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Analysis of Municipal Water Supply and Drainage Pipe Design Technology

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Abstract: The quality and safety of residents' water rely heavily on the design of municipal water supply and drainage pipes. Therefore, this paper aims to enhance the optimization of municipal water supply and drainage pipe design by focusing on design requirements, principles, and key elements. Drawing from relevant design optimization experiences, technology advancements, and optimization measures, the research will analyze and consolidate the essential aspects of municipal water supply and drainage pipe design. The goal is to fundamentally elevate the quality standards of these designs, ensuring they meet the criteria for engineering project excellence. Through this comprehensive approach, we aim to contribute to the improvement and sustainability of water supply and drainage systems, safeguarding the well-being of residents.

Keywords: Municipal water supply and drainage; Pipe layout; Rainwater; Sewage; Design technology

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1. Introduction

The construction cycle of municipal water supply and drainage pipeline projects is lengthy and involves complex processes. Inadequate implementation of preliminary design work poses a significant threat to water safety for residents and fails to meet the essential requirements for livelihood protection. In recent years, designers have focused on achieving excellence in municipal water supply and drainage pipe design by leveraging past experiences, adhering strictly to design requirements and principles, and addressing challenging design issues. Furthermore, designers must align their efforts with municipal planning requirements, ensuring comprehensive deployment of water supply and drainage pipe design technology to guarantee the safe and efficient operation of the entire water supply and drainage system in the future.

2. Municipal water supply and drainage pipe design requirements and principles

2.1. Design requirements

In municipal water supply and drainage pipe design, it is crucial to thoroughly understand the environmental characteristics of the construction area, as well as the comprehensive distribution of underground pipelines and other influencing factors [1]. Collaboration between the design and construction departments is essential to ensure accurate implementation of construction area surveys and measurements. These surveys should be conducted scientifically, considering factors such as construction scale, engineering geological conditions, and underground line structure. Furthermore, the design department must integrate the site's environmental characteristics into drainage pipe construction planning and line design optimization. Design optimization efforts require accurate and reliable data, particularly for optimizing gravity flow line pipe design. Additionally, it's important to analyze the distribution of existing underground pipelines and identify potential risk issues during the layout of water supply and drainage pipelines. By conducting scientific coordination or relocation, threats to the safe operation of existing underground pipelines can be effectively mitigated [2].

2.2. Design principles

2.2.1. Principle of rationality

The dense urban population coupled with the constant flow of vehicles on nearby traffic routes throughout the year, poses a significant risk to underground water supply and drainage pipelines, making them prone to rupture and other quality issues. Therefore, designers must proactively consider the environmental characteristics surrounding the water supply and drainage pipes, as well as the flow of people and traffic. Efforts should be made to avoid routing pipelines through high-traffic areas to ensure the safe operation of water supply and drainage systems while also safeguarding the daily safety of people's travel routes.

2.2.2. Coordination principle

In municipal drainage pipe design, it is essential to proactively consider potential professional clashes with other pipelines. Designers must focus on identifying any risks of clashing with other municipal pipelines such as power lines, gas lines, and heating lines during the design phase [4]. Generally, the construction of smaller pipelines should be prioritized to avoid conflicts with larger pipelines and to ensure the smooth flow of construction activities. Rational layout and optimization adjustments of water supply and drainage pipelines are necessary to mitigate the risks of clashing. In instances where water supply and drainage pipelines unavoidably encounter other pipeline issues, designers can implement measures such as adjusting pipe diameters and elevations to enhance the feasibility and safety of the overall design [5].

2.2.3. Rain and sewage diversion principle

Given favorable conditions, designers can optimize the design of municipal water supply and drainage pipeline systems, particularly for rain and sewage diversion. This optimization process begins with a comprehensive understanding of urban rain and sewage diversion patterns and areas prone to road waterlogging. By analyzing historical rainfall data and runoff coefficients, designers can accurately calculate the volume of rainwater. Key data obtained from these calculations inform the optimization and adjustment of water supply and drainage pipeline projects [6]. Additionally, determining the burial depth of pipes requires careful consideration of slope and the actual conditions of household pipes within the service area to ensure safe pipeline operation. Furthermore, sewage project design must align with regional sewage discharge standards, with pipeline fullness and specific flow rates determined accordingly. Equipped with this data, designers can establish minimum pipe diameter and slope parameters for a rational and efficient design [7].

