Journal of World Architecture

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Table of Contents

1 **Application of BIM in Architectural Design, Project Construction, and Project Management**
Yujie Li

7 **Application of Distributed Intelligent Power Supply Technology in Expressway Tunnels**
Yuling Zhang

13 **Application of BIM in the Structural Design of Architectural Engineering**
Fei Sun

19 **A Review on the Post-Earthquake Emergency Conservation Project of Fulong Taoist Temple**
Yuhua Zhu, Bowen Li

31 **How Multi-Sensory Perception Plays a Landscape Restorative Role in Adelaide's Urban Green Space**
Shiyao Li

37 **BIM-Based Strategies for Construction Quality Control in Building Engineering**
Bin Zhang

43 **Comprehensive Recycling Technology of Waste Residues in Zinc Hydrometallurgy**
Yun Fan

49 **Countermeasures for the Maintenance Management of Expressway Bridges and Tunnels**
Yuan Yin

56 **Application of Green Design Concept in Interior Design Practice**
Xiao Han

63 **Research on the Integration of Structural Design and Material Parameters of Long-life Asphalt Pavement**
Yongjun Shen

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Application of BIM in Architectural Design, Project Construction, and Project Management

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Abstract: The construction quality and efficiency of construction engineering are directly related to people's daily life. Therefore, construction enterprises must keep pace with the times and actively introduce advanced technical means into architectural design, project construction, and management, so as to ensure the quality and safety of construction to the maximum extent. The application of BIM not only improves the efficiency of construction and construction quality, but also realizes the control of construction cost. This study explores and analyzes the advantages of BIM as well as proposes application strategies of BIM in architectural design, project construction, and management, hoping to contribute to the smooth construction of construction engineering.

Keywords: BIM; Architectural design; Project construction; Project management

Online publication: May 17, 2022

1. Introduction

Building Information Modeling (BIM) is a new technical means that has the advantages of visibility, optimization, coordination, simulation, and relevance. Hence, this technical means can be widely used and promoted in the field of construction [1]. In construction engineering, construction enterprises must realize the application of BIM in architectural design, project construction, and management as well as strengthen the study of BIM, so as to give full play to the application of BIM and its advantages to effectively control the construction cost while ensuring the construction quality and the completion of construction engineering [2].

2. BIM

BIM is used to present the various components of building engineering through the application of digital building components, so as to reflect the entire construction cycle of construction engineering. The application of BIM in the construction is to intuitively present data and information about the building through the use of computer software to compare and analyze it, so as to timely identify the differences between the data and information [3]. The application of BIM in architectural design can ensure the rationality of architectural design through simulation and analysis, as well as prevent the poor progress of subsequent construction in view of unreasonable architectural design.

3. Advantages of BIM

3.1. Visual advantage

In construction engineering, it is difficult to describe the construction content and construction technology

clearly and comprehensively only with plane drawings and texts. With the application of BIM, the structure and size of the construction project can be shown from a three-dimensional level. It not only presents three-dimensional architectural drawings, but also construction contents through the establishment of three-dimensional models, which helps construction personnel to accurately and comprehensively interpret the drawings, so that the data information related to construction engineering can be accurately grasp. The establishment of three-dimensional models can enhance the visual experience of construction personnel as well as assist them in identifying the existing problems in the construction process and solve them in a timely manner [4].

3.2. Optimization and coordination advantages

The application of BIM has shown much benefits in problem handling, especially for complex construction projects. Through the application of BIM, complex construction contents can be sorted out and analyzed; in addition, the loopholes in project management can be identified in a timely manner [5]. It is also possible to realize smooth communication between departments, prevent information asymmetry between departments, as well as ensure that all departments and staff are able to grasp correct information and cooperate well, so as to improve the effectiveness and efficiency of each construction communication link, form departments, significantly enhance the coordination ability of the staff, and eventually improve the construction quality of construction engineering. Therefore, the application of BIM in the construction field has the advantages of optimization and coordination [6].

3.3. Simulation advantage

Construction has the characteristic of continuity. If there are mistakes in the early stage of construction, it is bound to affect the smooth progress of subsequent construction. In order to prevent engineering changes in subsequent construction, it is important to conduct simulation experiment to fully prepare for engineering construction. Before construction, all kinds of factors affecting the quality and safety of construction are concealed. BIM uses existing construction engineering information to analyze and predict subsequent construction. It also simulates specific construction situations, so as to identify problems, effectively improve and optimize the construction plan, as well as contribute to the reasonability of the emergency construction plan [7].

3.4. Affiliate advantage

The application of BIM in construction engineering projects aids in presenting all the information about construction engineering through various parameters established by engineering models. The data information carries the characteristic of integration; hence, the logical relationship of the data information is more ideal. For different parts of the construction project, the parameters of the corresponding model also vary, but there is a certain correlation among these parameters [8]. Therefore, when information changes, it is necessary to modify the corresponding parameters in the construction engineering model, so that the other parameters will be automatically adjusted, and the construction engineering model will also change accordingly. With that, the information change is more efficient.

4. Application of BIM in architectural design

4.1. Using animation to display architectural renderings

Through research, one of the obvious characteristics of BIM is diversity. The application of BIM in architectural design not only establishes corresponding models according to the architectural design, but also renders and analyzes the construction design scheme. It can be expressed through the establishment of three-dimensional models; hence, BIM is widely used in architectural design. Compared with three-

dimensional models, two-dimensional models are generally more abstract. When browsing the two-dimensional mode, only professional technicians can clearly understand the content, and in the establishment of three-dimensional building models, even non-professional technical personnel can easily grasp the content. This is also an advantage in the application of BIM in architectural design. In addition, BIM is relatively simple to operate, and with only a few simple steps, the architectural design effect map can be shown through animation [9].

4.2. Collaborative architectural design using BIM

Architectural design involves a lot of content, and these contents are complex, usually requiring mutual cooperation and communication between various departments. With the rapid social and economic development, people's living standards have improved significantly, and at the same time, the requirements for construction projects are constantly expanding. Construction engineering not only requires the function of living, but also some other functions [10]. When using BIM for collaborative architectural design, the organic integration of BIM with other disciplines is crucial to reduce the construction cost. In the past, CAD is commonly used in architectural design. Although it meets the basic requirements of architectural design, problems gradually arise with the development of the construction industry, especially with the advent of information age. In the field of construction, BIM is widely used, with good development prospective. The application of BIM in architectural design can realize the collaborative design between multiple parties.

4.3. Visual architectural design scheme

The application of BIM in architectural design can visualize the architectural design scheme through the establishment of virtual models [11]. In the past, the architectural design scheme is static and flat, but through the application of BIM, the architectural design scheme is more dynamic and intuitive using simulated systematic architectural design models. The main purpose of architectural design scheme is to meet the needs of customers. The application of BIM in architectural design aids in presenting the design of various details in an ideal manner, especially in terms of lights and colors. This greatly strengthens customers' subjective feelings toward the architectural design, thus contributing to user satisfaction [12].

5. Application of BIM in construction projects

5.1. Application of BIM in cost control

Through the application of BIM, the cost of a construction project can be determined through preliminary calculations. It relieves the accounting pressure of the staff and formulates budgets more accurately. The construction settlement is usually sorted out according to the different stages of the construction. The application of BIM assists construction personnel in calculating the number of raw materials and equipment, so as to ensure the proper use of raw materials and construction equipment purchase or lease. This not only ensures that the construction materials and equipment can be used at the construction site to promote progress, but also prevents the waste of raw materials and equipment [2]. In addition, the implementation of relevant policies and local climate conditions may affect the construction project [13]. For example, during winter, it is chilly and snowy in northern China, thus posing a challenge to construction projects. The application of BIM aids in updating settlement reports based on the construction results of the project.

5.2. Application of BIM in the inspection of collisions

With the continuous development of the society and the accelerating pace of urban construction, the area available for construction in the city is decreasing. In the future, the buildings in the city will mostly be super high-rise and high-rise buildings, in which their structures will be more diverse and complex [14]. Since each element and the pipelines are interlaced, it is a challenge to conduct a comprehensive inspection

of the construction project using the traditional three views. Therefore, the application of BIM should be considered, in order to strengthen the inspection of the collision in the construction, such as whether there is a collision between different construction processes, different pipelines, different steel bars, etc. In addition, it is necessary to carefully check for any collisions in the gap between the entities. The application of BIM not only helps in identifying collisions systematically and automatically, but also in generating collision inspection reports after the inspection. In that way, architectural designers can make timely corrections to the design scheme based on the collision inspection report.

5.3. Application of BIM in previewing the construction process

Through the application of BIM, virtual building models can be established according to certain proportions, and the whole construction process can be rehearsed on this basis [16]. BIM can dynamically and repeatedly simulate each construction process and the important parts of construction to form virtualized animations and images. Through these models, the appearance of the building can be examined, and the internal structure of the building can be presented accurately. According to research, the accuracy of the establishment of the simulated model directly affects the accuracy of the rehearsal of the construction link. By previewing the construction process through BIM, construction personnel will be able to accurately grasp each link of the construction process, construction quality, and construction requirements, so as to avoid substandard construction quality and inconsistencies with the construction requirements and rework in view of insufficient standard operating procedures [16]. In addition, through the BIM preview virtual construction, it is possible to bring more real experiences to businesses, and project construction leaders can also use this opportunity to perform technical disclosure to the construction personnel, so as to help them understand the construction needs and the importance of emphasizing safety measures.

6. Application of BIM in building management

6.1. Application of BIM in construction progress management

An indispensable part of building management is construction progress management. In some construction project management, it is difficult to control the construction progress of construction projects because there is no in-depth analysis of the construction progress or strict construction progress control scheme. Once there is a progress delay, beyond the specified construction cycle, it is bound to lead to an increase in construction cost, thus causing an adverse impact on the benefit of the construction project [17]. Based on the actual situation of the construction site, models can be established with the use of BIM. In that way, construction police uniforms can be planned more reasonably, and supervision of the construction site can be done via the installation of cameras. This will help construction management personnel to timely grasp the actual situation of the construction site, identify hidden factors that might affect the construction progress, and carry out effective measures to eliminate these factors in a timely manner. The application of BIM in construction progress management not only ensures the completion of the construction project on time, but also modifies the construction progress plan for those unfinished construction parts in accordance with the architectural design scheme.

6.2. Application of BIM in construction quality management

The construction quality of construction projects is not only related to the safety of the construction, but also the benefits of the construction projects, including both economic benefits and social benefits. Therefore, in the process of construction management, it is crucial to focus on strengthening the management of construction quality, so as to avoid the impact on people's normal production and life. It is also important to follow the development of the times and strengthen the application of BIM in construction quality management. In construction, a large number of construction materials are required, and the quality

of these materials directly affects the construction quality. With the help of relevant data and information, the specifications, quantity, and quality requirements of construction materials required for construction can be clarified [18]. The management of construction equipment and personnel should also be strengthened through the application of BIM. In addition, BIM can also be used to establish simulation projects and prefabricate construction schemes, so that more scientific and reasonable decisions can be made to further ensure the quality of construction.

