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Innovative Practice in the Renovation of Fire Water Supply Systems for Historic Buildings: A Case Study of the Fire Water Supply System Renovation of a Cultural Center

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Abstract: Taking a cultural center as the research object, this paper proposes an innovative scheme balancing cultural relic protection and modern fire safety to meet the renovation needs of fire water supply systems for historic buildings. By in-depth analysis of the building's structural characteristics and fire hazards, adaptive measures such as automatic sprinkler fire extinguishing technology and jet-type automatic tracking fire extinguishing devices are adopted, effectively realizing the unification of fire risk prevention and control and historic style protection. This provides a reference technical paradigm for the fire renovation of similar existing venues.

Keywords: Cultural center; Fire water supply renovation; Historic buildings; Automatic fire extinguishing; Jet-type automatic tracking fire extinguishing device

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1. Introduction

As a national first-class cultural center, the venue undertakes important functions including the research of Mao Zedong's literary and artistic thoughts, intangible cultural heritage protection, and mass cultural services. Its architectural complex integrates traditional sloping roofs with modern glass curtain walls, with a reinforced concrete main structure and high fire load. The fire renovation project launched in December 2024 aims to improve the reliability of the fire water supply system while maximizing the protection of the building's historic style. Combining the unique architectural characteristics and renovation practice of the cultural center, this paper systematically proposes an optimization scheme for the fire water supply system, intending to provide theoretical support and practical reference for the fire safety of historic buildings.

2. Architectural characteristics of the cultural center

2.1. Building overview

Located in Hongtaiyang Square of a city, the cultural center covers a construction area of approximately 3,851 square meters. Adhering to the design concept of "taking root in the earth and emerging dynamically", the architectural complex skillfully integrates traditional sloping roofs with modern glass curtain walls, forming a complex spatial structure. It includes functional areas such as a projection hall, VIP hall, reading room, exhibition hall, collection room, research room, and office. With 3 above-ground floors, a building height of 16.53m, and a fire resistance rating of Grade II, the external outline of the cultural center is shown in **Figure 1**.

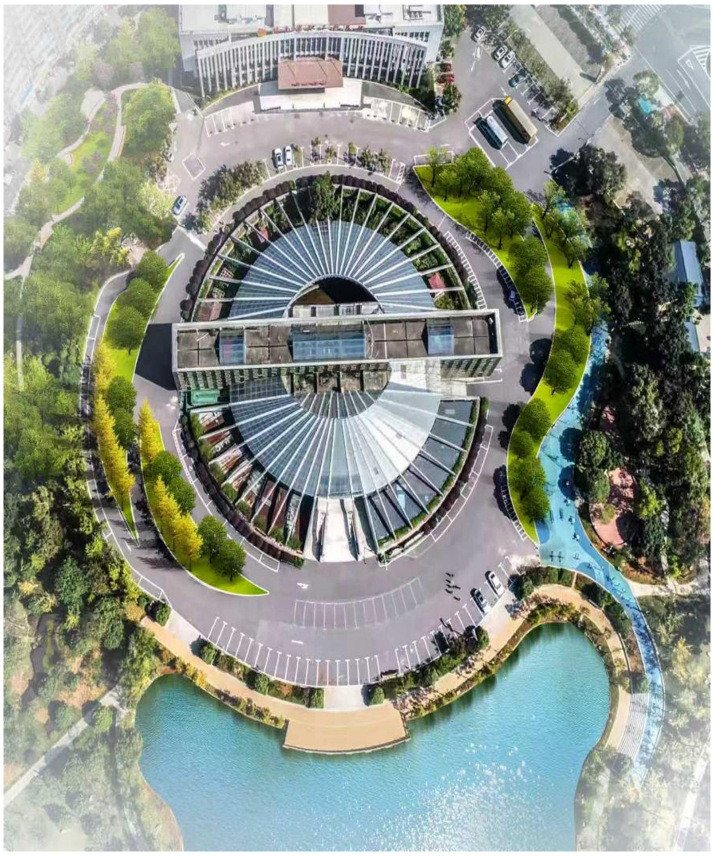

Figure 1. Aerial view of the cultural center

2.2. Materials and structure

The main structure is reinforced concrete, with wooden beam frames in some areas featuring low fire resistance. A large number of wooden materials and other combustible materials are used for internal decoration, and a centralized air conditioning system with supply and return air ducts is installed, resulting in a high fire load. This imposes higher requirements on the response speed and coverage of the fire water supply system [1].

