Research on Energy-Saving and Water-Saving Technologies in the Water Supply and Drainage Design of Civil Buildings

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Abstract: Against the backdrop of the "dual carbon" goals and the green development of buildings, the water supply and drainage system in civil buildings serves as a crucial link in water and energy consumption. The application of energy-saving and water-saving technologies is of great significance for reducing building operating costs and enhancing resource utilization efficiency. Therefore, during the design phase of the water supply and drainage system, it is essential to actively incorporate principles of environmental protection, energy conservation, and water conservation to effectively improve the implementation effectiveness of engineering projects and bring richer economic benefits and greater social recognition to enterprises. This paper focuses on the water supply and drainage design of civil buildings, analyzing from the two dimensions of water saving and energy saving, and proposes application measures for water-saving and energy-saving technologies in building water supply and drainage design, aiming to provide certain references for relevant practitioners to effectively conserve water resources.

1. Introduction

With the acceleration of urbanization in China, the scale of civil buildings continues to expand. As a fundamental support for building functions, the water supply and drainage system has increasingly prominent issues of water resource waste and energy consumption. Against this backdrop, the Green Building Evaluation Standard (GB/T 50378) explicitly includes the energy saving and water saving of water supply and drainage systems as core indicators for building green evaluation, driving the industry to transition from "traditional design" to "efficient energy-saving and water-saving design." Therefore, sorting out energy-saving and water-saving technology paths suitable for different types of civil buildings and clarifying key points for technology application are of practical necessity for improving the operational efficiency of building water supply and drainage systems and facilitating the low-carbon development of the construction industry.

2. Energy-Saving Technologies in the Water Supply and Drainage Design of Civil Buildings

2.1 Energy-Saving Optimization Design of the Water Supply and Drainage Pipe Network System

The water supply and drainage pipe network, as the core carrier for system transportation, requires energy-saving optimization centered around "reducing hydraulic losses and minimizing ineffective energy consumption." During the pipe network planning stage, it is necessary to reasonably determine the pipeline routing based on the overall building layout, giving priority to straight-line laying to avoid excessive detours and turns. Simultaneously, control the matching degree between the pipeline laying slope and pipe diameter to ensure a smooth water flow and reduce both along-route and local head losses. In terms of pipeline material selection, priority should be given to pipes with smooth inner walls and low resistance coefficients to reduce energy consumption during water transportation. Additionally, pressure control in the pipe network should be combined with building height and the distribution of water consumption points. By reasonably setting up zoned water supply methods, energy waste caused by excessively high single water

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supply pressure can be avoided. Meanwhile, pressure monitoring devices should be installed at key nodes of the pipe network to monitor the operational status of the pipe network in real time and adjust pressure parameters promptly to ensure the system operates within an efficient energy consumption range.

2.2 Integrated Application of Renewable Energy in the Hot Water Supply System

The hot water supply system is a major contributor to energy consumption in water supply and drainage systems, and the integrated application of renewable energy is a key path to achieving energy saving. During the design process, it is necessary to combine the climatic conditions and resource endowments of the region where the building is located and give priority to selecting renewable energy forms with strong adaptability. For regions with sufficient sunlight, solar thermal collection systems can be arranged on the roofs or facades of buildings. By reasonably matching collectors with hot water storage tanks, the maximum utilization of solar energy resources for hot water preparation can be achieved. For regions with small temperature variations and suitable air humidity, air-source heat pump systems can serve as the core hot water preparation devices. They convert heat by absorbing heat from the air, with significantly higher energy consumption efficiency than traditional electric heating methods. Simultaneously, renewable energy systems need to form a linkage mechanism with auxiliary energy equipment. When the supply of renewable energy is insufficient, auxiliary energy can promptly step in to ensure the stability of hot water supply and avoid additional energy consumption caused by energy supply interruptions[1].

2.3 Energy-Saving Selection and Operational Control of Water Supply and Drainage Equipment

The energy-saving performance of water supply and drainage equipment directly determines the overall energy consumption level of the system, and its selection and operational control should run through the entire design process. Specifically, during the equipment selection stage, it is necessary to abandon the traditional approach of "large parameter redundancy" and precisely determine the rated parameters of the equipment based on the hydraulic calculations of the system. Priority should be given to selecting products that meet the national first-class energy efficiency standards, especially core energy-consuming equipment such as water pumps and water heaters, to ensure a high match between the rated operating conditions of the equipment and the actual operating requirements of the system. For water pump equipment, variable frequency speed control technology should be adopted. By monitoring parameters such as pipe network flow and pressure in real time, the water pump speed can be automatically adjusted to keep the water pump operating within an efficient operating range and avoid long-term inefficient operation of the equipment at full or low loads.