6.3. Application of BIM in construction safety management

There are many unforeseeable factors in construction projects. Even a slight negligence is likely to result in unforeseen circumstances or even potentially endanger the lives and safety of construction personnel. Therefore, it is necessary to strengthen the safety management of construction projects throughout the entire process. In order to achieve a more ideal safety management effect, the application of BIM in construction safety management should be encouraged [19]. First of all, through the application of BIM, construction projects can be simulated. In that way, the safety hazards concealed in the construction site can be determine, thus reducing the occurrence of safety accidents in the formal construction process. Second, through the application of BIM, hidden dangers can be intuitively presented in front of the construction personnel, so as to strengthen their safety consciousness. This can be carried out in strict accordance with the construction process, construction specifications, and construction requirements. Finally, certain monitoring equipment can be used to monitor the situation of the construction site in real time, so as to identify the factors that may cause safety accidents and eliminate them in time [20].

7. Conclusion

In conclusion, architectural design, project construction, and project management are the key links in any construction project. They do not only affect the construction quality of construction projects, but also the benefits of construction projects. The application of BIM in construction design, project construction, and project management has shown many benefits. Therefore, construction enterprises must vigorously promote the use of BIM to improve the scientificity and rationality of architectural design, enhance the visual experience of the architectural design scheme, strengthen the management of the construction links in construction projects, as well as clarify the construction process, construction standard, and construction quality of each construction link through the establishment of simulation models.

Disclosure statement

The author declares no conflict of interest.

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Application of Distributed Intelligent Power Supply Technology in Expressway Tunnels

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Abstract: With the coordinated development of today's social economy with science and technology, various advanced technologies are being used in highway engineering, especially the distributed intelligent power supply technology in expressway tunnels, which has a very significant advantage. In order to realize the effective application of this technology and promote the power supply effect in expressway tunnel, this study analyzes the advantages of this technology and its application in expressway tunnel, hoping to provide scientific reference for the application of distributed intelligent power supply technology and the engineering development of expressway tunnels.

Keywords: Distributed intelligent power supply; Power supply technology; Expressway tunnel

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1. Introduction

In the traditional expressway tunnel power supply, a large number of high voltage and low voltage cables are required; there are also many bus cables, in which the cost is very high. The overall construction is very complicated because the traditional power supply system uses a three-phase power supply, in which the three-phase load balance needs to be maintained, and the lamps need to be connected separately. In addition, if there is a need for power monitoring and voltage regulation, the additional power monitoring system and voltage regulator settings will further increase the construction cost. In order to solve the aforementioned problems and fully meet the power supply demand in expressway tunnels, relevant units and technicians need to explore the distributed intelligent power supply technology and make it fairly applicable to the power supply in expressway tunnels.

2. Main power consumption facilities in expressway tunnels

In expressway tunnels, the main power facilities are equipment ventilation facilities, monitoring facilities, and lighting fittings. In expressway tunnels, the main ventilation equipment is the tunnel ventilator. At present, the main monitoring equipment applied to expressway tunnels are lane indication signs, smart boards, cameras, evacuation indication signs, and various detectors. The lighting section in the tunnel is usually divided into five parts: the first is the reinforced lighting section at the entrance; the second is the reinforced lighting section at transition 1; the third is the reinforced lighting section at transition 2; the fourth is the basic lighting section; and the fifth is the lighting section at the outlet. When dividing based on the function of lamps, the expressway tunnel can be divided into three: the first includes strengthening the lighting lamps; the second includes basic lighting lamps; and the third includes emergency lighting lamps.

3. Analysis of the power supply scheme in traditional expressway tunnels

The traditional expressway tunnel power supply scheme is mainly used for power facilities, including ventilation equipment, monitoring equipment, and lighting fixtures.

3.1. Power supply scheme for ventilation equipment in traditional expressway tunnels

When supplying ventilation facilities in expressway tunnels through the traditional power supply scheme, it is necessary to set up the loop of each fan separately and choose the cable specifications based on the actual length of the loop. Setting the fan control cabinet at the lower end of the fan allows for a more regulated soft start and positive and negative rotation.

3.2. Power supply scheme for monitoring equipment in traditional expressway tunnels

In regard to the power supply for expressway monitoring equipment through the traditional power supply mode, various detectors, indicators, smart boards, and cameras need to be jointly connected to the same power supply cable, and the power supply circuit needs to be set separately from the lighting lamp circuit. At the same time, the circuits need to be configured separately based on the different types of monitoring equipment. In such cases, a large amount of cable laying is required.

3.3. Power supply scheme for lighting fixtures in traditional expressway tunnels

In the traditional expressway tunnel power supply scheme, it is necessary to draw out 380V from the low-voltage cabinet in the substation, and then equipped the distribution box of lighting fixtures in the expressway tunnel through the switch at the low-voltage cabinet, in order to realize the power supply for lighting fixtures. Several bus power supply circuits should be allocated according to the different types of lamps. In this case, there will be a number of trunk cables in the expressway tunnel. Since the power supply of 380V is considerably high, there are requirements for a thicker cable; hence, thick four-core cables are usually used. In this way, the step-down requirements can be effectively met.

3.4. Main problems existing in the power supply scheme of traditional expressway tunnels

From the analysis of the traditional expressway tunnel power supply scheme, there are three main problems. First, high-voltage and low-voltage cables are required, and there are many bus cables. This situation not only increases the construction cost and the difficulty of operation and maintenance, but also brings about certain risks. Second, the power supply system in traditional expressway tunnels utilizes the three-phase power supply. Only by ensuring the three-phase load balance can we achieve good power supply effect. Therefore, it is necessary to connect the lamps to the three-phase, respectively, whose construction is difficult and complex. Third, in order to achieve good power monitoring and voltage regulation, it is necessary to include an additional power monitoring system and voltage regulator configuration, which will increase the engineering cost.

4. Advantages of applying distributed intelligent power supply technology in expressway tunnels

4.1. Improve the overall economic benefit

Compared with the traditional expressway tunnel power supply technology, the application of distributed intelligent power supply technology can significantly improve the overall economic benefit. First of all, the application of the technology can realize the overall system construction investment savings. It only needs to set the upper power supply equipment in the substation to directly supply power to the reinforcement lamps at the entrance of the tunnel, and a single hole only requires one basic lighting and reinforcement lighting loop, as well as one monitoring equipment and emergency lighting loop. Compared with the traditional expressway power supply technology, the application of this technology can achieve a

significant reduction in the number of lines, and the cable diameter will also be greatly reduced, so as to achieve further savings in its construction cost [1]. Secondly, the system mainly uses the single-phase distributed long-distance power supply technology. In that case, the three-phase imbalance can be effectively avoided, so as to further extend the application lifecycle of the equipment in the tunnel, thus reducing the costs for operation, maintenance, and replacement [2]. Finally, this technology can realize the reasonable adjustment of ventilation and lighting in the tunnel, so as to further reduce the electricity cost. It can be seen that the reasonable application of this technology to the power supply in expressway tunnels allows a significant improvement in terms of the overall economic benefit [3-6].

4.2. Improve the energy-saving effect

Compared with the traditional power supply technology applied in expressway tunnels, the application of distributed intelligent power supply technology can achieve better energy-saving effect. First of all, through the reasonable application of line loss reduction technology, the power supply radius and load can be taken on the basis of ensuring the actual power supply demand to realize an apposite increase of power supply voltage, so as to reduce the cable current and realize the reasonable reduction of line loss. Secondly, through the application of reactive power compensation technology, the overall power factor of the system can be improved significantly, so that the reactive power loss can be prevented, and the overall power consumption can be effectively reduced [7-9]. Finally, through the application of lighting voltage regulation technology, dimming of lights can be carried out based on the actual situation in the tunnel, so as to minimize the power loss caused by the lighting while meeting the actual brightness demand of the expressway tunnel. Therefore, it can be said that the application of this technology has a very good energy-saving effect.

4.3. Improve social benefits

In addition to good economic benefits and energy saving effect, the application of distributed intelligent power supply technology also brings about social benefits. First of all, through the application of this technology, the overall expressway tunnel distribution system can realize remote monitoring, which has a positive role in promoting the improvement of the operation and maintenance levels of the system. Secondly, through the application of this technology, the lighting in the expressway tunnel can be more uniform, and the light sensing effect can be effectively reduced, so as to ensure the safety of vehicles. In this way, the social benefits of this technology are apparent.

5. Analyzing the distributed intelligent power supply technology in expressway tunnels

In order to achieve good intelligent power supply effect, relevant units and technical personnel need to integrate the main power facilities in expressway tunnel projects, in order to formulate a reasonable intelligent power supply scheme. As mentioned above, lighting fixtures, monitoring equipment, and ventilation equipment are the main consumption facilities in expressway tunnels. Hence, in the process of designing, formulating, and implementing the intelligent power supply scheme, relevant units and technical personnel need to deeply explore the intelligent power supply technology of these power supply facilities, including the intelligent lighting power supply technology, the intelligent monitoring power supply technology, and the intelligent ventilation power supply technology. These are reasonable intelligent designs, and a variety of electrical equipment power supply automation and intelligent control have been realized through the corresponding intelligent control system and control technology.

5.1. Intelligent lighting power supply technology

In tunnel lighting, the application of distributed intelligent power supply technology is mainly to set the upper computer in the substation to replace the traditional low-voltage distribution cabinet and the

traditional lighting distribution box by setting the lower computer in the position of the original lighting distribution box. The bus power supply loop of the single hole output (two in total) is connected to the lower machine. With the help of the lower machine, the volume output loop can be separately switched and controlled by the voltage control, so that the lighting lamps can be grouped according to different requirements [10-13]. **Figure 1** is a schematic diagram of the connection of the intelligent lighting power supply system.