3. Fire protection system and water consumption

In accordance with the current codes General Code for Building Fire Protection and Prevention GB55037-2022 and Code for Fire Protection Design of Buildings (GB 50016-2014) (2018 Edition), the cultural center shall be equipped with fire water supply systems such as an outdoor fire hydrant system, indoor fire hydrant system, and automatic sprinkler fire extinguishing system [2].

Based on the current codes General Code for Fire Protection Facilities GB 55036-2022, Code for Design of Fire Protection Water Supply and Hydrant Systems GB 50974-2014, Code for Design of Automatic Sprinkler Fire Extinguishing Systems GB 50084-2017, and Technical Standard for Automatic Tracking and Positioning Jet Fire Extinguishing Systems GB51427-2021, the design flow of the outdoor fire hydrant is 30 L/s with a fire duration of 2h, corresponding to a water consumption of 216m^3; the design flow of the indoor fire hydrant is 15L/s with a fire duration of 2h, corresponding to a water consumption of 108m^3; the design flow of the automatic fire extinguishing system (including the automatic sprinkler system and jet-type automatic tracking fire extinguishing system) is 30L/s with a fire duration of 1h, corresponding to a water consumption of 108m^3; the total water consumption for a single fire extinguishing is 432m^3.

4. Main hidden dangers of the fire water supply system

4.1. Insufficient reliability of fire water sources

The cultural center has introduced one DN150 water pipe from each DN250 municipal water pipe on surrounding different municipal roads, forming a DN150 annular water pipe within the land red line to supply domestic and fire water for the project. The water pressure of the municipal water supply network near the land is approximately 0.30Mpa (relative to the elevation of the first-floor ground of the cultural center). The original indoor and outdoor fire water supply systems of the cultural center both adopt municipal water sources for water supply. However, the municipal water supply flow cannot meet the water supply requirements of the indoor and outdoor fire water supply systems simultaneously, and the pressure fails to meet the requirements of the indoor fire water supply system [3].

In the event of an emergency such as a fire, key fire extinguishing facilities including indoor fire hydrants and automatic fire extinguishing systems will completely fail due to lack of water. The complete cutoff of the fire water source will undoubtedly greatly accelerate the spread of the fire, significantly increase the difficulty of firefighting and the risk of personnel evacuation, and pose a serious threat to the life safety of personnel in the center and the protection of cultural property [4].

4.2. Lack of automatic fire extinguishing systems in local spaces

No automatic fire extinguishing systems are installed in areas such as the main entrance lobby, vestibule, and exhibition hall on the second floor with a clear height of 8–12m. Once a fire breaks out in these areas, the initial fire is difficult to detect and extinguish in a timely manner, and the fire will spread rapidly.

4.3. Lack of elevated fire water tanks and pressure stabilization devices

Due to the complex external structure formed by the clever integration of traditional sloping roofs and modern glass curtain walls of the cultural center, it is impossible to install elevated fire water tanks and pressure stabilization devices on the roof. This easily results in the lack of initial fire extinguishing water in the fire system and failure to maintain the pressure of the system under the quasi-working state.

4.4. Pipe network aging and layout defects

Old pipes, valves, and other fire protection facilities have hidden dangers of corrosion and leakage. The layout of the indoor fire hydrant pipe network does not form a closed loop. If a failure occurs at a key node, the overall water supply will be affected [5].

5. Design of the fire water supply renovation scheme

5.1. Optimization of the reliability of fire water sources

Through the analysis of the current fire protection data of the cultural center, the municipal water supply can meet the flow and pressure requirements of the outdoor fire hydrant; therefore, the outdoor fire hydrant system maintains the current situation and adopts municipal water sources for water supply. To solve the water source problem of the indoor fire hydrant and automatic fire extinguishing system, there are the following two schemes.

5.1.1. Scheme 1

Construct a new fire water tank and water pump room at an appropriate location around the cultural center, and install fire pumps to meet the water supply requirements of the indoor fire system of the cultural center.