3. Municipal water supply and drainage pipe design elements analysis

3.1. Water supply pipe design elements

Optimizing the arrangement of water supply pipelines is crucial for ensuring that municipal water supply systems operate in line with expected design standards, meeting the needs of urban residents for production and daily living water. To achieve the scientific distribution of water resources and ensure the safety of residents' drinking water, designers must clarify key design elements. (1) Water pipeline optimization design: Designing the water pipeline system based on the actual water consumption of urban residents is essential to ensure sufficient and safe water supply. (2) Addressing remote or elevated areas: Designing water pipelines for remote or high-terrain regions may pose challenges. To mitigate risks, designers should prioritize reducing system energy consumption and consider incorporating pressurized pumping stations into the design. These stations can ensure sufficient water pressure reaches residents' homes, enhancing water safety. (3) Considering maintenance needs: Water supply pipeline optimization design should also consider long-term maintenance requirements. Choosing high-quality and performance-compliant water pipelines during the early design phase can help prevent corrosion or damage issues during long-term operation, thereby extending the service life of the water pipeline infrastructure [8].

3.2. Drainage pipe design elements

Generally speaking, municipal drainage pipe design must prioritize sewage drainage pipe and rainwater drainage pipe design. For sewage drainage pipe design, considerations should include the environmental characteristics surrounding the pipeline and the presence of industrial areas. After assessing these factors, designers should focus on sewage drainage pipe design, especially emphasizing leakage prevention measures. When designing rainwater drainage pipes, it's essential to fully consider the average annual rainfall characteristics of the city and optimize flood control and drainage designs accordingly. The arrangement of rainwater drainage pipes should align with the principles of sustainable development and effectively prevent waterlogging risks, thus ensuring the safety of residents' daily travel routes.

4. Municipal water supply and drainage pipe design technology application analysis

4.1. Water supply pipe design technology

In water supply pipe design, optimization of the pipe network layout form and alignment is crucial. The choice of pipe network layout form should prioritize ensuring a stable water supply in the city while fully coordinating the operation of existing and proposed pipe networks to prevent the risk of pipe clashes. Currently, two commonly used pipe network layout forms are the ring network and tree network. The ring network design is particularly suitable for projects with strict urban water supply capacity requirements. However, it typically entails higher construction costs and longer pipeline lengths. Therefore, designers must carefully consider factors such as cost budget and design requirements when selecting the appropriate layout form for implementation [9].

Pipe network alignment must strictly adhere to basic principles to minimize pipeline length and prevent excessive entanglement, which could jeopardize safe operation. Dry pipes should be processed along long lines to ensure consistent water flow direction with the pipe network. Additionally, to further shorten trunk pipe length, water distribution can be implemented on both sides of the street. When configuring trunk pipe alignment, environmental factors must be considered, and placement should be away from bridges and tunnels whenever possible. Sufficient distance should be reserved during the laying process to avoid clashes.

4.2. Sewage pipe design technology

4.2.1. Sewage treatment performance requirements

To expedite the urban sewage treatment goal, municipal sewage pipeline design must align with the city's comprehensive environmental management requirements. This entails considering factors like sewage treatment rate and other vital indicators to ensure comprehensive sewage treatment performance and processing speed. During the design optimization phase, emphasis should be placed on diversion and interception design for reasonable planning. Additionally, planning and design for critical areas like river downstream sewage outfalls are essential. By addressing these aspects comprehensively, municipalities can effectively enhance sewage treatment efficiency and meet environmental management objectives promptly.

4.2.2. Export grille design technology

Urban wastewater composition is typically complex, often containing fibers, plastics, and other debris. This garbage poses a significant risk of clogging drainage pipes, exacerbating the challenges of pipeline cleaning and dredging. Moreover, excessive floating materials can accumulate in pumping station grilles over time, leading to pipeline clogging and damage to pump impellers. To mitigate these hazards, designers must incorporate lessons learned into early sewage pipeline design optimization. For instance, designers can strategically place interception grilles at sewage pipe entrances and schedule regular cleanups by professional personnel to prevent clogs and maintain efficient sewage flow.

3.2.3. Precipitation bottom design technology

Over time, sewage pipes may experience reduced water flow rates and volume, leading to hidden risks such as debris accumulation and increased pipeline clogging. Dredging and cleaning these pipes entail significant financial and human resource investments, thereby elevating maintenance and management costs for municipal units. To optimize economic benefits, designers must depart from traditional design thinking and consider upgrading to a precipitation check well bottom. This approach involves sinking the bottom of the well to a controlled depth of 30–50 cm, facilitating the deposition and processing of sewage debris and hindering its downstream flow. Additionally, relevant units can establish a professional technical team to regularly remove debris from the bottom of the well, thereby reducing future maintenance costs.