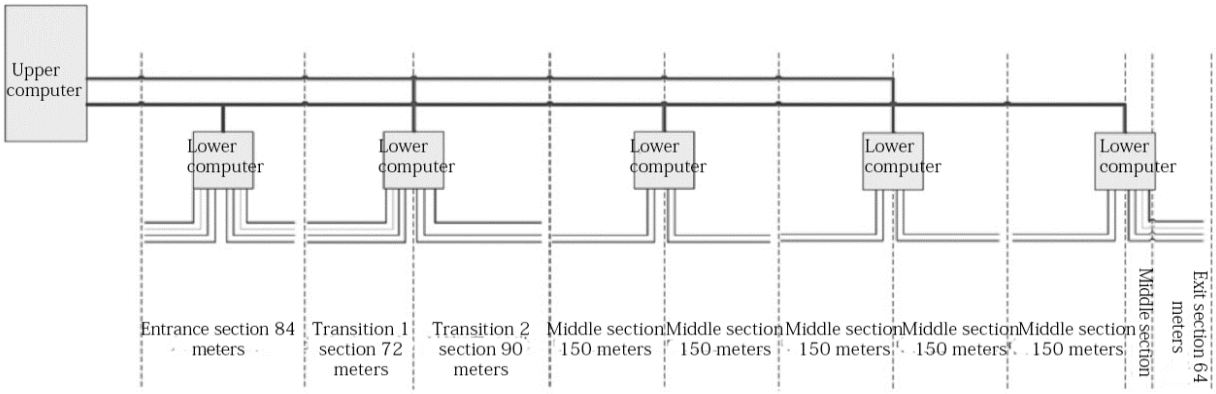

Figure 1. Schematic diagram of the connection of the intelligent lighting power supply system

The upper machine at the entrance of the expressway tunnel can be divided in two forms: the first is the basic lighting and enhanced lighting form, and the other is the upper computer in the emergency form. The emergency form requires the configuration of uninterrupted power supply cabinet. After a series of operations, such as voltage stabilization, compensation, and filtering, there will be an output of 3.3KV single AC power to the lower machine, and the system will reduce it to 220V through the lower machine, so as to meet the actual power supply demand of the lamp. The lower machine is configured in the original distribution box. There are four main forms of lighting: the first is to strengthen lighting, the second is the transition lighting, the third is the basic lighting, and the fourth is the emergency lighting. Among them, the lower machine of the enhanced lighting form needs to be configured at the entrance of the expressway tunnel. Its main purpose is to supply power to the lamps at the entrance and exit of the tunnel. The lower machine of the over-lighting form needs to be configured in the first lighting distribution room after the expressway tunnel enters the hole. Its main purpose is to supply power to the enhanced lighting lamps in the first ITD and the second ITD. The basic lighting and emergency lighting subunits need to be interleaved at other lighting distribution rooms in the expressway tunnel. Their main function is to supply power to other lamps in the tunnel [14]. For practical application requirements, EPS emergency power should be set in the emergency monitoring engine and connected to the power supply engine of the emergency lighting system. For other forms of lower computer, they can be combined in the design and then connected to the enhanced lighting and basic lighting forms.

5.2. Intelligent monitoring power supply technology

For expressway tunnel engineering, monitoring is a crucial electrical equipment. Hence, in the application of distributed intelligent power supply technology in expressway tunnel power supply design and construction, relevant units must pay full attention to the reasonable application of this intelligent monitoring power supply technology. In expressway tunnels, all the monitoring equipment needs to be connected with EPS power supply. Its connection mode and emergency lighting power supply have similar properties; hence, it does not need to lay other cables separately in the design and application process, only the monitoring loop through the emergency and monitoring machine output, so that the actual power

demand of all monitoring equipment in the tunnel can be well met [15-18]. The power supply circuit needs to be consistent with the original monitoring circuit, but the power supply section should be divided based on the emergency power supply section.

5.3. Intelligent ventilation power supply technology

In the design and construction of the power supply system of expressway tunnels through the distributed intelligent power supply technology, the power supply of the ventilation system is also a very important aspect. Hence, relevant units must reasonably apply this intelligent ventilation power supply technology. In its application, the upper engine of the fan should be set in the distribution room of the intelligent power supply system, and a voltage of 3.3KV should be transmitted to the lower engine of each fan via a three-core cable. At most times, the same bus cable can be used for the three sets of fans, but the cable needs to be laid on a cable trench bracket in the expressway tunnel. With the help of the fan engine, the voltage output of three circuits can be realized, in which the output voltage of each loop is 380V. The fan engine and the fan should be connected by a four-core cable [19,20]. Each fan's lower engine can supply power to three fans, and each fan should be set with a forward turn function, a reverse function, and a soft start function. In this way, the power supply effect of the fan is ensured, guaranteeing its operation to effectively provide sufficient ventilation in expressway tunnels and further improve the comfort and safety of drivers.

6. Conclusion

In conclusion, the lighting, monitoring, and ventilation conditions will have a direct impact on the quality and safety of traffic. In order to realize a good guarantee of these functions, relevant units and technical personnel need to innovate their power supply technology. The distributed intelligent power supply technology has significant advantages from its application. The application of this technology will not only realize the expressway tunnel power supply construction and operation as well as maintenance cost savings, but also achieve better energy-saving effect, reduce the operation intensity of staff, and improve the traffic safety. Therefore, relevant units and technical personnel must strengthen the research on this technology, so as to give full play to its advantages and promote the construction, application, and development of highway engineering.

Disclosure statement

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Application of BIM in the Structural Design of Architectural Engineering

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Abstract: Structural design is an important component of architectural engineering. BIM is integrated into structural design to form a complete, linked, and information-based data platform. Therefore, in line with the features of BIM, such as interaction and coordination, information integration, as well as data simulation, this study analyzes the advantages of BIM in architectural structural design, proposes several optimization measures using BIM for architectural structural design, and promotes the rationality of architectural structural design.

Keywords: BIM; Architectural engineering; Structural design

Online publication: May 17, 2022

1. Introduction

The application of BIM in the construction industry optimizes the industry's construction design and management technology, thus reflecting its application value. Combined with information technology, the digital engineering design method can be reflected. In the design process, the construction of information models can timely control and monitor the architectural engineering design. BIM has pre-simulation characteristics. By applying BIM to the construction, operation, maintenance, and design of architectural engineering, its application effect is evident [1]. Through field simulation, scientific prediction is carried out to simulate the final effect, solve architectural construction problems, and improve the quality of architectural structural design. Architectural structural design is an important component of architectural engineering. It is necessary to constantly grasp the operation characteristics of structural design and integrate BIM into architectural structural design to form a complete and interconnected data information platform. More in-depth analyses of architectural structural design are required in hope to improve the overall safety of architectural engineering.

2. Features of BIM

2.1. Interaction and coordination

Engineering project management is a collaborative process among different departments. When there are obstacles in engineering construction, it is necessary to analyze the problems in a timely manner and take effective measures. BIM can generate accurate data for possible data conflicts occurring among different departments and solve problems in the cross-departmental process. In engineering design, design institutions and other departments should put forward operable adjustment suggestions for BIM visual model and maintain coordination with various departments.

2.2. Information integration

Information integration is obviously embodied in design information integration and design process integration. As a form of professional information model, the whole project has strong information construction. BIM's information integration has built a professional design platform, promoted the smooth development of architectural structural design, and improved the integration of architectural engineering structural design process [2]. The database generated by the 3D computer model is the core of the architectural information model. It contains data information centered on the geometric size and spatial information of architectural structures, which meets the differentiated information needs. The traditional architectural structural design is mainly operated by designers, using two-dimensional graphics to demonstrate the designs. The efficiency of this method is not ideal, and the engineering design intention and information are easily affected by human factors. The establishment of BIM models can realize the transformation from two-dimensional designs to three-dimensional designs. The software can generate architectural design models, convert abstract plane graphics into vivid three-dimensional images, and prevent design errors from occurring. Architectural drawings are created by professional designers. The 2D drawings created from CAD tools cannot vividly express the design effect or accurately produce the structural design effect of buildings [3]. Applying BIM to architectural structural design can overcome the aforementioned shortcomings and reflect the relationship between different components in the form of visualization. In the process of creating BIM models, all design processes can be visualized. The design results automatically generate renderings and build design tables, allowing project participants to display the design process and effect under the condition of visualization.

2.3. Data simulation

BIM models can realize the numerical simulation of building structure and also simulate the experimental environment. In engineering design, BIM can simulate various intelligent modes of structural design. The reasonable use of BIM models in project bidding and construction can simulate the construction layout and determine the best construction scheme based on the designs by construction organizations [4]. BIM uses modeling and data processing to simulate the numerical value of structural design. In the process of parameter change, it can fully simulate various architectural forms according to people's needs and adapt to the individual characteristics of the architectural environment. The model can also simulate the building structure in the real environment and improve the efficiency of measurement. BIM can be used to form three-dimensional graphics from data prior to the actual construction. These virtual graphics are the simulation of real objects, including internal structures, such as steel frame and wall frame. Employees can carry out dynamic test according to the input of previous construction data or the survey data of the construction site, so as to observe the changes in the data model before and after, as well as timely adjust it according to the changes, thus avoiding problems in the actual construction. In traditional graphic design, designers use CAD drawings. This method not only has errors in the actual data [5], but also ensues difficulty in correcting problems, which prolongs the construction time and wastes the team's energy. Through the 3D model design plane graphics provided by BIM, this technology ensures the accuracy of drawings and allows for changes in the design parameters. In the project implementation, the parameters of drawings are very important because any drawing errors will delay the progress of the entire project [6]. It has the function of automatically creating and replacing when there are problems in the parameters during the design process as well as modifying the remaining data to create a new model. It not only ensures the correctness of data, but also prevents the loss of drawings [7].

3. Optimization measures using BIM for the structural design of building engineering

3.1. Creating a schedule and optimizing the design parameters

The structural complexity of residential engineering projects is increasing, and the engineering quantity of residential structural design is increasing. In order to provide effective guidance for subsequent construction, the 3D model component schedule generation function can be used to create residential walls, columns, beams, and other building components. After selecting a wall, column, or beam from a category and clicking "OK," the software will display a dialog box on schedule properties, where formatting, fields, and appearance can be set. Clicking the dialog box will help create the model, structure, purpose, function, volume, and other contents [8]. After creating a schedule, one can set ungrouping, attribute, grouping, and so on in the left, upper corner of the schedule. In the existing two-dimensional design method, the structural analysis of the model can be checked in the process of dividing the structural model units, and the structural model of residential buildings can be optimized and adjusted according to the architectural structural model. However, the structural parameters of residential buildings are high; hence, complex and single structural element analysis cannot guarantee the design process [9]. In this case, it is necessary to use the structural optimization processing ability of BIM to directly export architectural drawings and geometric information from the analysis and evaluation of its database. At the same time, the rationality of construction drawings is analyzed by inputting the corresponding BIM database. One can then optimize the architectural structural design process, effectively review and analyze each design link, as well as timely identify and solve the architectural structural design problems.