5.1.2. Scheme 2

Share the existing fire water supply facilities such as the fire water tank, fire water pump room, and fire pumps with surrounding buildings. After on-site investigation, the Wuyi Hotel, located approximately 40 meters east of the cultural center, completed its fire renovation in 2023. A fire water tank and water pump room have been installed on the first basement floor (approximately 4.0 m lower than the first-floor ground of this building). The effective volume of the fire water tank is $222m^3$ (see **Figure 2** for the layout of fire protection facilities in Wuyi Hotel). The water pump room is equipped with 2 indoor fire hydrant pumps (Q = 15L/s, H = 75m, N = 37Kw, one in use and one standby) and 2 automatic sprinkler pumps (Q = 30L/s, H = 80m, N = 45Kw, one in use and one standby). However, the Wuyi Hotel and the cultural center are managed by different units and have different property rights [6].

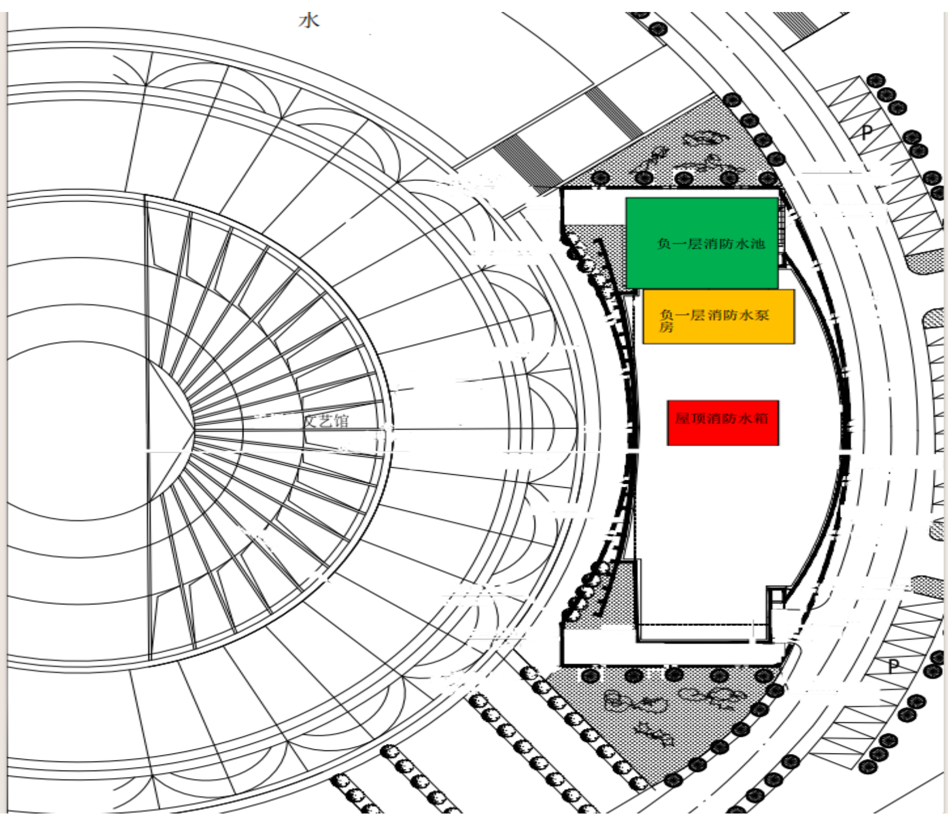

Figure 2. Schematic diagram of the layout of fire protection facilities in the cultural center and Wuyi Hotel.

Since excavation is not allowed in Hongtaiyang Square where the cultural center is located to reduce damage to the outdoor current situation and save costs; after multiple rounds of communication with the construction unit and relevant departments, Scheme 2 was finally determined, and the automatic sprinkler pump was replaced with a fire pump with parameters (Q = 30L/s, H = 105m, N = 55Kw).

