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Research on the Application and Management of Green Construction Technologies in Building Engineering

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Abstract: Against the macro background of intensifying global climate change and increasingly stringent resource and environmental constraints, the construction industry—one of the major sectors of energy consumption and carbon emissions—has been placed at the center of sustainable development transformation, which has become both a national strategy and a broad social consensus. As a core pathway for promoting green and low-carbon development in the construction sector, green construction is not only closely related to environmental protection, but also profoundly affects the economic efficiency, safety performance, and social reputation of construction projects. This paper aims to systematically explore the current application status, core components, and practical pathways of green construction technologies in building engineering, while deeply analyzing the key problems existing in current green construction management systems. On this basis, by integrating policy orientation, technological innovation, and project management theory, a comprehensive green construction management system is proposed, encompassing organizational support, institutional development, process control, technological innovation, and performance evaluation. The results indicate that strengthening top-level design, improving standards and regulations, promoting advanced technologies, optimizing incentive mechanisms, and enhancing whole-process collaborative management can effectively improve the level of green construction, thereby providing theoretical support and practical references for the high-quality and sustainable development of China's construction industry.

Keywords: Green construction; Green construction technology; Construction management; Energy conservation and emission reduction; Environmental protection

Introduction

As a pillar industry of the national economy, the construction sector is also a major consumer of resources and a significant source of environmental pollution. With the acceleration of urbanization in China and the continuous expansion of construction scale, pressures on resources and the environment have increased sharply, rendering the traditional extensive construction model unsustainable. A transition toward green, low-carbon, and circular development has therefore become imperative. In this context, the concept of green construction has emerged. It emphasizes achieving the objectives of "four savings and one environmental protection"—namely energy saving, land saving, water saving, material saving, and environmental protection—through scientific management and technological advancement, while ensuring construction quality and safety. Green construction aims to provide healthy and efficient built spaces and to support the realization of the national "dual-carbon" goals. Although the concept of green construction has gained widespread recognition, its practical implementation still faces numerous challenges. Some enterprises have only a superficial understanding of green construction, focusing more on slogans than on effective execution. Moreover, the lack of a systematic and efficient management framework has hindered the integration of green construction technologies throughout the entire project life cycle. Therefore, in-depth research on the application of green construction technologies and the establishment of an effective management system is of both theoretical significance and practical value. This paper starts with an analysis of the connotations of green construction, systematically reviews key technological systems, examines major management bottlenecks, and proposes integrated optimization strategies for green construction management, with the aim of providing reference and guidance for industry practice.

1. Application System of Green Construction Technologies in Building Engineering

Based on the framework of "four savings and one environmental protection," green construction technologies in building engineering can be classified into the following major categories.

1.1 Energy-Saving Technologies

(1) Energy saving in temporary facilities: Temporary offices and living areas on construction sites are major sources of energy consumption. Container-type houses or light steel structure buildings can be adopted, as they provide better thermal insulation performance than traditional prefabricated panel houses. Energy-efficient LED lighting should be fully applied, combined with sound- and light-controlled switches. High–energy-efficiency products should be selected for air-conditioning systems, water heaters, and other electrical equipment.

(2) Energy saving in construction machinery and equipment: Priority should be given to variable-frequency, hybrid, or electric construction machinery—such as electric excavators and electric tower cranes—which can significantly reduce fuel consumption and exhaust emissions. Meanwhile, strengthened maintenance and regular inspection of construction equipment are essential to ensure optimal operating conditions and to avoid energy waste caused by malfunctioning or inefficient operation.

(3) Utilization of renewable energy: Where site conditions permit, solar photovoltaic power generation systems can be installed to supply electricity for temporary lighting, surveillance systems, and office equipment. In addition, solar water heating systems can be used to provide domestic hot water for on-site personnel.

1.2 Land-Saving and Construction Land Protection Technologies

(1) Scientific planning of site layout: Building Information Modeling (BIM) technology can be applied to conduct three-dimensional site simulations, optimizing the layout of tower cranes, construction roads, material storage areas, and processing zones. This approach reduces secondary material handling and improves land-use efficiency.

(2) Development and utilization of underground space: In foundation pit support design, the adoption of techniques such as the top-down construction method can effectively shorten construction duration and reduce long-term occupation of surrounding land resources [1].

(3) Ecological protection and restoration: Prior to construction, ancient trees and valuable vegetation within the site should be identified, marked, and protected. During construction, exposed soil should be promptly covered or temporarily greened to prevent erosion and environmental degradation. After project completion, permanent landscaping and greening should be implemented in accordance with planning requirements to restore ecological functions.

1.3 Water-Saving and Water Resource Utilization Technologies

(1) Utilization of non-traditional water sources: A comprehensive rainwater harvesting system can be established to collect rainwater from roofs and paved areas and convey it to sedimentation tanks. After basic treatment, the collected rainwater can be reused for road spraying and dust suppression, vehicle washing, concrete

curing, and landscape irrigation. Similarly, a reclaimed water reuse system can be developed to treat greywater generated from living areas—such as wastewater from bathing and laundry—for secondary use.