4.3. Rainwater pipe design technology

3.3.1. Optimize pipe outlets

In urban areas, rainwater is typically managed through drainage pipes, which discharge into nearby rivers. However, in areas with specific topographic conditions, the design of rainwater pipe outlets may involve submergence. This means that the outlet part is positioned lower than the water level of the receiving water body. Since no valve is typically installed at the outlet location, downstream stormwater pipelines may face safety risks such as backflow from the river. During the summer flood season, significant water accumulation in low-lying areas can pose safety hazards to people and vehicles. Therefore, in the optimized design of pipeline outlets, adjustments should be made according to local topographic conditions and rainfall patterns to mitigate these risks effectively.

4.3.2. Optimized design of rainwater outlet

The optimization design of rainwater outlets involves several key considerations to ensure efficient drainage and mitigate potential risks. Designers must assess the elevation of outlets relative to the water level of receiving bodies, implementing overflow gates or pumps as necessary to manage excess rainwater. Additionally, alignment with local topographic features and catchment area size is crucial to optimize drainage efficiency, considering factors such as slope and catchment area during design. Coordination with longitudinal road design is essential to prevent water accumulation along roadways while adjusting outlet density in areas prone to rainwater accumulation can improve drainage effectiveness. By addressing these factors comprehensively, designers can optimize rainwater outlet design to enhance drainage efficiency and reduce the risk of water accumulation during rainy seasons.

4.3.3. Sponge city design technology

In the new phase of municipal stormwater drainage pipe design, integrating sponge city design methods is crucial for fostering resilient urban development. To address the negative impacts of rainwater pollution sources, designers should adopt sponge city design concepts when establishing drainage routes and zoning. This approach involves strategically deploying rain gardens, rainwater wetlands, and other environmental protection facilities to safeguard local natural runoff safety. By emphasizing the recycling of rainwater resources, these measures help mitigate the risk of flooding caused by excessive rainwater, contributing to the overall sustainability and resilience of urban areas.

5. Municipal water supply and drainage pipe design optimization measures

5.1. Do a good job of preliminary investigation, scientific selection of materials and equipment

During the pre-preparation phase, surveyors must thoroughly assess factors influencing municipal water supply and drainage pipe construction, including engineering geological conditions and environmental characteristics. Additionally, they should accurately locate and analyze the operational status of other municipal pipelines such as gas and electric power lines to identify risks of clashing during water supply and drainage pipeline installation. Design units should consider operational requirements and select suitable pipeline materials and equipment for on-site use, ensuring a comprehensive and rational plan. Furthermore, construction units must adhere to construction design drawings and conduct thorough quality inspections of materials and equipment as per specifications.

5.2. Avoiding clashes using building information modeling technology

BIM technology offers distinct advantages in virtualization, visualization, and synergy, enabling designers to proactively mitigate risks of clashing in drainage pipe installation. Unlike traditional site investigation methods, utilizing the BIM model allows for comprehensive clash detection using tools like Revit and Navisworks. Designers can analyze existing pipeline designs for potential risks of clashes, ensuring thorough examination of pipeline connections and precise location identification. This approach facilitates a comprehensive review of pipeline configurations in three-dimensional models, enhancing accuracy and enabling effective clash detection during the design phase.

Upon identifying the risks of clashes, prompt adjustments to the pipeline installation position are essential to ensure smooth pipeline alignment. By addressing clash points swiftly, designers can maintain optimal pipeline configuration. Additionally, BIM models can be annotated with data from pipeline design drawings, aiding designers in decision-making processes. For vertical design considerations, BIM technology enables measurement and analysis of the relationship between pipeline materials and external loads, as well as simulation and analysis of temperature effects on different pipeline materials. This facilitates informed decisions regarding pipeline standards selection, mitigating the risk of pipeline rupture or other quality issues during subsequent use [10].

6. Conclusion

In the preliminary design optimization phase of municipal water supply and drainage pipe projects, designers must prioritize safety to prevent pipeline clashes, damage, and other hazards. By adopting a quality-first approach and embracing proactive hidden danger management concepts, designers can optimize technical aspects of water supply and drainage pipeline design. This involves integrating lessons learned, focusing on key technical points, and considering site environmental characteristics and operational requirements. Optimization efforts should encompass pipeline layout, material selection, clash detection, and other critical technical aspects. By implementing these measures, designers can ensure the safe and efficient operation of municipal water supply and drainage pipelines.

Disclosure statement

The author declares no conflict of interest.

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