3.2. Applying BIM in collision design

In the spatial collision design of architectural engineering, a BIM information model is used to accurately process the sketch model to ensure that the constructed information model is complete. For some applications, the collision model has a lot of basic information, so in this process, it is important to pay attention to the number of floors and create column drawings and walls to form beams, columns, and floors. It is also necessary to set the same number of layers and stack layers to ensure the scientificity of the number of layers, build a pillar network, and promote the improvement of the pillar network system [10]. While drawing walls, their parameters can be set in the dialog box. The toolbox can be used to select the method of drawing the baseline to form a plan, vertical view, and indoor elevation while drawing curtain walls. In the planning stage, the main contents of the BIM model are preliminarily completed, and other parameters are improved with the construction of beam, column, and panel. The high bearing pressure and high strength requirements of industrial buildings should be considered in the design process; the cross section of these structures is also larger than that of ordinary structures. In order to control the section height, it is necessary to use BIM to reasonably determine the reinforcement [11]. The quality of the beam column structure can be improved by the beam column at the same time. The load ratio applied on the cantilever beam is small and can be made by the section design method. The cantilever beam floor reinforcement design should ensure an appropriate safety system. Due to the large load, the reinforcement must be increased appropriately, and the length of the wall must meet the structural design. When designing a lintel, the stress condition must be simulated and verified. The integrated design of ring beam and lintel can facilitate operation and improve seismic performance [12].

3.3. Meeting the requirements of architectural structure and environment through BIM

The construction and design of large-scale projects are not only related to the construction process, but also affected by the selection of building materials to a certain extent, which has a certain impact on the quality of subsequent construction. In the structural design of architectural engineering, the geographical environment of each construction area can be measured in real time by using GPS, in which relevant factors

such as culture and geology can be considered in the process. It is important to ensure that the completed project meets the requirements of basic engineering design and plays an active role in its subsequent use [13]. After various inspections and evaluations, the design and integration of the overall structure of the project can be integrated in terms of planning, design, and improvement, so that the relevant contents of the construction project can be completed in a reasonable and orderly manner. In the functional analysis and application of buildings, BIM plays an important role in predicting and calculating the functional and local application requirements of buildings [14]. In the actual BIM model construction process, the model is reasonably planned through data measurement to control the stability and structural strength of buildings. At the same time, corresponding measures should be taken based on certain conditions. After the input of disaster data into the BIM system, it can be seen that when the external environment changes rapidly, the basic performance indicators of the model structure can meet the expected requirements [15]. At the same time, in order to identify the index configuration with the best performance, it is necessary to modify the model structure appropriately through repeated experiments. BIM can be used to effectively improve the stability of architectural structures in the design stage. Carrying out data test according to the requirements ensures that the building meets the local climatic and geographical conditions as well as realizes the safety and service life of the building [16].

3.4. Coordinating various professional designs through BIM

In structural design, BIM can realize the exchange of plumbing, electromechanical, architectural, and other systems through the digitally generated analog information model. The information conveyed by the model can be exchanged with other professional teams as needed. Whether construction companies, manufacturers, owners, structural engineers, equipment engineers, or architectural designers change the way it is used, all who are involved in architectural design will obtain the information they need and use this information for their work. Hence, they can work effectively with the same parameters as the basic building model [17]. By converting the BIM model, the equipment engineer will install the corresponding equipment based on the location, quantity, and mode of the new equipment, and then test it. If there is an anomaly, the overall design of the building is debuggable based on the data information of various equipment. The effective application of BIM in the coordinated design of various disciplines enables the staff of various disciplines to share information [18]. It is conducive to collaborative development and the smooth progress of architectural structural design and construction, thus achieving excellent quality. In addition, by using BIM to realize the integration of architectural structural design with various field data analysis functions, the design process of the analysis model can be improved, along with the measurement accuracy of the land and the information on the surrounding ecological environment [19]. Architectural structural design can better integrate external ecological factors, such as greening. The application of BIM information model enables architectural designers to use relevant performance-based simulation analysis to determine the annual sunshine and shadow changes at the site. In addition, architects can use multidimensional BIM tools and methods to simulate different structural design situations, make judgments and predictions, as well as establish preliminary concepts and standards to promote the economic benefits of architectural structural design [20].

4. Conclusion

In conclusion, the application effect of BIM in architectural engineering is evident. In order to better improve the effect of the structural design of architectural engineering, it is necessary to constantly standardize, scientifically apply BIM, and strengthen the overall research to lay a foundation for the development of architectural structural design. Architectural structural design is a very important component in architectural engineering. It is possible to fully comprehend the safety, stability, and

interoperability of the structure, as well as improve the overall structural design. It is necessary to improve the construction technology in line with the actual situation. In designing the overall layout, it is important to consider the geographical location and give full play to the role of BIM in architectural engineering.

Disclosure statement

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A Review on the Post-Earthquake Emergency Conservation Project of Fulong Taoist Temple

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Abstract: The 2008 Wenchuan earthquake in Sichuan Province caused significant damage to Dujiangyan irrigation system, which is one of the world's cultural heritages. After the earthquake, the Chinese government launched the post-earthquake emergency conservation project for cultural heritages. The Fulong Taoist Temple in Dujiangyan was the first to adopt the conservation project. The earthquake-damaged Fulong Taoist Temple was restored in just 18 months. This article reviews the entire emergency conservation project of Fulong Taoist Temple in Dujiangyan after the earthquake, discusses the restoration principles and technical methods used in this project, and uses the comments of the Asia-Pacific Heritage Protection Award to expound the historical significance of this protection project.

Keywords: Post-earthquake emergency; Heritage conservation project; Fulong Taoist Temple

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1. Introduction of the project

The post-earthquake emergency conservation project of Fulong Taoist Temple is one of the most important cultural heritage conservation projects implemented in China in 2009 (**Table 1**). The project started in June 2008 and lasted for 18 months. It was the first cultural heritage conservation project to be carried out in the disaster-hit area after the earthquake on May 12, 2008, and also the first project of its kind to be completed.

Table 1. Details of the post-earthquake emergency conservation project of Fulong Taoist Temple

Location	Dujiangyan City, Sichuan Province, China
Site area	3000 m^2, with a floor area of 1900 m^2
Conservation design	Cultural Heritage Conservation Centre, Beijing Tsinghua Urban Planning and Design Institute
Date of completion	December 2009

Under the background of Sichuan's great reconstruction after the earthquake, the project has attracted attention from the public across the country. Experts in the field of cultural heritage conservation, in particular, consider these serious post-earthquake emergency restoration projects in Sichuan as practical examples of efficient responses to sudden catastrophes. The conservation project of Fulong Taoist Temple is undoubtedly one of the best practices (**Figure 1** and **Figure 2**).

Figure 1. Northeast view of Fulong Taoist Temple

Figure 2. Northwest view of Fulong Taoist Temple

There are four objectives in this conservation project. The first is to resume the integrity of Fulong Taoist Temple based on careful site investigation, damage recording, and the maintenance of authentic materials. The second is to enhance the structural stability and safety of the temple. The third is to maintain the characteristic local historical buildings by adopting their traditional techniques and materials. The fourth is to revive local cultural tourism and rebuild the daily life and confidence of the local community.

There are five main conservation works in this project. The first involves the removal of potential dangers and risks at the site. The second involves the collection and storage of original building components. The third involves site investigation and damage evaluation, followed by conservation plan design. The final involves the implementation of the project and on-site supervisory control.

The project started in June 2008 and ended in December 2009, which lasted 18 months. From the historical progress of the project, it can be divided into several stages.

(1) On May 12, 2008, the earthquake took place in Sichuan Province, China.
(2) In early June 2008, the conservators from Cultural Heritage Conservation Center conducted their first site investigation, recorded the damage, and completed the site investigation report.
(3) In late June 2008, they completed the post-earthquake emergency rescue work and conservation design plan of Fulong Taoist Temple.
(4) June 30, 2008, marks the start of the Fulong Taoist Temple conservation project.
(5) In February 2009, the foundation reinforcement of Fulong Taoist Temple was completed.
(6) In May 2009, the consolidation of the timber structures of Laowang Hall and Tiefo Hall was completed.
(7) In October 2009, the reconstruction of Yuhuang Hall was completed.
(8) On December 26, 2009, the entire project was completed.

2. History and present buildings of Fulong Taoist Temple

Fulong Taoist Temple is located at Li Dui Hill, the foot of Bao Ping Kou (an irrigation channel shaped like a bottle), which is one of the ancestral temples in commemoration of Li Bing and also part of the Dujiangyan irrigation system in Sichuan Province (**Figure 3**).

According to legend, Li Bing, the local governor during the Qin Dynasty, defeated the wicked dragon, and excavated the hills here, inducting river water into the lands of Chengdu Plain, making the plain a wealthy region for thousands of years. As early as Northern Song Dynasty (13th to 14th century), Fulong Taoist Temple had been developed and reserved for the commemoration of Li Bing. Its name has remained unchanged ever since. The temple has been conserved and restored in each succeeding dynasty before reaching its current state.

At present, Fulong Taoist Temple covers an area of 3,000 square meters, with a floor area of 1,900 square meters. The building can be divided into three parts, each of which is dominated by Laowang Hall, Tiefo Hall, and Yuhuang Hall, respectively. The whole complex is built from timber structures that rise in arrays along the longitudinal axis of the terrain and are connected by the overlaid corridors. Outside of the courtyard, Wangjiang Pavilion is situated in front of the temple, while Huaigu Pavilion is situated behind it. The temple, of which three sides are built on the steep cliffs of Li Dui Hill, is set on the bank of Min Jiang River. With its unique location and environment, the temple looks especially majestic and serene, naturally and harmoniously blending into the environment (**Figure 4**).

Figure 3. Dujiangyan City in China

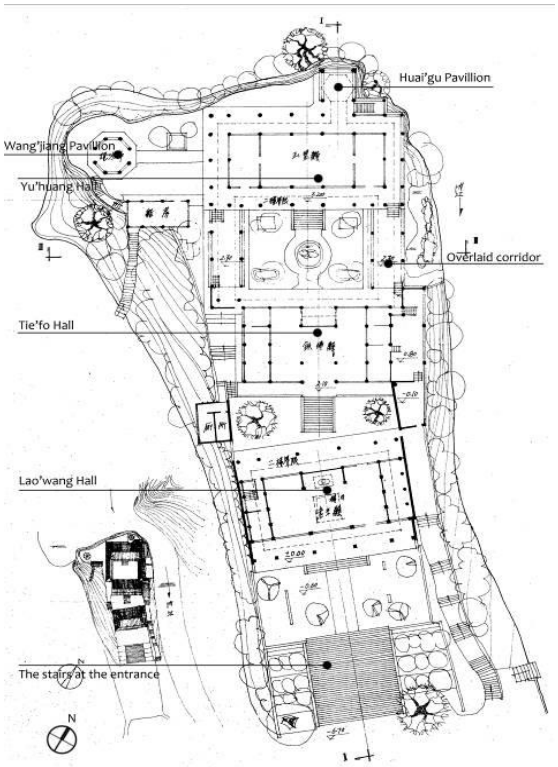

Figure 4. Site plan and 1st floor plan

Laowang Hall covers an area of 386 square meters, having hip and gable roofs with double eaves. The precious statue of Li Bing is laid inside. Tiefo Hall has a double-pitched roof and covers an area of 304 square meters. Yuhuang Hall, on the other hand, reflects a modern architecture built in masonry structure in 1959, with its external appearance imitating a traditional timber building. The newly constructed Yuhuang Hall and the corridors have caused some negative impact on the historical environment and structure; especially, the connection of the two side corridors inserted into the roof structure of Tiefo Hall has damaged the original timber structure used during the Qin Dynasty.