(2) Water-saving fixtures and construction techniques: All faucets and sanitary fixtures on construction sites should be water-saving products. For concrete curing, technologies such as moisture-retaining curing membranes and spray-applied curing compounds can be adopted to replace traditional flooding curing methods, thereby significantly reducing water consumption.

(3) Intelligent water-use monitoring: Smart water meters can be installed to enable real-time monitoring and data analysis of water consumption in different areas of the construction site, facilitating the timely detection of abnormal conditions such as leakage, dripping, or pipe bursts.

1.4 Material-Saving and Material Resource Utilization Technologies

(1) Application of green building materials: High-performance concrete, high-strength reinforcement steel, and ready-mixed mortar should be preferentially selected to reduce material consumption. Recyclable and reusable materials—such as aluminum alloy formwork systems, disk-lock scaffolding, and standardized safety protection facilities—should be widely adopted.

(2) Building industrialization and prefabricated construction technologies: This represents the core direction of material conservation. By prefabricating components such as beams, slabs, columns, wall panels, staircases, and other elements in factories and assembling them on-site, the material loss rate can be reduced from 5%–8% in traditional cast-in-place construction to less than 1%. At the same time, on-site wet operations and the generation of construction waste can be substantially reduced.

(3) BIM-assisted material management: Building Information Modeling (BIM) can be used to perform accurate quantity take-offs and enable procurement based on actual demand, thereby avoiding waste caused by excessive ordering. Through clash detection in BIM models, potential design conflicts can be identified in advance, reducing material losses resulting from rework.

1.5 Environmental Protection Technologies

(1) Dust control: Dust pollution control is a top priority in urban construction environmental management. Key measures include fully enclosed perimeter fencing around construction sites, installation of automatic vehicle washing facilities at site entrances and exits, hardened internal roads equipped with fog cannons and sprinkler systems for routine dust suppression, and full coverage of dust-prone materials such as sand, gravel, and cement.

(2) Noise control: Low-noise construction machinery and equipment should be selected, and high-noise operations should be reasonably scheduled to avoid disturbance during nighttime hours. Sound insulation barriers can be installed around major noise sources to mitigate environmental impacts.

(3) Reduction and resource utilization of construction waste: Waste generation should be minimized at the source through measures such as precise material cutting and optimized construction schemes. Construction waste should be classified, collected separately, and centrally stored. Recyclable materials—including metals, timber, and plastics—should be transferred to professional recycling companies, while inert waste such as concrete and masonry debris can be crushed and reused as road base backfill material or recycled aggregate, achieving resource recovery and reuse.

(4) Water pollution control: Sedimentation tanks, oil–water separators, and other wastewater treatment facilities should be installed to ensure that construction wastewater and vehicle washing effluent are discharged only after meeting relevant standards. The use of toxic or hazardous waste materials as backfill is strictly prohibited.

2. Major Problems in Current Green Construction Management

2.1 Insufficient Awareness and Inadequate Emphasis

Some project owners and contractors still regard green construction as a cost-increasing burden rather than a strategic investment to enhance core competitiveness. Management often lacks a long-term perspective and adopts an “inspection-oriented” mindset, resulting in green construction being implemented only superficially.

2.2 Incomplete Management Systems and Lack of Systematic Approach

In many projects, green construction management

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remains fragmented and reactive, failing to establish a complete management system covering the full Plan–Do–Check–Act (PDCA) cycle. Clear organizational structures, responsibility allocation, and assessment mechanisms are often absent.

2.3 Lagging Standards and Inconsistent Enforcement

Although national and local governments have issued a series of guidelines and evaluation standards for green construction (e.g., *Evaluation Standard for Green Construction of Building Engineering, GB/T 50640*), some standards lag behind technological development and lack mandatory legal enforceability [2]. Significant differences exist among regions and enterprises in the interpretation and implementation of these standards.

2.4 Insufficient Technological Innovation and Integrated Application

Green construction technologies are frequently applied in a fragmented manner, without forming an efficient integrated technological system. The deep integration of next-generation information technologies—such as Building Information Modeling (BIM), the Internet of Things (IoT), and big data—with green construction is still at an early stage, and the level of intelligent and refined management requires further improvement.

2.5 Absence of Incentive and Constraint Mechanisms

The market lacks effective economic incentive policies (e.g., tax incentives and green finance) to encourage enterprises to proactively invest in green construction. Meanwhile, penalties for violations of environmental regulations and severe pollution incidents are sometimes insufficient to create a strong deterrent effect.

2.6 Lagging Development of Professional Talent

There is a serious shortage of interdisciplinary professionals who possess both engineering expertise and proficiency in green construction management and related regulations. This talent gap constrains the effective promotion and practical implementation of green construction concepts and technologies.

3. Establishing a Systematic Green Construction Management System

In response to the above problems, it is essential to establish a systematic, whole-process, and dynamic green construction management system to ensure the effective implementation of various green construction technologies.

