Application of Sponge City Concept in Water Supply and Drainage Design of Civil Buildings: Dilemmas and Solutions

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Keywords: Civil Buildings; Water Supply and Drainage Design; Sponge City Concept; Maintenance Management; Spatial Constraints

Abstract: The rapid urbanisation rate has brought new challenges such as water scarcity and urban waterlogging. Ordinary water supply and drainage design models for civil buildings are rarely able to solve these complex problems related to water. The design of water supply and drainage in civil buildings according to the concept of Sponge City has become a trend under statistical significance. Practical implementation of however faces a lot of obstacles. This paper explores the significance of integrating Sponge City into water supply and drainage design for civil buildings, analyzes the dilemmas in its application, and puts forward reasonable and feasible implementation pathways. It intends to serve as an important reference for the rational use of urban water resources and the sustainable development of ecological environment.

1. Introduction

Meanwhile, as a result of climate change and urban development, such the problems of urban waterlogging and water environmental pollution are becoming more seriously increasingly. The Sponge City approach advocates urban planning, construction and management that uses ecosystems (including roads, green areas and water bodies) to absorb ambient rainwater with natural infiltration and purification. Civil buildings are composite components of cities, and the largest extension representing in Sponge City perspective is water supply and drainage system design. However, in the water supply and drainage design of civil buildings implement Sponge City concept also faces many challenges. So high application path of Sponge City concept under this background with a certain realistic significance for urban sustainable development.

2. Importance of Applying the Sponge City Concept to Water Supply and Drainage Design in Civil Buildings

2.1 Enhancing Urban Flood Prevention and Drainage Capacity

Sponge City, the application in water supply and drainage design of civil buildings can from multi-dimensional to improve urban flood prevention and drainage capacity. At source, it uses decentralized rainwater management to alleviate runoff peak by utilizing facilities like roads, green roofs and sunken greening places. The aggregate of these building clusters can create micro-sponge entities that, in the event of heavy raining, slow down runoff through infiltration and storage, which gives enough buffer time for the urban drainage system [1]. At the same time, Sponge City also calls into civil building design in China to use facilities such as rain gardens and ecological tree pits for filtration of rainwater, which is then recycled and reused with vegetation water body or underground storage tanks. Sponge facilities are in a deep integration with civil building drainage systems to form a multi-level defense system. With three-dimensional design, single buildings turn into the power structure of the water control system completely within the city.

2.2 Optimizing Water Resource Recycling

The Sponge City concept in civil building water supply and drainage design has created good channels for systematic recycling of water resources [2]. The idea here is to develop a

  DOI: 10.25236/icacel.2025.193

three-dimensional system for the most efficient use of rainwater. Permeable paving facilities are selected for roofs and roads of buildings, thus greatly increasing the efficiency of rainwater infiltration. Purified water through a single unit as rain gardens, grassed swales can play vital role in cut and use of green irrigation and landscape water supplementation thus reducing the dependency on municipal supply for civil buildings. Sponge City concept implementation also enhances the closed-loop management capability of civil building water systems. The combination of rainwater collection and treatment with rainwater storage tank, reclaimed water treatment and recycling systems realizes the separation between rainwater and sewage as well as grey-water recycling, which greatly improves the utilization efficiency of water resources.

2.3 Improving the Building Microclimate Environment

Sponge City concept strategy in civil building water supply and drainage design: A case study to effectively improve the microclimate environment of buildings. Implementing Sponge City design schemes to adjust the temperature is adding facilities such as Verde Spaces around buildings and adopting measures like rain gardens, which greatly enhance surface permeability. Many of the vegetation communities within the Sponge City system also serve as dust adsorbers and actively produce large amounts of oxygen during the photosynthesis process, thus improving air quality around civil buildings and providing a relatively healthier breathing environment for residents. In addition, the design of Sponge City facilities also helps direct natural ventilation. Sunken green spaces, vegetation buffer strips can create relatively clean outdoor air, and the topography formed by these measures is conducive to increasing the wind speed, improving ventilation conditions in the leeward areas of buildings, and enhancing the natural ventilation effect between building clusters.

3. Dilemmas in Applying the Sponge City Concept to Water Supply and Drainage Design in Civil Buildings

3.1 Insufficient Adaptability of Technology and Facilities

In applying the Sponge City concept to civil building water supply and drainage design, one of the common problems is that technology does not match with facilities. A few of the applied sciences for a sponge facility are still in their infancy. The rainwater storage tanks are made of materials that do not adapt to the soil environment and water quality properties, so there is an increase in seepage and corrosion problems that lead to interference with the normal functioning of storage. Meanwhile, it has barriers for the integration of current water resource management technologies to sponge facilities. Comparing traditional building drainage systems that focus on rapid drainage in a limited time frame with multi-faceted management as the goal of Sponge City construction. Moreover, the aseptic design of Sponge Cities is common, which makes sponge facilities unable to bring proper value in areas with unique climate conditions.

