, environmental factors and other 9 aspects according to the subsystem of the cable tunnel. Through the study, in order to better control the risk source, technical personnel should strengthen the detection and reinforcement of tunnel structure, focus on risk source of the monitoring of the tunnel, strengthen the standardized management of power cable and cable from personnel of course of the lean management, attaches great importance to the theory and technology research for the prevention of risk source in order to prolong the service life of tunnel and cable.

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