3.1 Strengthening Top-Level Design and Organizational Support

First, a dedicated leadership group should be established. Led by the project owner and jointly involving design, construction, supervision, and other participating parties, a green construction management leadership group should be formed to clarify responsibilities and create a coordinated governance mechanism. Second, a *Special Green Construction Plan* should be formulated. Prior to project commencement, a detailed and operable green construction plan should be prepared in accordance with project characteristics and local requirements. This plan should clearly define objectives, indicators, technical measures, resource allocation, and emergency response plans, and be incorporated into the overall construction organization design [3]. Third, a full-staff responsibility system should be established. Green construction objectives should be decomposed to each department and position, with responsibility agreements signed to ensure clear accountability and implementation at all levels.

3.2 Deepening Whole-Process Collaborative Management

(1) Design-stage involvement: The “Design for Manufacture and Assembly (DfMA)” model should be promoted to achieve design–construction integration. Contractors should be involved at an early design stage to provide green-oriented recommendations in terms of constructability, material selection, and structural detailing, thereby optimizing design solutions and creating favorable conditions for subsequent green construction.

(2) Refined control during the construction stage: A BIM-based smart construction site management platform should be established to integrate data related to personnel, machinery, materials, environment, safety, and quality. Through IoT sensors, key indicators such as PM2.5 concentration, noise levels, energy consumption, and water use can be monitored in real time, enabling visualized and dynamic management. The introduction of lean construction principles to eliminate various forms of waste in the construction process (e.g., waiting, transportation, defects) inherently represents a deeper level of green construction.

(3) Acceptance and post-evaluation: After project completion, in addition to conventional quality acceptance, a dedicated evaluation of green

construction performance should be conducted. Lessons learned should be systematically summarized to provide data support and reference for subsequent projects.

3.3 Improving Institutional Development and Performance Evaluation

First, internal management systems should be improved. Enterprises should formulate internal regulations and operational procedures covering green procurement, energy management, water resource management, waste management, and environmental protection. Second, a scientific KPI-based assessment system should be established. Quantified key performance indicators (KPIs) for green construction—such as energy consumption per unit floor area, water consumption per unit floor area, material loss rate, construction waste recycling and reuse rate, and compliance rate of online dust monitoring—should be defined and incorporated into the performance appraisal of project teams and employees, with results directly linked to rewards and penalties [4]. Third, third-party evaluation should be introduced. Enterprises should actively participate in national or local green construction demonstration project programs and leverage evaluations conducted by independent professional institutions to objectively assess their green construction performance, obtain authoritative certification, and enhance corporate brand image.

3.4 Strengthening Technological Innovation and Talent Development

First, an industry–academia–research–application collaboration platform should be established. Enterprises are encouraged to cooperate with universities and research institutes to jointly develop new green construction technologies, processes, and materials suitable for different application scenarios, and to accelerate the transformation of research results into practical use. Second, a digital empowerment engine should be developed. The application of BIM, GIS, artificial intelligence (AI), and 5G technologies in green construction management should be deepened. For example, AI algorithms can be used to optimize construction scheduling to reduce energy consumption, while unmanned aerial vehicles (UAVs) can be employed for inspections to monitor dust emissions and site conditions. Third, systematic training and education should be promoted. Regular green construction training programs should be organized for both management personnel and frontline workers to disseminate relevant knowledge, regulations, and operational skills, thereby cultivating a high-quality professional workforce specialized in green construction.

3.5 Optimizing the External Policy and Market Environment

First, efforts should be made to improve regulations and standards. Industry associations and leading enterprises should actively provide policy recommendations to the government, promoting the incorporation of mature green construction requirements into mandatory engineering construction standards and accelerating their updating and revision. Second, policy support should be actively sought. Enterprises should proactively understand and apply for incentives such as green building subsidies, special government funds, and floor area ratio (FAR) bonuses provided by governments at various levels. Third, a green supply chain should be cultivated. Long-term strategic partnerships should be established with reputable green building material suppliers and construction waste recycling enterprises to jointly build a sustainable and green industrial chain.

Conclusion

Green construction represents an inevitable path toward high-quality and sustainable development in the construction industry. It not only responds to the era's pressing challenges of resource constraints and environmental degradation, but also serves as a strategic approach for enterprises to enhance competitiveness and establish a positive social image. This study systematically analyzes the connotation of green construction, its technical system, and current management practices, identifies deep-rooted problems in implementation, and proposes a comprehensive management framework encompassing organizational structure, institutional mechanisms, process control, technological innovation, and performance evaluation. Looking ahead, green construction will become increasingly integrated with digitalization and intelligence, with technologies such as BIM and the Internet of Things providing strong managerial support. Meanwhile, driven by the advancement of the "dual-carbon" goals, the scope of green construction will expand from the traditional "four savings and one environmental protection" concept toward full life-cycle carbon footprint management. All project stakeholders should abandon short-term thinking and regard green construction as a systematic project and long-term strategy. Through continuous technological innovation, management upgrading, and cultural cultivation, green concepts can be effectively implemented in practice, enabling enterprises to gain a competitive edge while contributing to the construction of a "Beautiful China" and the harmonious coexistence between humans and nature.

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