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Analysis of the Intelligent Construction Path of Rural Buildings based on BIM Technology

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Abstract

Against the backdrop of the deep integration of the rural revitalization strategy and intelligent construction, rural buildings are transforming from traditional construction to intelligent and industrialized ones. Due to its environmental friendliness, high efficiency and strong adaptability, light steel structure has become an important development direction for rural construction. As the core support of intelligent construction, BIM (Building Information Modeling) technology can run through the entire process of design, construction and management, promoting the innovation of rural building construction models. Starting from the application prospects of rural light steel structures, this paper systematically explores the key role of BIM technology in the intelligent construction of rural buildings by combining intelligent construction equipment, construction plans, management methods and the collaborative application of intelligent equipment. Finally, it proposes an effective implementation path for the intelligent construction of rural buildings with light steel structures.

Keywords

BIM; Rural Construction; Intelligent Construction.

1. Introduction

The total volume of construction in rural areas of our country is large, but there have long been problems such as extensive construction methods, low technical levels and serious waste of resources. With the advancement of the "dual carbon" goals and the penetration of digital technology, rural buildings urgently need to upgrade towards green, industrialized and intelligent development. Light steel structures, due to their advantages such as light self-weight, good seismic performance, short construction period, and recyclable materials [1], are suitable for the characteristics of scattered rural homesteads and diverse personalized demands, and have gradually become one of the mainstream choices for rural residences. Meanwhile, BIM technology provides a technical foundation for the intelligent construction of rural buildings through three-dimensional visualization, data integration and collaborative management. The maturity of technologies such as the Internet of Things and artificial intelligence has further driven rural buildings to extend towards "smart homes". Functions like voice control interaction, remote control, and scene linkage of smart hotels are gradually being integrated into rural residences, enhancing the convenience and comfort of living. This article, based on the development needs of rural buildings, focuses on the integrated application of light steel structures and BIM technology, and combines the innovative practice of intelligent equipment to explore feasible paths for intelligent construction.

2. The Adaptability Advantage of Rural Light Steel Structures

Compared with traditional brick-concrete structures, light steel structures have significant advantages [4] : Firstly, they are lightweight and have low requirements for the bearing

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capacity of the foundation, which can reduce the cost of foundation treatment in rural areas due to complex geological conditions; Secondly, it has a high degree of industrialization. Components are prefabricated in factories and then transported to the site for assembly. The construction period is shortened by 30% to 50% compared with traditional methods, which is suitable for the seasonal shortage of rural labor force. Thirdly, it is energy-saving and environmentally friendly. The recyclable rate of steel exceeds 90%, and the thermal insulation performance can reach the standards of passive buildings through the optimization of the envelope structure. Fourth, it has strong seismic performance and can effectively deal with medium and low intensity earthquakes that are common in rural areas.

3. The Key Support for Intelligent Construction - The Synergy of Equipment, Solutions and Management

3.1. In Terms of Intelligent Construction Equipment, it Has Shifted from being Dominated by Humans to Replacing Them with Machines

Intelligent construction of rural buildings needs to adapt to the characteristics of decentralization and small-scale operation, and focus on developing lightweight and easy-to-operate intelligent equipment.

During the design stage, the 3D laser scanner can quickly obtain the terrain and surrounding environment data of the homestead, providing a real coordinate basis for the BIM model. Unmanned aerial vehicle (UAV) aerial surveying is used for large-scale topographic mapping to assist in site selection and site planning.

During the production stage, CNC plasma cutting machines and automatic welding robots achieve precise processing of light steel components. 3D printing equipment can be used for the production of personalized decorative components.

During the construction phase, light crawler cranes and automatic bolt tightening robots enhance the installation efficiency of components. Intelligent spraying equipment achieves efficient insulation and waterproofing treatment of the enclosure structure.

3.2. In terms of Intelligent Construction Plans, the Full-process Optimization of BIM Technology

The core of the intelligent construction solution is to integrate design, production and construction data through the BIM model to achieve dynamic adjustment [2].

Modular design involves breaking down light steel rural houses into standard modules such as wall modules, floor slab modules, and roof modules. Through BIM parametric design, multiple house type schemes can be quickly generated, and the thermal performance and lighting effects of different climate zones can be simulated.

Construction simulation, leveraging the 4D function of BIM [3], simulates the sequence of component hoisting, the conflict between workers' movement lines and mechanical operations, and optimizes the construction organization design. For instance, the traditional method of prefabricating the foundation first and then the main structure is adjusted to the simultaneous prefabrication of the foundation and the first-floor components, thereby accelerating the progress.