3.2 Lack of a Sound Maintenance Management Mechanism

Although most civil buildings have already implemented a sponge city in their water supply and drainage design, the maintenance of each functional area is not fully guaranteed under the practical application effect of sustainability. This reduces the efficiency of the low-impact development facilities (LIDs) and can ultimately result in failure in the general system. Many property management departments or owners do not have professional maintenance knowledge of sponge facilities, such as the correct way to clean infiltration trenches, how to freely replace filter layers, and dig out perforated pipes that may be blocked. There is often confusion about who is responsible for maintaining treatments, and other routine tasks (e.g., inspection, dredging, maintenance and equipment replacement) are restricted by the absence of a funding guarantee mechanism. Facility failures or functional issues are not repaired in a timely manner. Without a monitoring and evaluation system, maintenance exists without the support of data, whether in identifying nodes with problems accurately or planning targeted strategies. This, in turn, undermines the ecological function of Sponge City facilities and poses a threat to waterlogging due to poor drainage.

3.3 Spatial Constraints

Nevertheless, implementing the Sponge City concept to civil buildings water supply and drainage design brings forth significant challenges due to spatial constraints. Thus, in high-density urban areas, the land surrounding civil buildings is relatively scarce and it is challenging to reserve sufficient space for large sponge facilities such as sunken green spaces or rain gardens. The most obvious is that the internal space of buildings limits the installation of sponge facilities. Problems such as poor plant growth and insufficient drainage may arise with forced installation, compromising the performance and longevity of the sponge facilities. Moreover, spatial constraints not only influence hydrological behavior but also raise construction and maintenance costs, effectively restricting the large-scale propagation of Sponge City method in civil engineering.

3.4 Standardization Needs Updating

During the process of promoting the whole Sponge City concept in civil building water supply and drainage design, the lagging of updating standard norms has become increasingly apparent. The advancement of Sponge City technologies and materials innovatively has produced new pervious materials, intelligent monitoring and control systems, etc., but there is no standard for technical indicators, acceptance procedures and later operation management. Because even one of these must-have specifications is absent, it impedes the promotion of new technologies and makes it almost impossible to measure engineering efficiency. Static calculation methods are still used in some units, but they can neither accurately calculate the actual effect of Sponge City facilities under complex building environment conditions nor provide feedback for design improvement [3].

3.5 Poor Interdepartmental Collaboration

In the Further researchIn civil building water supply and drainage design, the application of Sponge City is a complex engineering issue which involves multi-disciplinary such as urban planning, architecture design, water supply and drainage engineering, landscape architecture and municipal management. Yet departments tend to be professional silos and have little or no awareness of overall coordination and synergy. Such situations can end up in & # 39; hellish & # 39; hand, when traced off the sponge facility must be re-done or renovated because it does not meet rearms summers industrial facility requirements. This disconnect in interdepartmental work flow is not simply affecting project timelines and budgets; it is severely hindering the successful implementation of the Sponge City concept. Most importantly, misunderstandings are often found between developers/contractors and—later—a facility operator: construction units might not be aware of hydrological principles and construct it poorly; property management departments lack professional expertise or a maintenance budget, ultimately abandoning the facilities. This complicates the conversion of Sponge City designs from plans to reliable and sustainable technologies.

4. Pathways for Applying the Sponge City Concept in Civil Building Water Supply and Drainage Design

4.1 Enhancing the Adaptability of Technology and Facilities

In civil building water supply and drainage design, the adaptability of technology to facility building in the application process of Sponge City concept should be further strengthened. Technical packages for buildings should be modular in concept. New building complexes should integrate rainwater collection systems so that facilities like sunken green spaces and permeable pavements can combine with vertical greening on building facades, which may form a multi-level rainwater retention and storage network. To ensure full-process management of rainwater runoff, the garage roof deck of high-rise buildings can be designed as a composite structure of permeable pavement and bioretention ponds. Lightweight adoptions with their need-based designs can be opted for ancient buildings since they lessen the burden on the edifice favicon. At the same time, the application of Sponge City Concept must get rid of traditional design thinking to achieve a new pattern of deep integration and it is impossible to abandon building space. Horizontal infiltration systems must also be installed, establishing the rain gardens in the ground floor or rooftop of buildings to maximize the vertical space use and achieve greater green bouquets. In addition, large data analytics can be used to analyze facility operation status by using IoT sensors to monitor rainwater collection volume and water quality indicators. According to the analysis findings, preventive maintenance actions can be created to reduce facility malfunctioning rates.