3. Water-Saving Technologies in the Water Supply and Drainage Design of Civil Buildings

3.1 Construction and Optimization Design of Building Reclaimed Water Systems

The building reclaimed water system is a core means of achieving water resource recycling, and its design should focus on "efficient collection, reasonable treatment, and precise reuse." In the collection stage of reclaimed water sources, it is necessary to divide collection areas based on water consumption scenarios within the building and give priority to collecting drainage with low pollution levels and easy treatment. By reasonably planning the routing and slope of collection pipelines, smooth drainage into treatment facilities can be ensured, and a decrease in collection efficiency caused by pipeline blockages or stagnation can be avoided. The selection of reclaimed water treatment processes should be determined according to reuse requirements, with a focus on controlling indicators such as suspended solids and organic matter to ensure that the treated water quality meets the requirements of reuse scenarios. Meanwhile, the treatment process should be optimized to reduce reagent consumption and energy input. The design of the reuse pipe network should be strictly distinguished from the tap water pipeline, with clear markings and anti-cross-contamination measures taken. Water pressure and flow control devices should be reasonably set according to different reuse scenarios to ensure efficient utilization of reclaimed water and reduce waste during the replacement of tap water[2].

3.2 Water-Saving Design of Water Appliances and End Systems

Water appliances, as direct carriers of water resource consumption, are key to optimizing water-saving performance at the end. During the appliance selection stage, priority should be given to selecting products that meet national water-saving standards, with a focus on the water outlet methods and flow control mechanisms of the appliances. By optimizing valve core structures and adopting flow-limiting technologies, the water consumption per unit time can be reduced while meeting usage functions. Meanwhile, the layout of end systems should be optimized according to the characteristics of water consumption scenarios. For example, in public water consumption areas, a combination of centralized water supply and decentralized control can be adopted to avoid continuous water leakage caused by a single appliance failure. In residential water consumption areas, the spacing between water appliances can be reasonably set to reduce invalid losses during water transportation. In addition, end systems should be equipped with leakage monitoring and early warning devices to monitor the operational status of pipelines and appliances in real time, promptly detect and repair leakage points, avoid hidden water leakage, and improve the overall water-saving efficiency of end water consumption systems.

3.3 Integrated Design of Rainwater Collection and Utilization Systems

Rainwater, as a renewable water resource, is an important way to supplement building water consumption and reduce dependence on tap water through its collection and utilization. During the system design stage, it is necessary to determine the scope and methods of rainwater collection based on the site conditions and climatic characteristics of the building. Priority should be given to using hardened surfaces such as building roofs, roads, and squares as rainwater collection areas. By setting up interception and filtration devices, pollutants such as suspended solids and impurities in the rainwater can be removed to reduce the difficulty of subsequent treatment. The design of rainwater storage facilities should determine the storage capacity and location according to the total rainwater runoff and reuse requirements. Priority should be given to selecting underground storage tanks or modular storage devices to reduce the land area occupied and improve storage stability. The reuse system should be connected to the non-potable water pipe network within the building. According to the water quality and quantity requirements of reuse scenarios, reasonable treatment processes and conveying equipment should be set up to ensure that the treated rainwater meets usage standards. Meanwhile, through intelligent control technologies, the utilization efficiency of rainwater resources can be maximized while ensuring water demand[3].

4. Application Measures of Water-Saving and Energy-Saving Technologies in Building Water Supply and Drainage Design

4.1 Technology Adaptability Planning Based on Building Functions and Regional Chara cteristics

In the early planning stage of applying water-saving and energy-saving technologies, it is necessary to construct a targeted technology selection system with the functional attributes and regional resource endowments of the building as dual cores to ensure that technology application is highly compatible with actual needs from the source. First, it is necessary to conduct an in-depth analysis of the building's functional positioning and water and energy consumption characteristics. Different types of buildings have significant differences in water consumption scenarios, water consumption periods, and energy consumption distribution, which should be used to clarify the key directions of technology application. For example, the water consumption of residential buildings is concentrated in daily household scenarios, and there is a time-based characteristic of hot water demand. Therefore, it is necessary to focus on the water-saving optimization of end water appliances and the energy-saving design of domestic hot water supply systems. Commercial buildings cover a variety of scenarios such as shops, catering, and offices, with high water consumption frequency in public areas and a large amount of condensed water generated by air conditioning systems. Therefore, it is necessary to strengthen the intelligent control of public area water consumption equipment and the construction of condensed water recovery and utilization systems.

Second, it is necessary to fully consider the climatic conditions, water resource status, and energy supply characteristics of the region where the building is located. Regional natural conditions directly affect the application effect of water-saving and energy-saving technologies. For example, regions with abundant precipitation have rich rainwater resources and have the foundation for large-scale layout of rainwater collection systems. Through systematic design, rainwater can be transformed into non-potable water sources. Regions with sufficient sunlight are rich in solar energy resources and are suitable for taking solar hot water technology as the core means of hot water supply to reduce dependence on traditional energy sources. In cold regions, the winter temperature is low, and pipelines are prone to damage due to freezing and swelling, and the heat loss of hot water pipe networks is significant. Therefore, it is necessary to focus on optimizing the design of pipeline insulation structures and select pipes and insulation materials that are resistant to low temperatures and have good insulation performance to reduce heat loss and pipeline maintenance costs[4].