At the same time, the existing 18m^3 effective water storage fire water tank on the roof of Wuyi Hotel (the lowest effective water level of the water tank is 1.167m higher than the highest point of the cultural center's roof) and the pressure boosting and stabilizing equipment for the fire hydrant system are utilized. The fire pressure boosting and stabilizing equipment can ensure that the static pressure at the most unfavorable fire hydrant of the cultural center is not less than 0.15Mpa; a new set of pressure boosting and stabilizing equipment for the automatic fire extinguishing system (XW(L)-II-1.0-74-ADL, equipped with 2 ADL3-19 pressure stabilizing pumps, one in use and one standby, Q = 1L/s, H = 74m, N = 1.5KW; 1 air pressure tank with an effective volume of 900L; the starting pressure of the pressure stabilizing pump is 0.70MPa, and the stopping pressure is 0.80MPa) and a flow switch (the signal is connected to the fire control room, and when the flow reaches 1.3L/s, the fire pump in the fire water pump room is started) are added. The pressure boosting and stabilizing equipment for the automatic fire extinguishing system can ensure that the static pressure at the most unfavorable sprinkler of the cultural center is not less than 0.15Mpa, and the pressure at the most unfavorable jet-type automatic tracking fire extinguishing device of the cultural center is not less than the working pressure of 0.70MPa.

5.2. Supplementing the missing automatic fire extinguishing system

For areas such as the main entrance lobby, vestibule, and exhibition hall on the second floor with a clear height of 8–12m, since no ceiling is installed on the top and the architectural top shape is complex with irregular glass used for the daylighting roof, it is difficult to install an automatic sprinkler fire extinguishing system.

In response to this situation, the design adopts a jet-type automatic tracking fire extinguishing system for protection. Automatic tracking and positioning jet fire extinguishing devices with built-in ultraviolet-infrared composite fire detectors (single-unit design flow 10L/s, working pressure 0.70MPa) are arranged such that any part of the protected area can be reached by two fire extinguishing devices simultaneously. Since the main entrance lobby, vestibule, exhibition hall and other areas on the second floor are separated from other spaces by firewalls or Class A fire doors. After a fire breaks out anywhere, the jet-type automatic tracking fire extinguishing system and the automatic sprinkler fire extinguishing system will not act simultaneously. Therefore, the design flow of the jet-type automatic tracking fire extinguishing system is 20L/s.

5.3. Replacement and upgrade of the pipe network system

The replacement of old pipes, valves, and other fire protection facilities must be carried out under the guidance of scientific and prudent principles. Among these, the three core principles of "minimum intervention", "style coordination", and "concealed protection" are crucial to ensuring that the replacement project not only effectively solves safety problems but also takes into account environmental, historical, and aesthetic values [7].

The core essence of the "minimum intervention" principle is to minimize the disturbance of the replacement project to the existing environment and building structure. During the design, detailed on-site investigation and accurate drawing review should be conducted to clarify the specific location, model specifications, and surrounding environment of aging and damaged pipes and valves, avoiding unnecessary damage caused by blind implementation [8].

The “style coordination” principle is more reflected in the replacement of pipes and valves, which should not only meet functional restoration but also pay attention to the harmonious unity with the overall architectural style, historical context, and landscape environment.

The “concealed protection” principle is an important guarantee for realizing the organic unity of function and aesthetics, safety and long-term effectiveness [9]. This means that during the replacement of pipes and valves, they should be installed in concealed locations as much as possible, or effective protective measures should be taken to prevent them from external physical damage, chemical corrosion, or natural environmental erosion.

In summary, combined with the actual situation of the specific project, refined design can eliminate potential safety hazards, improve fire protection capabilities, and at the same time maximize the protection of the existing environment, continue the historical context, beautify the urban landscape, and realize the organic unity of functionality, safety, and humanism [10].

6. Conclusion

Through technological innovation and management optimization, the fire water supply renovation project of the cultural center has successfully achieved the organic unity of historic building protection and modern fire safety. After the renovation, the fire risk of the system has been significantly reduced, and a safer and more comfortable experience environment has been provided for visitors. In the future, it is recommended to establish a long-term maintenance mechanism, regularly carry out fire drills and facility inspections to ensure the sustainability of the renovation effect. In addition, active exploration can be made to build a smart fire platform, integrating advanced technologies such as the Internet of Things and big data to further improve the intelligent level of fire safety management for historic buildings.

Disclosure statement

The author declares no conflict of interest.

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