4.2 Establishing a Sound Maintenance Management Mechanism

When introducing the Sponge City concept into civil building water conveyance and drainage scheme, it is essential to build a sound maintenance administration mechanism, molding a full-cycle management system. Set up standardized operation and maintenance processes to define maintenance cycles of facilities such as permeable pavement and green roofs, the acceptance standard of maintenance work is traceable. Establishing cross-professional maintenance teams — integrated by property management, landscaping a nd water supply and drainage engineering professionals to regularly solve the common failures of sponge facilities. Relevant units should also construct BIM models for sponge facilities, and merge analyze construction records and maintenance log information. By pinpointing where the facilities are accurately with GIS technology, we can then have data support for reliable fault location in the later stages and upgrade. Realizational construction: Establish a collaborative communication platform for design units, urban management departments and water authorities to carry out real-time sharing of extreme weather information and coordinate the schedule time arrangement of sponge facilities within the building area. It is therefore important to hold regular open days for owners with permeable pavement experiments that can familiarize residents with the Sponge City concept, encouraging them to better participate in the maintenance of green roof vegetation. Second, economic safeguards need to be developed by maintenance management through a multi-channel fund-raising mode and selection of trees well adapted to the weather at low-maintenance costs. It changes sponge facilities from a construction-oriented thinking into a management oriented appeal, and provides the basic support for urban resilient development.

4.3 Breaking Spatial Limitations

In order to carry out the Sponge City theory in civil building water supply and drainage design, it is necessary to overcome space limitations with multi-dimensional, cross-regional collaborative strategies. A three-dimensional aspect for rainwater storage and use can be accomplished by extending vertical space. At the same time, big unit should strengthen horizontal space linkage construction between enclosure building and surrounding environment breaking boundary limitations of site. The rainwater runoff within the building property line can be guided into surrounding public green spaces or municipal storage facilities forming a regional linked sponge-net-work through the implementation of pervious pavements, sunken green spaces and other low-impact development facilities. Some more common designs for using terrain elevation differences include ecological drainage ditches or grassed swales that can link separate rainwater collection facilities into a corridor of continuous rainwater transmission channels, able to connect the building site with urban green spaces and synergistic public infrastructure including roads. In addition, dynamic monitoring of rainfall and runoff conditions should be implemented in real-time through the use of IoT sensors on building roofs and sites by relevant units, dynamically adjusting the operating status of rainwater facilities to optimize utilization efficiency with regards to rainwater resources and flood prevention capacity in a limited space. It forms a multi-dimensional spatial adaptation system for successfully implementing the Sponge City idea in high-density building environments.

4.4 Establishing Standardized Norms that Meet the Needs of Contemporary Development

The Sponge City concept must be applied to create standardized norms for civil building water supply and drainage design that meet the needs of modern development [4]. The main work is to build a complete life cycle standard system from design, construction, operation and maintenance, and clarify technical parameters and acceptance standards for each stage. Therefore, the pipeline materials for rainwater collection systems should meet corrosion resistance and permeability requirements; storage facilities should have waterproofing, anti-seepage and water quality monitoring functions; water storage capacity thresholds should be determined differentially according to scale of buildings and climatic environmental conditions. Dynamic update mechanism of stormwater facilities should be enhanced relevant unit shall regularly revise maintenance standards for sponge facilities according to regional rainfall characteristics and new technology applications. Define the dredging cycle period of permeable pavement and set up interception baskets replacement frequency at rainwater inlets, form a full-chain standardized standard system with quantitative practical paradigm for Sponge City construction. In addition, the application design of Sponge City concept should be entrained through by promoting BIM-based performance simulation and smart management platforms for real-time monitoring and efficiency evaluation processes of stormwater regulation as an essential basis of digital empowerment. In order to ensure the continuous, efficient and effective operation of facilities in civil engineering projects, construction units, designers, contractors and property managers shall bear management responsibilities for long-term operation and maintenance mechanisms and post-evaluation systems.

4.5 Implementing Interdepartmental Collaboration

The integration of sponge city concept into the design of civil building water supply and drainage discharge system is also necessary to enhance inter-departmental collaboration, etc. A multidisciplinary team composed of, for example: architecture, landscape and municipal engineering (lots), and the limits/responsibilities and technical links between each lot in rainwater collection–infiltration–storage–purification. Multi-party cooperation should permeate the whole project cycle. In the construction phase, the design department should carry out on-site communication work with construction and supervision units for key processes such as permeable material paving and grassed swale slope treatment to guarantee the construction quality of sponge facilities. They should cooperate with property management departments and prepare long-term operations & maintenance plans such as dredging rainwater tanks and vegetation maintenance in the operation and maintenance phase to prevent the early failure of facilities due to insufficient later maintenance. The design department, meanwhile, should be in contact with the electrical specialty to include in the building intelligent management system control, monitoring and alarm systems for rainwater reuse. This not only ensures that Sponge City facilities will continue to work throughout their entire lifecycle as any structure constructed for runoff control, rainwater utilization, and ecological benefits should, but it also transforms the Sponge City concept from technical drawings into buildable and manageable engineering practice so that sustainable construction can be achieved which is truly harmonious with the environment.

5. Conclusion

Incorporating sponge-city concept into water supply and drainage design of civil buildings is an effort to promote sustainable urban development and improve human living environment quality. But it has many problems in its practical use. Thus, domestically the application of Sponge City concept needs to enhance technology facilities adaptability, strengthen perfect maintenance management mechanism, break spatial restrictions, and create new standards norms interdepartmental department effective connection expectations build an ecological livability urban space.

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