Meanwhile, the building scale and spatial layout also need to be included in the planning considerations. Small and medium-sized buildings have a small footprint and relatively low total water and energy consumption. If large centralized systems are adopted, equipment idleness and resource waste are likely to occur. Therefore, decentralized reclaimed water systems and local energy-saving equipment are more suitable, such as setting up small reclaimed water treatment devices for single residential buildings and equipping independent shops with energy-saving water heaters. Large building complexes have a large scale of water and energy consumption, and there is resource complementarity among buildings. Therefore, it is suitable to construct centralized resource recycling systems and regional energy linkage mechanisms, such as uniformly building reclaimed water treatment stations to provide reclaimed water for multiple buildings and setting up regional solar thermal collection arrays to achieve centralized hot water supply, improving the application efficiency and economy of technologies through scale effects.

4.2 Collaborative Integration and Operational Control of Technologies within the Water Supply and Drainage System

The application of water-saving and energy-saving technologies is not the independent implementation of a single technology but requires breaking down the barriers between technologies and forming an efficient and interconnected whole through the collaborative integration of multiple technologies within the system to achieve a superimposed improvement in water-saving and energy-saving efficiency. At the level of pipe network system design, it is necessary to organically combine the selection of water-saving pipeline materials with the layout of energy-saving pump sets. Water-saving pipeline materials should have good sealing and anti-aging properties to reduce water resource leakage losses during long-term use. At the same time, their smooth inner walls can reduce water flow resistance and reduce energy consumption during water pump transportation. Energy-saving pump sets need to be precisely selected according to the hydraulic calculations of the pipe network to ensure that the rated parameters of the pump sets match the pipe network requirements. Meanwhile, by reasonably laying out to shorten the water transportation distance, along-route head losses can be reduced, further reducing the energy consumption of water pump operation. The combination of the two can achieve the dual effects of "water transportation energy saving" and "water consumption reduction."

In the hot water supply system, it is necessary to build a linkage system of solar thermal collection technology, insulated pipe network design, and variable frequency water replenishment devices. Solar thermal collection technology, as the core heat source, needs to determine the collector area and installation location according to the building's hot water demand to ensure solar absorption efficiency. Insulated pipe network design should select high-performance insulation materials to wrap hot water transportation pipelines, reduce heat loss during transportation, and further reduce heat loss by reasonably planning the pipe network routing to shorten the transportation distance. Variable frequency water replenishment devices need to monitor the water level of the hot water tank and the pressure of the pipe network in real time and automatically adjust the water replenishment flow and pressure according to changes in water load to avoid energy waste and system failures caused by excessive water replenishment or unstable pressure. The collaboration of the three can achieve the whole-process energy saving of "efficient heat source collection - effective heat retention - stable system operation."

4.3 Construction of a Full-Cycle Management and Maintenance Mechanism for Technology Application

To ensure that water-saving and energy-saving technologies continue to play a stable role throughout the entire life cycle of the building, it is necessary to construct a full-cycle management and maintenance mechanism covering stages such as design, construction, operation, and maintenance to form a closed-loop control over technology application. During the design stage, it is necessary to introduce technology feasibility assessment and economic analysis processes. Technology feasibility assessment needs to determine whether the selected water-saving and energy-saving technologies are in line with actual application scenarios based on building functions, regional conditions, and system requirements. For example, in regions with scarce water resources but sufficient sunlight, assess the feasibility of the combined application of solar hot water technology and reclaimed water systems to ensure that the technology can be effectively implemented in actual operation. Economic analysis should comprehensively consider the initial investment cost, long-term operating cost, and maintenance cost of the technology to avoid blindly selecting high-cost technologies that lead to later operating pressures. For example, compare the investment return cycles of centralized and decentralized reclaimed water systems and select a plan that is more in line with the building's long-term development. Through preliminary assessment and analysis, a solid foundation is laid for technology application.

During the operation stage, a regular inspection and maintenance system needs to be established. Regularly check the sealing of water-saving appliances, such as whether faucets and valves have dripping phenomena, and promptly replace aging seals. Monitor the treatment effect of the reclaimed water system, regularly detect the water quality indicators of the reclaimed water to ensure compliance with reuse standards, and clean impurities and dirt in the treatment equipment to ensure treatment efficiency. Check the operating parameters of energy-saving equipment, such as the energy consumption of variable frequency water pumps and the thermal efficiency of solar thermal collection systems. If abnormal parameters are found, promptly troubleshoot the faults. For example, abnormal noise from water pumps may be caused by bearing wear, and components need to be replaced in a timely manner.

5. Conclusion

In conclusion, the application of water-saving and energy-saving technologies in the water supply and drainage design of civil buildings is a systematic project that runs through the entire life cycle of the building. Its core lies in achieving efficient utilization of water resources and energy through technology adaptation, system collaboration, and full-cycle management while taking into account building functional requirements and long-term operating economy. With the in-depth application of water-saving and energy-saving technologies in the water supply and drainage design of civil buildings, it requires the joint efforts of designers, construction teams, operation and maintenance personnel, and industry management departments to jointly promote the water supply and drainage system of civil buildings towards a more efficient, environmentally friendly, and sustainable direction and contribute to the construction of a green and low-carbon building ecological system.

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