3. Articulation of heritage values and significance

Fulong Taoist Temple is one of the most famous ancestral temples in commemoration of Li Bing for the Dujiangyan irrigation system. With its unique geographical location, its well-conserved building complex, and its integrated landscape between manmade works and natural environment, the temple reveals its significance in historical, aesthetic, and scientific values.

(1) Fulong Taoist Temple is part of the world's heritage history and culture of Dujiangyan irrigation system, having exceptional historical significance.

(2) Since the Han Dynasty, the old edifices of Fulong Taoist Temple have served as a memorial to Li Bing. Most of the existing buildings were built during the Qing Dynasty, carrying abundant historical value.
(3) Fulong Taoist Temple embodies a typical wooden-structured style of southern regions in China, embodying distinct decoration features of western Sichuan, thereby having scientific value for further research.
(4) The interior and exterior courtyards of Fulong Taoist Temple are excellent examples of gardening art, where patios are paved with stone pavements and decorated by the greeneries, reflecting the traditional gardening concepts of Chinese ancestral temples. It is also an important standpoint to admire the Dujiangyan irrigation system that has fairly high aesthetic value and research value.
(5) Fulong Taoist Temple is also a well-known tourist destination in Dujiangyan, where tourists can learn about the city and appreciate the hydraulic project. The site also provides a great opportunity for local employments. In this way, it demonstrates the realistic value for social education and cultural propagation.

The ancient buildings of Fulong Taoist Temple that were under conservation included Laowang Hall, Tiefo Hall, Yuhuang Hall, the eastern and western overlaid corridors, Huaigu Pavilion, and Guanlan Pavilion. The goal of the conservation project was to reduce the negative impact caused by the earthquake, repair the damage to these historical buildings, and resume the integrity of the building. The main restoration works took place in several aspects.

(1) Part of the eastern corridor structure inserted into the roof of Tiefo Hall, which damaged the integrity and stability of the original timber structure, caused significant damage to Tiefo Hall during the earthquake. In this conservation project, the eastern corridor structure was restored according to its disassembled components, the historical information left on the joints of other wooden members, and the timber structure of the western side of the corridor. After the restoration, the eastern timber system regained its structural wholeness, thus guaranteeing the safety of the building.
(2) Laowang Hall used to be an exhibition room for the public, and the separations of each end were adapted to storage rooms of two stories high. Before the earthquake, it was dangerous to use the temporary staircases to go up and down. Through this restoration, the wooden staircases were rebuilt following the traditional technique. This solution does not add any more load on the original structure, but rather coheres with the original timber structure.

4. Methodology and principles of restoration

Based on the investigation report, Laowang Hall and Tiefo Hall are both historical buildings of the Qing Dynasty, whereas the other buildings were reconstructed or refurbished in modern times. The objectives of this conservation project were not at all complicated, but the issue lies in the aim of this restoration project. The aim of this project is to resume the integrity Fulong Taoist Temple in a rapid speed. Besides, the conservation project should not only meet the principles of authenticity, but also gain emotional recognition from the local community.

This conservation sought to simultaneously recover the authenticity and integrity of the structure of Fulong Taoist Temple in a rapid manner based on careful site investigation and the thorough understanding of restoration principles. Therefore, a few basic restoration principles were set while designing the project (**Figure 5**).

(1) Principle of authenticity
   (a) Preserve the physical carrier of historical information (**Figure 6**)
   (b) Retain the authenticity in the cultural and emotional values of Fulong Taoist Temple

(2) Principle of preserving the original form of heritage

(a) Preserve the original architectural space and building form based on the site plan before the earthquake (**Figure 7**)

(b) Do not add or eliminate any construction parts

(3) Principle of maintaining the historical environment

All the geological or foundation consolidations should not alter the historical environment, including the site landscape, the pavement of the yard, and the plantings (**Figure 8**)

Figure 5. Front view of Fulong Taoist Temple after the earthquake

Figure 6. Interior of the first floor of Laowang Hall after the earthquake

Figure 7. Cracks seen on the brick column of Yuhuang Hall after the earthquake

Figure 8. Front yard of Tiefo Hall after the earthquake

Practically, the conservation should not only meet the principles of authenticity, but also gain emotional recognition from the local community and meet the needs of tourism in the future. The restoration project emphasized on several points.

(1) An organization system with high efficiency

The professional conservation institutes and conservators made their first on-site investigation as soon as the disaster took place, and they then established the conservation principles. Not only the construction company but also the design institute visited the site right after.

(2) The use of traditional materials and techniques

Special attention was paid to the historical information found during the conservation. Therefore, the project was technically accorded with the national requirements on historic building conservation.

(3) A project based on the site plan before the earthquake
The style and features of the buildings remained the same as those before the earthquake. This is thought to be a useful tool to retain the emotional link of the local community.

5. Technical issues in the conservation project

5.1. Adoption of traditional maintenance techniques

The most common problems in using wood include corrosion, termites, splitting, cracking, disconnection of joints, inclination, loss of components, weathering, and fading of colors. Different traditional techniques were used based on the degree of damage in terms of its level and position. However, the general principle was to retain the original members and structures on the premise of ensuring the rationality of the structures and the load-bearing capacity (**Table 2**).

Table 2. Traditional conservation techniques

Types of decay	Level or position of damage	Maintenance
Rot decay and termite-biting of columns	Damage less than 1/3 of the column height	Replacement of the decayed column (partial)
	Damage more than 1/3 of the column height	Replacement of the whole column
Decay and termite-biting of other components	Slight	Partial mending and replacement (reinforced with iron hoops)
	Severe but not occurring at the site bearing the main load	Replacement in local areas
	Severe or at the site bearing the main load	Replacement of the whole component
Splitting and cracking of wood members	Slight	Patching
	Severe or too extensive	Replace with a new one
Pulling out of tenons and inclination	Slight or severe	Force back to their old positions
Loss of components	Entire	Complement based on their original forms
	Partial	Partial repair or complementing
Weathering and color fading	Slight	Retain the original form
	Severe	Color enhancement
Insect-preventive and antiseptic treatment	New members	Soak in medicinal solvent
	Original members	Coat with medicinal solvent

5.2. Different treatments for different buildings

In the conservation, different treatments were used based on the severity of the damage (**Table 3**).

Table 3. Conservation treatments for different buildings

	Traditional maintenance methods	Restoration to the original form or appropriate adjustment	Retaining historical information clues
Laowang Hall	Timber structure, interior wooden decorations, walls, floors, decorative plaster moldings, color painting, and oil painting	Stairs (four-flight stairs to two-flight stairs)	The outer room wall with murals under the rear eave, and the structure frame on the second floor

(Continued on next page)

(Continued from previous page)

	Traditional maintenance methods	Restoration to the original form or appropriate adjustment	Retaining historical information clues
Tiefo Hall	Timber structure, interior wooden decorations, walls, decorative plaster moldings, color painting, and oil painting	Restoration of the damaged timber structure and floor finishing layer between the two ends of the rear eaves (restoration of the original height of the floor)	
Eastern and western overlaid corridors	Timber structure, interior wooden decorations, floor finishing of the eastern corridor, decorative plaster moldings, color painting, and oil painting	Floor finishing of the western corridor (cemented floor to wooden floor), and restoration of steps of the western corridor (cemented steps to wooden steps)	
Yuhuang Hall	Existing timber structure, interior wooden decorations, walls, floors, decorative plaster moldings, color painting, and oil painting	Restoration of the first-floor masonry (changed to wooden ones), the adjustment of the beam frame on the second floor, and the demolishment of the suspended ceiling	
Huaigu Pavilion	Existing timber structure, interior wooden decorations, floors, decorative plaster moldings, color painting, and oil painting	Reconstruction of the reinforced concrete (changed to wooden ones)	
Guanlan Pavilion	Existing timber structure, interior wooden decorations, decorative plaster moldings, color painting, and oil painting	Roof tiles and floor finishing (cemented floor changed to stone-slab floor)	

5.3. Restoration of Yuhuang Hall

Yuhuang Hall was rebuilt in the 50s of the last century. The connections between the masonry columns and the concrete floor panel were enhanced by I-beams in 2002. After the earthquake, vertical cracks were found in almost every masonry column, indicating that the building had lost its load bearing capacity. Given that Yuhuang Hall was not designated as a historical building and had been used for nearly 50 years, its style and image had become part of the overall building image as well as a part of public memory. Therefore, it had been decided that Yuhuang Hall should be restored to its original form, preserving its appearance carefully, which includes its windows, doors, and decorations. However, the interior structure was changed to traditional timber, which showed better anti-seismic performance.

5.4. Adjustment of the eastern and western corridors

The eastern and western overlaid corridors and Yuhuang Hall, which were linked to each other, were both timber structures built in last 50s. In view of the inappropriate design of that time, the end of the eastern corridor was inserted into the roof of Tiefo Hall, which damaged the roof structure. During the conservation, the structures of the two corridors were restored after carefully studying their original dimensions. The form and style of the two corridors were maintained, while the staircases at the ends of the corridors made it more convenient to walk up and down (**Figure 9**).

5.5. Using appropriate local craft techniques in the conservation

5.5.1. Decorations on the roof ridge

The decorations on the roof ridge of Fulong Taoist Temple were lively and interesting. The themes were based on local community patterns, including fishes, float grass, Chinese dragons, and characters in mythologies. These decorations were made from cement, grass, and clay materials by local craftsmen. Unfortunately, these decorations, which represent the strong characteristics of traditional craftsmen, were severely damaged by the earthquake. For the conservation, all the fragmented decorations were first collected. Restorations were made to those decorations that had slight damage, while those badly damaged were dismantled and recast by local experienced craftsmen following the local tradition of plaster casting. For those pieces that were lost, the decorations were reproduced by referring to old photos. Since rain occurs frequent in that area, the original paintings on the decorations had faded; hence repainting was also done but strictly only on the missing color parts, while ensuring they had the same color as the original ones (**Figure 10**).