Precise installation: The QR codes of components exported through the BIM model guide on-site workers to accurately locate them. Combined with AR glasses, the installation nodes and operation instructions of components are displayed in real time, lowering the technical threshold.

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3.3. In Terms of Intelligent Construction Management, Data-driven Full-cycle Control is Implemented

Traditional rural building management relies on experience, which is prone to problems such as delayed progress and quality risks. Intelligent management integrates multi-party data through the BIM platform, such as design drawings, material lists, personnel qualifications, equipment status, etc., to achieve dynamic monitoring.

Progress management, based on the 5D model of BIM, compares the planned progress with the actual progress in real time. For instance, it monitors the completion rate of component installation through sensors, automatically warns of lagging links and adjusts resource allocation.

Quality management, through BIM-associated material inspection reports of components, construction process parameters, and combined with on-site drone inspection images, enables traceability of quality issues.

Safety management utilizes BIM to simulate high-risk operation scenarios and identify hazard sources in advance. Through smart safety helmets and construction site cameras, potential safety hazards are warned in real time.

4. Intelligent Applications in Rural Buildings - From Living Spaces to Smart Living Scenarios

With the popularization of the Internet of Things, artificial intelligence and smart terminal devices [5], rural buildings are breaking through the traditional physical space scope and extending to smart living scenarios. The application logic of its intelligent equipment is similar to that of smart hotels, but it is more in line with the actual needs of rural residents, such as adapting to an aging population, low cost, and easy operation. The core functions include the following aspects.

4.1. Voice Interaction and Remote Control Create a Contactless Living Experience

By deploying intelligent voice assistants, such as localized terminals integrated with Baidu Dueros and Alibaba Tmall Genie, rural households can control indoor devices through voice commands, such as turning on the living room lights and setting the air conditioner temperature to 26℃. This is particularly suitable for convenient operations by the elderly or when hands are busy. Meanwhile, based on the equipment point information associated with the BIM model, such as the physical positions and circuit interfaces of lamps, sockets, and household appliances, the intelligent system can achieve a closed-loop control of "voice command - equipment positioning - command execution".

The remote control function relies on home Wi-Fi or 5G networks. By binding the device parameters in the BIM model through a mobile phone APP, residents can check the status of their homes in real time and control them remotely even when they are out working or traveling. For instance, when going out in winter, you can remotely turn on the floor heating through the APP, and it will automatically adjust to a comfortable temperature half an hour before you get home. In summer, the sunshade can be remotely closed to lower the indoor temperature.

4.2. Internet of Things (iot) Integration to Achieve Scenario-based Intelligent Services

By integrating all the intelligent devices within the building through the BIM model, a linkage network of "devices - space - user demands" is constructed to form multiple preset scenarios:

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In the homecoming mode, when the resident enters through the smart door lock, the BIM system automatically triggers the lights to gradually brighten, the curtains to open, the air conditioner to the commonly used temperature, and plays background music at the same time.

In sleep mode, during night rest, voice commands or the timer function can turn off unnecessary lights, dim corridor lighting, start the bedroom air purifier, and maintain the indoor temperature and humidity within the preset range.

Energy-saving mode: Through the energy management system associated with BIM, the electrical appliances in idle rooms are automatically turned off, and photovoltaic energy storage power supply is given priority. If it is detected that there is no one in a certain area for a long time, the lights and air conditioners in that area will be turned off.

5. Core Applications of BIM Technology in Intelligent Construction of Rural Buildings

BIM technology serves as a digital link connecting all aspects of intelligent construction in rural buildings. Its core value is not only reflected in the construction stage but also runs through the implementation of intelligent functions.

5.1. Full Life Cycle Data Integration

The BIM model not only contains geometric information but also integrates multi-dimensional data such as material properties, construction techniques, operation and maintenance requirements, and control logic of intelligent equipment, forming a digital twin covering "design - production - construction - operation and maintenance". For instance, during the design stage, BIM can avoid installation conflicts later by simulating the wiring paths of different smart devices. During the operation and maintenance stage, BIM directly associates the real-time data of sensors, providing a basis for fault diagnosis.

5.2. Multi-disciplinary Collaborative Design

The intelligent functions of rural buildings require the collaboration of multiple specialties such as architecture, structure, equipment, and weak current. The BIM collaborative platform supports real-time online editing by various specialties. Through the collision detection function, it automatically identifies conflicts between pipelines and steel beams, as well as between intelligent equipment and structural components, and optimizes the design scheme.