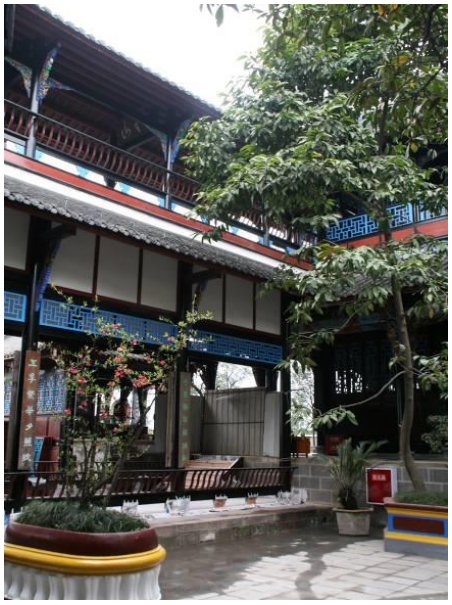

Figure 9. Eastern corridor after the conservation

Figure 10. Conservation of decorations on the roof ridge

5.5.2. Removing inappropriate additions to history in Huaigu Pavilion

The main load-carrying members (columns and beams) on the first floor were changed into reinforced concrete structures during the maintenance process in the last century. However, the structures on the second floor remained as timber frames. Due to the inconformity of different types of structures, the building had low resistance against the earthquake. In consideration of the safety requirements, it was agreed on that traditional Chinese wooden structures would be used for restoration, while the joinery work, colored drawings, and lime-and-straw decorations on the roof ridges would all be replaced according to their original locations.

5.6. Using appropriate materials

5.6.1. Oil and color paintings

In Fulong Taoist Temple, the main timber frames were painted with dark black lacquer, while the windows and roof were overlaid with red lacquer. Since the Chinese lacquer (main ingredient of oil painting) is sensitive to temperature and humidity, oil painting should be mixed and applied based on the local weather. Local painters were hired to carry out the painting work, so that there would be more appropriate adjustment

on the ratio of painting cycles. For color paintings, if the colors had faded vehemently, color enhancement or repainting was performed. The new colors, however, would not imitate the original colors, but would merely preserve the painting patterns.

5.6.2. Roof tiling

The most apparent damage caused by the earthquake is that most of the roof tiles were destroyed as they slipped to the ground. This is because the roof tiling is a juxtaposition of small grey tiles, meaning that the grey tiles are overlapped with one tile facing downwards, while the neighboring tiles face upwards. The tiles are merely placed on the rafter without any fixation. This is a special tiling method used in southern China, which can reduce the weight of roofs and make it easy to alter when necessary. However, there are drawbacks to this method. These small grey tiles can be easily blown to the ground in windy conditions. Moreover, even small animals can shatter the tiles into pieces when running across the roof. Therefore, the main consideration in this conservation was to maintain the traditional technique while making improvements in its stability. It was suggested for holes to be made in the tiles, followed by nailing the tiles to the rafters. The holes were punctured 5 centimeters from the ends, making it possible for the nails to be covered by the neighboring tiles, thus concealing the areas of human intervention and rendering the overall tiling technique consistent with the traditional one. This method would neither add weight to the roof nor cause the slipping of tiles.

6. The impact of the project on conservation practice and policy

The emergency conservation project of Fulong Taoist Temple is one of the rescue projects after the May 12 earthquake. It is urgent to complete the conservation project as soon as possible, in order to rebuild the local community's confidence and allow them to resume their normal lives. In view of the particularity of this project, the normal conservation work is unable to keep up the speed of restoration. In the face of such a sudden event, design and construction institutions came together to conduct on-site surveys, determine the main principles and targets, as well as precede the conservation work in a timely manner. The foundation of this project lies in the high-efficiency planning, the widely recognized conservation principles, and the complexity of the management in linking every process. In the construction practice, the traditional techniques and traditional materials are adopted with necessary improvements after careful discussion and comparable analysis of different plans, so as to guarantee the consistency and coherence of the conservation treatments in the entire process. The cooperation between conservators and constructors is also enhanced during the implementation. Therefore, the conservation project of Fulong Taoist Temple is a good example of heritage conservation practices for disaster restoration in China, and it is worth improving in the future.

6.1. Complexity, sensitivity, and technical consistency of the methodology

The project adopts the conservation approach, in which the design and construction are executed almost at the same time after establishing the general principles and aims. Therefore, in the restoration process, the cooperation between design and construction institutions should be enhanced on one hand, and the well-studied feasible restoration approaches should be adopted as much as possible on the other hand. The keystone of this project lies on the high-efficiency working plan and the complexity of the management in linking every process. In the construction practice, the traditional techniques and traditional materials are adopted, with necessary improvements after careful discussion and comparable analysis of different plans, so as to guarantee the consistency and coherence of the conservation treatments in the entire process.

6.2. Socio-economic viability and relevance of the project

After the completion of the project, Fulong Taoist Temple, which is open to the public, has been attracting

many tourists from all over the country. On the National Day in 2009, the number of visiting tourists resumed to the same level before the earthquake, which drives the vigor of the city and improves the economic development of the local community.

(1) This project is not only a conservation for a historic building, but also to rebuild the people's confidence after the earthquake. The project did not follow the usual public biding system but was directly planned by the national cultural heritage department, with its framework perfected by experts, and its design and construction commissioned. Success was gained in the shortest possible time, and it remarkably strengthened the faith of the people around the disaster area.

(2) The project's expenditures were covered by the nation. In line with the conservation plan, the national cultural heritage department organized the investigation and approval of the budget as well as directly transferred it to the management authorities of Fulong Taoist Temple and the management committee of Dujiangyan Cultural Tourism Scenic Area. This committee gathered the local community staff and encouraged them to cooperate with the construction company to carry out the conservation.

(3) After the completion of the conservation, Fulong Taoist Temple is still the main world heritage scenery – Mount Qingcheng and Dujiangyan irrigation system – and the exhibition place of Dujiangyan hydraulic construction and the hydraulic relics of the Han Dynasty for tourists from all around the world.

(4) After the completion, Fulong Taoist Temple, which is open to the public, has been attracting many tourists from across the country. On the National Day in 2009, the number of visiting tourists resumed to the same level before the earthquake, which drives the vigor of the city and improves the economic development of the local community (**Figure 11**).

Figure 11. The 2009 Completion Ceremony hosted by the State Administration of Cultural Heritage

7. Contribution of the project to the local community

The Fulong Taoist Temple is part of the Dujiangyan irrigation system, which is a world heritage site, under the management of Dujiangyan Cultural Tourism Scenic Area. The temple is one of the most famous sites for tourists and even local communities to visit and learn about the Dujianyan irrigation system. Besides, this tourism area provides the local community huge economic benefits and employments every year.

Throughout the whole conservation process, the people of Dujiangyan City were actively involved in the logistics service and the conservation project. Just after the earthquake, the people of Dujiangyan actively appealed to the society and the nation for the conservation, and they voluntarily offered themselves in the movement to salvage important relics and exquisite wood components at Fulong Taoist Temple. In the progress of the conservation, the administration of Fulong Taoist Temple continued to organize meetings to discuss on cooperation and services as well as actively promote the effective progress of the conservation, which brought on the recovery of Fulong Taoist Temple over such a short period of time. The project gained admirable support from the Scenic Area Management Department and the local community.

From the 2010 UNESCO Asia-Pacific Heritage Award, the completion of this project not only repaired the damage caused by the earthquake, but also refurbished the display and exhibition of the heritage, resuming its original exhibition function. Most importantly, this project was part of the reconstruction work after the earthquake, which helped the local community overcome their difficulties and rebuild their land (**Table 4**).

Table 4. Comments from the 2010 UNESCO Asia-Pacific Heritage Award

"Launched in the immediate aftermath of the deadly 2008 earthquake in Sichuan Province, the restoration of Fulong Taoist Temple represents a noteworthy model for post-disaster reconstruction and restoration of cultural heritage. …Following a rapid damage assessment and the development of general guidelines, the project implemented a restoration methodology that called for design and construction to be executed almost simultaneously. …The project was carried out in conformity with international conservation principles calling for retention of as much historic fabric as possible and restoration to the last known condition. With its completion achieved in a short 18-month span, the project has restored not only a major monument of outstanding value, but also the confidence and spirit of the people of Sichuan."

After the completion of the project, Fulong Taoist Temple has been attracting many tourists from all over the country. On the National Day in 2009, the number of visiting tourists resumed to the same level before the earthquake, which drove the vigor of the city and improved the economic development of the local community (**Figure 12**).

Figure 12. 2010 UNESCO Asia-Pacific Heritage Award

Disclosure statement

The authors declare no conflict of interest.

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How Multi-Sensory Perception Plays a Landscape Restorative Role in Adelaide's Urban Green Space

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Abstract: Urban green space is an effective psychological restoration landscape site. However, Adelaide's urban green space tends to focus on visual design but neglect non-visual senses. Sensory influence is interactive and has profound and subtle effects on tourists. The purpose of this study was to investigate the relationship between auditory, tactile, and psychological restoration of urban green space from a multi-sensory perspective. This study used quantitative research methods to investigate auditory and tactile-related landscape factors that have a positive effect on restoration. It is expected that this study will contribute to the high-quality restoration of urban green space and promote human health.

Keywords: Urban green space; Multi-sensory design; Restoration; Auditory and tactile design

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1. Introduction

Urban green space is essential for health and human well-being. It has been proven to have many functions, such as to lower blood pressure, reduce stress, and create a sense of pleasure [1].

A survey on Australian engagement in nature conducted by the Australian government showed that 73% of Australian adults have visited urban green space in a period of 12 months, with the Botanic Garden being the most popular (52%) [2]. Therefore, the demand for urban green space in Australia is extremely high.

However, currently, many designs of urban green space only focus on visual design, and with the development of the times, the satisfaction of users not only depends on visual stimulation, but also the use of multi-sensory elements in landscape design. In addition to visual experience, auditory and tactile experiences are the most basic and commonly employed methods of perception [3]. Therefore, they both play an essential role in the restoration of landscape.

The influence of sound on the experience of landscape design has been re-studied and has received increasing attention in recent years. For example, natural sound has been shown to have a positive effect on restoring individual attention [4]. Similarly, the tactile experience of a landscape is a concern for users in terms of landscape details. Exquisite details can often leave a deep impression; even a slight change can have a great impact on the overall landscape environment [5]. "Multi-sensory landscape" refers to a landscape based on different senses and how different senses perceive each other [6]. Moreover, good sensory elements can impress visitors and increase the attractiveness of a landscape, whereas bad experiences weaken the visual perception and appreciation of the landscape [7]. Therefore, it is crucial to explore the restoration effect of urban green space from a multi-sensory perspective and to determine the factors that play a positive restoration effect.

2. Research questions

The purpose of this research is to determine tactile- and auditory-related factors that have positive restorative effect on people.

Primary question: What are the most popular perception factors that play a positive landscape restorative role?

Sub-questions:

(1) What is urban green space?
(2) What are the functions of urban green space?
(3) How does multi-sensory perception affect one's feelings?
(4) Which landscape elements are most perceptible through auditory perception or tactile perception in urban green space?
(5) What kind of landscape factors relating to auditory and tactile perceptions will bring negative effects to people?

3. Objectives

The purpose of this study was to investigate the auditory- and tactile-related landscape factors that play a restorative role for urban green space. Quantitative investigations were conducted to achieve this goal. Specifically, an experiment was carried out to investigate the effects of auditory landscape factors on mental recovery, and a survey was conducted to examine the effects of tactile perception on landscape factors. This investigation is beneficial for landscape designers in studying the role of non-visual factors, paying attention to how auditory and tactile factors can be used to enrich landscape design techniques and the diversity of urban green space design; for people who do not have high requirements for visual stimulation, such as the blind or those visually impaired, in order to meet their needs to use urban green space for restorative purposes; for children as they not only gain tactile sensations by walking, but also when coming into contact with objects through other parts of the body; it is especially important to meet the needs of tactile perception in children. The Urban Planning Department of the Australian government can also benefit from this research, using this research as a guide to satisfy the demand of residents for urban green space. In addition, this research will help to maximize the restorative function of urban green space through multi-sensory factors and meet the needs of residents in a variety of ways in limited green spaces.

4. Significance to the discipline

Exposure to stimuli in densely crowded cities generally requires focus, resulting in mental fatigue [8]. Therefore, in order to alleviate this problem, a design that allows people to recuperate is crucial [9].

Urban green space is an open space that allows people to breath and move freely. It is regarded as a "green lung" [10]. Substantial evidence has reported that nature has healing functions [11] and contributes to human health, mental recovery, as well as happiness.

Although 80% of the surrounding environment is perceived visually, 20% of the information is still perceived by auditory, tactile, taste, and smell senses [12]. The overall human experience is multi-sensory; the senses interact with each other in the environment, and different senses have their own advantage.

Nature is the largest environment where humans can gather information, and at the same time a lot of information is perceived through auditory and tactile senses [13]. In addition, the perception of these two senses is crucial not only for normal people, but also the visually impaired and blind [14].

In the past ten years, sound landscape and tactile landscape have begun to attract more and more attention. Multi-sensory design and planning of urban green space is thought to be extremely important and a necessary field to investigate. For example, Hong and Jeon pointed out that it is beneficial to introduce pleasing sounds into a polluted urban sound environment, as this can contribute to human wellbeing [15].

Furthermore, with regard to sound landscape, Rainbolt, Benfield, and Bell studied the effects of man-made sounds on national historical parks and claimed that whether or not the sound at a scenic spot or the noise made by an aircraft is explained, it is all negative. Similarly, Zhou also pointed out the factors that can be perceived by tactile senses in urban green spaces: floor paving, materials, and passive perceptions, such as temperature, wind, etc., using tactile experience as the focus; the entry point of designs, with more consideration of human tactile factors in these designs; the shaping of a landscape space that makes the human body more at ease [16]; and the contact and interaction between the human body and the landscape [17].

However, most researchers neglect the assessment of auditory and tactile cognitions in the restorative function. They pay more attention to studying the formation of sound landscape and tactile landscape, in addition to the relationship between visual and non-visual senses, rather than on the restorative effects of non-visual senses. In addition, the site of the investigation was not in Australia. Different research sites may have different effects on the results [18]. Therefore, it is necessary to focus on the non-visual senses of auditory and tactile perceptions in relation to landscape factors that play a restorative role in Adelaide's urban green space.

5. Theoretical framework and methods

Three scenic pictures (Adelaide, Adelaide Botanic Garden, and Himeji Garden in Adelaide) were selected in combination with sounds to determine the auditory-related landscape factors that have a good restorative effect on people.

Only three pictures were selected to create a relatively single visual scene, weaken the visual effect, and help subjects focus on the auditory elements. The six selected sounds were categorized into nature-related sounds (sound of water, wind, and birds singing) and man-made sounds (traffic noise, people speaking, and background music). These are common factors in urban green spaces and are directly related to the auditory sense. These factors were tested by using single playback and combined playback. The combined playback involved the use of Adobe VoCo to combine these sounds in pairs, such as the sound of water and the sound of wind, the sound of wind and people speaking, birds singing and traffic noise, etc., according to the principle of non-repetition; there were a total of 16 kinds of combined playback.

Canon EOS 3000D with EF-S 18-55mm was used to take pictures, and the three best-quality photos from each site were selected to represent the visual landscape of the site. The photos were displayed on a projector (QKK Latest Upgraded 4200 Lumens Mini Projector). The sounds used were all selected and downloaded from a website and played at 45dB through a speaker.

By combining the three photos with 22 (6 + 16) sounds using Adobe Premiere, 66 (3x22) sound-visual photo combinations were obtained. After testing each sound and photo combination, the subjects were required to fill in a form (**Figure 1**) that included the emotional, psychological, and cognition aspects of the subjects using a seven-point Likert scale, with 1 indicating strongly disagree, and 7 indicating strongly agree. After the test, the average value of each combination was determined. A high score indicated a better restorative effect of the factor. Hundred and twenty students were selected from the University of Adelaide, and the ratio of men to women was balanced.

		scale						
Emotion	I feel peaceful and less stressful	1	2	3	4	5	6	7
Psychology	I feel I reduce the feeling of lonely	1	2	3	4	5	6	7
Cognition	My concentration is more focused	1	2	3	4	5	6	7

Figure 1. Auditory testing form

A survey was conducted to investigate tactile-related psychological restoration.

Since Adelaide Botanic Garden is located at the heart of Adelaide and is bordered by residential areas, it is an ideal location for the survey. In addition, it is surrounded by various natural elements, including shrubs and trees, with a green area of 94%. Therefore, it is an excellent location for the study.

The survey was conducted in two ways. The first was face-to-face random sampling, where questionnaires were distributed to visitors who visited the green space from 10 am to 4 pm in a week; the second was online research, where this method focused on people who had visited the Botanic Garden in the past but have not participated in face-to-face research. The purpose of the online survey was to expand the scope of the target population, so as to obtain more data and improve the credibility of the conclusion.

A five-point Likert scale was developed to measure the perceived psychological restoration. The options in the questionnaire were divided into natural elements (stepping on the lawn, walking on the soil, and feeling of temperature) and artificial elements (floor paving, seats, and fountains or pools). The subjects were required to rate the following statements: (1) "Stepping on the soft lawn gives me a pleasurable feeling"; (2) "Walking on the soil makes me feel that I am a part of nature"; (3) "The temperature here makes me feel comfortable"; (4) "The floor paving makes me feel good"; (5) "The seats here are comfortable and makes me feel relaxed"; (6) "Being in contact with water from fountains or pools makes me feel less stressed and anxious." The statements were rated by using the five-point Likert scale, with 1 indicating strongly disagree, and 5 indicating strongly agree.

The subjects were required to fill in the questionnaire truthfully. If there was an element that had not been noticed by the subjects, the "Unnoticed" option box can be checked, and the subjects were allowed to drop the study.

All results were presented in tables and bar charts to ensure the clarity of the results.

Considering the cost of equipment and labour, the budget list is shown in **Table 1**.

Table 1. Budget list

Item	Type	Cost
camera	EOS 3000D with EF-S 18-55mm	$239.10
projector	QKK Latest Upgraded 4200Lumens Mini Projector	$109
speaker	Portable JBL Flip 5 Portable Bluetooth Stereo Speaker	$145.25
printer (for questionnaire)	Epson Expression Home XP-3100 Print	$99.16
The salary of the assistant who issued the questionnaire	7 days in all	$400
Paid websites download sound	6 typers of sound	$30
Total		**$1,022.51**

The research timeline is shown in **Figure 2**.

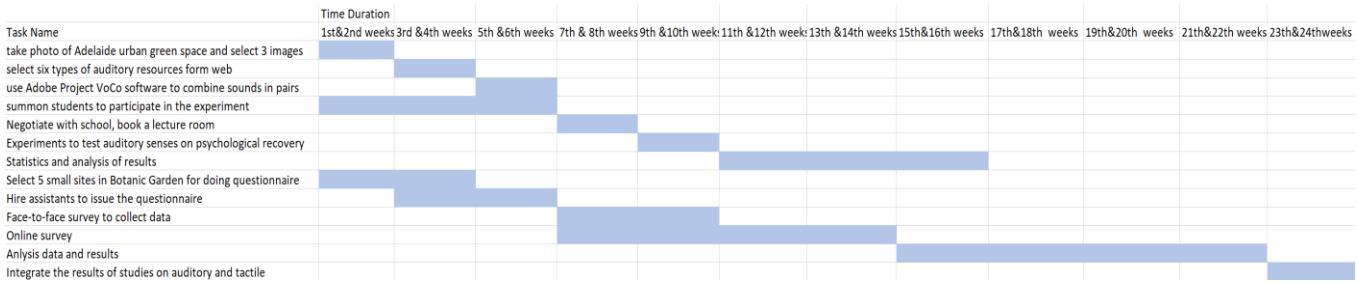

Figure 2. Research timeline

6. Skills training and professional development

Adobe VoCo is needed to synthesize sounds, while Adobe Premiere is required for combining pictures and sounds. Before starting the research, it is necessary to learn literal scale systematically and set accurate and appropriate options as well as corresponding values.

Disclosure statement

The authors declare no conflict of interest.

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BIM-Based Strategies for Construction Quality Control in Building Engineering

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Abstract: In order to improve the construction quality and steadily promote the improvement in the level of the construction industry, this paper expounds BIM-based strategies for construction quality control. This paper first identifies the factors affecting the construction quality, analyzes the advantages and value of the application of BIM in construction, and finally analyzes the scenario of applying BIM for future references.

Keywords: BIM; Building engineering; Construction quality control

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1. Introduction

The demand for buildings is expanding in tandem with the global acceleration of social construction and the constant growth in the number of people, which plays a vital role in promoting the development of the construction industry. The number of construction companies is also gradually increasing, with more people being interested in engendering profits from the construction industry, thus heightening the competition in this industry [1]. The construction engineering industry has now become the core industry supporting social and economic development. The characteristics of construction engineering and the working environment at the construction site suggest that this industry is in fact a "high-risk" industry [2]. Especially in recent years, many construction engineering safety mishaps have occurred, causing people of all walks of life to pay more attention to this aspect. Casualties due to unnecessary potential safety hazards in the actual construction process bring serious economic losses to enterprises and unstable factors to the society [2]. Research related to construction quality has always been a major focus of the construction industry, and the stability of construction quality is not only related to the safety of social groups living in buildings, but also affects the interests of the construction party [3]. In short, the research on construction quality control and management of related projects is a comprehensive work, which is accompanied by the technical requirements of the project construction unit for project implementation, scientific mix proportion, and standardized material use. Although the asset management of the construction process and the later stage of the service project have attracted attention from the construction side, there are still many loopholes in the operations of the construction supervision and technical personnel in the implementation stage. In addition, the construction period is usually long, and many construction operations involve dangerous high-altitude and field operations, making the impact on the construction project more uncontrollable and affected by these factors to a certain extent. This puts forward higher requirements for the safety guarantee of the construction party. Under the social background of the positive development of market economy, the construction industry must constantly adjust the market structure. The industry can only continue to develop

if an ideal control system in terms of economy and profit is established.