5.3. In-depth Interaction with Smart Devices

The BIM model provides precise instructions for intelligent equipment. For instance, embed the installation position of the voice control terminal and the network interface parameters of the sensors into the model to guide the precise pre-embedding during the construction stage. Associate the control protocol of the smart home system with the device codes in BIM to achieve seamless integration of "BIM model - intelligent central control - terminal devices".

6. Effective Paths for Intelligent Construction of Light Steel Structure Rural Buildings

Based on the above analysis, the implementation of intelligent construction for rural light steel structure buildings should take BIM technology as the core, integrating equipment, solutions, management and intelligent applications. The specific path is as follows:

6.1. Demand-oriented Customized Pre-design

Based on the living habits, economic capabilities and natural conditions of rural residents, a multi-scheme comparison model is generated through BIM parametric design, and the site

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layout is optimized in combination with the terrain data from unmanned aerial vehicle mapping. At the same time, investigate the priority of residents' demands for intelligent functions and reserve interfaces for smart devices during the design stage.

6.2. Component Production Integrating Industrialization and Intelligence

At the factory end, component processing drawings are generated based on BIM models. Core components such as light steel keels and connecting parts are automatically produced through CNC equipment, and RFID chips are embedded to record production batches, material parameters and other information. Simultaneously produce the enclosure structure and simulate the component splicing nodes through BIM to ensure immediate installation and use on site. For intelligent devices, compatible interfaces should be pre-embedded during component production.

6.3. Dual-wheel Drive Construction of Intelligent Equipment and Digital Collaboration

During the construction phase, the BIM model serves as the command center. Through intelligent hoisting equipment, components are precisely installed in accordance with BIM instructions, and AR is utilized to assist workers in completing complex node operations. Real-time monitoring of construction progress and quality safety through drones, and dynamic adjustment of construction plans in combination with the BIM platform; Collect structural health data through intelligent sensors to provide a foundation for later operation and maintenance. At the same time, strictly follow the intelligent equipment wiring diagram and installation points in BIM to complete the pre-installation and debugging of terminals such as voice assistants, sensors, and intelligent switches.

6.4. Long-term Operation and Maintenance Services Empowered by Digital Twins

After completion, the BIM model will be connected to the Internet of Things system to build a digital twin of the light steel rural house, and monitor the structural safety, equipment operation, energy consumption data and living environment in real time. Maintenance reminders and equipment usage suggestions are pushed to farmers through mobile phone apps, and energy dispatching is optimized through AI algorithms. Eventually, the full-cycle intelligent management of "construction - residence - operation and maintenance" is achieved, enhancing the safety, comfort and sustainability of rural buildings.

7. Conclusion

Intelligent construction of rural buildings is an inevitable trend for the upgrading of the construction industry under the background of rural revitalization. Light steel structures, with their adaptability and green advantages, have become the preferred solution for rural residences. BIM technology, through data integration and collaborative management, provides core technical support for intelligent construction. The integration of intelligent devices such as the Internet of Things and voice interaction has further expanded the functional boundaries of rural buildings, promoting their transformation from physical living Spaces to carriers of smart living. In the future, as the cost of intelligent equipment decreases and rural digital infrastructure improves, the intelligent construction model centered on "BIM+light steel structure + intelligent equipment" will be accelerated in rural areas, providing a solid guarantee for the construction of livable, prosperous and beautiful villages.

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References

[1] Li Xiongfei:BIM Technology Facilitates the Upgrade of Intelligent Construction Management in Building Engineering , Sichuan Architecture, Vol. 42 (2022) No.4,p.299-304.

[2] Hu Yuejun, Luo Kun, Qiao Mingyu: Exploration of Intelligent Construction Technology Based on BIM , China Construction Informatization,(2019) No.16 ,p.52-53.

[3] Liu Zhizhong, Shen Jingyu:The Application of BIM Technology in Intelligent Construction System , Intelligent Building and Smart City,(2021) No.10,p. 39-40.

[4] Li Chenguang : Research and Practice on Key Technologies of Prefabricated Light Steel Rural Houses, Construction Technology,(2020) No.15,p.1-6.

[5] Zhang Wei : Application Scenarios and Implementation Paths of Internet of Things Technology in Smart Buildings, Intelligent Building and Urban Information,(2022) No.5,p.12-18.