2. Factors affecting the technical quality of building construction

There are often many uncertainties in the construction process. Factors causing low construction quality are seen throughout the entire project. They include human, material, object, environment, method, and other factors. These factors affect the quality of construction technology, and eventually the completion of the construction project [4].

2.1. Human factors

People play an important role in the construction process and take the lead in completing construction projects. Large-scale construction projects usually require more manpower. Construction technology and quality work often require personnel with high comprehensive quality and professional level, but in practice, many construction units have low professional level and weak awareness of safety management, thus affecting the quality to a certain extent [5]. Construction technology is mostly affected by human factors. It is controlled by people, which is most likely to result in the low construction quality.

2.2. Material factors

The most basic factor to ensuring construction quality is the use of verified building materials. The quality of materials determines the quality of construction technology. However, some construction units often only seek immediate interests and use non-suitable building materials to reduce material costs, thus leading to quality issues in completed buildings.

2.3. Environmental factors

Since most buildings are built outdoors, weather, terrain, hydrogeology, and other conditions have a great impact on construction projects, thus increasing the uncertainty in the construction process of these projects.

2.4. Mechanical factors

The majority of construction projects use complex and large-scale construction technology that necessitates a huge quantity of mechanical equipment. As a result, when mechanical equipment fails, the overall construction quality of the construction project is easily affected.

2.5. Process factors

Due to technical reasons, the construction process tends to be complex, as there are many kinds of processes, with each process having different quality standards. Therefore, the construction process is not covered, and the standards and requirements of each process are not specified. In that case, the technical quality of the construction cannot be guaranteed. In the current market economy, due to the nonstandard construction contract management and fierce competition in the construction process, many construction enterprises have reduced the standardization of construction management in order to improve their economic interests. Therefore, enterprises lack quality control. Due to the continuous development of the society and economy in China, the improvement of the construction market cannot keep up with the market economy. Many enterprises move forward in pursuit of economic benefits [6]. Using cheap materials to reduce costs, construction projects do not have quality supervision; in addition, the purpose of the construction contract has been disregarded, becoming a dead letter, which does not play any role in the actual construction process. Construction supervision is an important means of construction quality control, and supervision is also an important link and influencing factor in construction technology. A quality supervision of construction technology is very important for quality control because it covers all aspects of construction projects from

design and development to material procurement and the actual construction process. Due to the lack of supervision or effective supervision measures for ensuring the quality of construction projects, many construction enterprises have hidden dangers in the later use of buildings, which are prone to safety incidents and unimaginable repercussions.

3. Advantages of applying BIM in the construction quality management of prefabricated buildings

3.1. Improve the efficiency of quality control

The scientific application of BIM in the construction management of prefabricated buildings makes the presentation of information data more efficient, scientific, intelligent, and electronic. With the help of visual data platform, managers can manage the construction quality more scientifically and effectively, with the operation being more scientific and standardized. It effectively makes up for the shortcomings of traditional paper information storage and transmission methods, with safer information storage, more efficient construction quality management, more accurate control of relevant parameters, and improved management efficiency [7].

3.2. Construction quality control based on simulation

BIM features a simulation function that mimics the construction scheme analysis mode, which can organically associate the 3D model of a building structure with time and develop a 4D spatial construction model as well as a 5D communication technology platform on this basis. Moreover, the structural framework and architectural appearance of each construction link can be simulated and compared with the actual construction appearance to determine any quality issues [8]. The building information model based on BIM allows for different modeling with various accessories in different types and sizes. In that way, the supervision department and relevant technicians can fully understand the construction information and further optimize the installation process and implementation process. The construction will be transparent, and the construction quality will be fully guaranteed.

3.3. Traceability of the entire process in terms of quality responsibility

Taking a prefabricated building as an example, its construction involves multiple links, of which different personnel are responsible for. Based on the scientific application of BIM, the role of internet of things and mobile devices can be maximized to link the construction process organically. By maximizing the role of cloud storage and other technologies, construction instructors can achieve control and guidance remotely, as well as real-time supervision and management of the construction process. In addition, various indicators and parameters formed during the construction process can be uploaded to the cloud, so that relevant staff can fully, timely, comprehensively, and accurately gauge the actual situation in the construction process [9]. They will be able to achieve supervision and traceability of the entire construction process and its quality.

4. Application of BIM in construction quality control

4.1. Before construction

4.1.1. Drawing review

A good drawing review enables one to determine the loopholes and correct them in time, which would help reduce errors in the construction process and improve the quality as well as efficiency of the construction project.

4.1.2. Collision inspection and reserved hole design

Before pipeline and electromechanical installation, BIM can be used to identify conflicts and possible issues, so as to enable specific measures to be taken for optimization and repair. By determining the problems in

advance and reducing the rework in the later stage, the project cost and quality issues caused by rework can be reduced.

After completing the BIM model of the electromechanical pipeline, the BIM representative outlines the opening in each professional drawing of the project. Thereafter, it is necessary to further design the details of the reserved opening. This allows the construction personnel to plan their location and drill holes in advance to prevent mistakes from occurring in later stages. BIM can also be used to integrate multiple professional models of architecture, structure, electromechanics, and so on. These models can be transmitted to Navisworks for cloud computing, and the collision results can be derived from the software after calculation [10]. By referring to the output of the software, if problems are found, the model can be reoptimized after correction.

4.1.3. Site layout optimization

It is necessary to use BIM to establish the site environment model, plan and organize office and living facilities in advance, as well as manage the main entrances and exits, temporary roads, material storage areas, rotating fields, mechanical equipment, and so on, in order to avoid construction delays [11]. It realizes cross-task interaction and uses the BIM model to coordinate and manage the general layout of the construction in each stage.

4.2. During construction

4.2.1. Construction process simulation

Before the formal construction of complex structural shear wall using BIM, shear wall construction is used to simulate the construction process from reinforcement binding to wall formwork and concrete pouring. In the simulation process, on the one hand, problems can be found in advance to optimize and solve the problems; on the other hand, the construction technology can be disclosed to frontline construction personnel to help them familiarize with the construction technology and process. Therefore, it can effectively improve the quality control effect in the construction process of shear wall.

4.2.2. Change in construction scheme design

Temporary changes are common in the construction process, but the effect after the change is often difficult to visualize. After comparing the technical variables, feasibility, economic benefits, and constructability of the construction method after the site change, the comparison scheme before and after the change can be identified and submitted to the head office. The BIM collaborative management platform can be used to communicate with the design unit online and provide data sheets.

4.2.3. BIM mobile application

The on-site construction management personnel can use the mobile terminal of the self-developed C8BIM collaborative management platform to view the model, plan, component details, size, elevation, and some other areas that are difficult to view on a handheld mobile device. Quality inspection is a great convenience. The construction management personnel can intuitively identify on-site quality issues, record them on the mobile equipment, and rectify them in time [12].

4.2.4. UAV and intelligent platform application

UAV is used to conduct on-site inspection, identify potential safety hazards in time, inspect the construction quality in an all-round way, and collect video data of key construction nodes. It may be beneficial to generate data information instead of manual mapping, create a 3D model, and compare it with the BIM model to identify construction quality issues in time.

4.3. After construction

4.3.1. Information management

The construction cycle of an engineering project is usually long, especially for large-scale projects with complex structure. From the beginning of the project to the completion of the entire project, there will be an accumulation of a large number of engineering data files. All these materials are printed on paper for storage. This process requires a lot of time and experience, with a low efficiency. Dealing with these materials is a challenge for data owners. When there are problems in the construction process, it will be inconvenient to look for the drawings, and it will also be a challenge to obtain accurate information in a timely manner [13]. Using the archival data collaborative management platform can effectively alleviate this problem. During modeling, BIM technicians can directly input the material and equipment parameters into the model, and the BIM collaboration platform allows the site manager to upload the data collected in the construction process to the BIM model in time, so as to realize the availability of data. At the later stage of the project, when there are quality problems, relevant personnel can key in the corresponding number in the collaborative management platform and identify the cause of the problem as well as the person responsible for it.

Inputting material and equipment parameters as well as construction information (technical parameters, manufacturer, production date, construction date, construction unit, warranty period, etc.) in the BIM model and linking them with the corresponding engineering design will be convenient for various construction management drawings and subsequent asset management operation and maintenance [14-16].

4.3.2. QR code data management

BIM administrator can use a BIM-related software to generate a QR code for each component in advance and then paste the QR code into the built component. By scanning the QR code of digital products, such as mobile phones or tablets, one can quickly view the information model of the corresponding part, and managers themselves can intuitively inspect the information model and detection data to provide information convenience.

5. Conclusion

In conclusion, construction quality is affected by many factors. In general, they can be divided and placed under five categories: people, things, environment, machinery, and technology. In order to avoid the influence of these five factors on the construction quality, it is necessary to strengthen the application of BIM to improve the efficiency of construction quality control, realize the simulation experiment design of construction quality, and ensure that the quality responsibility of a construction project is clear with good traceability. Construction quality control can be divided into before construction (drawing review, collision inspection and reserved hole design, as well as site layout optimization), during construction (construction process simulation, construction scheme design, BIM mobile application, and intelligent platform application), and after construction (information management and data information management). BIM can be applied throughout the entire process of building construction quality control.

Disclosure statement

The author declares no conflict of interest.

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Comprehensive Recycling Technology of Waste Residues in Zinc Hydrometallurgy

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Abstract: In order to improve the refining effect of zinc ore and promote the development of this industry, taking the hydrometallurgical zinc smelting process as an example, this paper first establishes a model for the recycling of waste residues in the hydrometallurgical process, proposes optimization measures based on proven comprehensive recycling technology for purifying residues to obtain higher valuable metal recovery rate, and provides reference for those in relevant fields.

Keywords: Zinc hydrometallurgy; Valuable metal; Comprehensive recycling technology; Waste residue

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1. Introduction

Zinc is one of important mineral resources in China. Proved zinc reserves account for more than 18% of the world's total reserves. Due to the increasing demand for zinc in China, current production cannot meet the demand. Therefore, recycling from zinc-containing waste residues is of great significance, which can promote the recycling of this mineral resource and its sustainable development. Zinc-containing waste residue pollutes water, air, and soil, and it has high toxicity. It endangers the ecosystem and threatens human life and health [1]. In addition, zinc ore is usually associated with precious metals. such as copper, silver, and gold. Recycling its waste residue not only increases metal production, but also reduces environmental pollution. Therefore, it is necessary to develop a comprehensive recycling technology to improve the value in resource utilization. In China, the blast furnace and hydrometallurgical processes are used in zinc smelting. Zinc hydrometallurgy has several advantages, including low energy consumption and low pollution discharge; it is widely used in the production of metallic zinc [2-6]. Taking the zinc hydrometallurgical process as the research subject, a comprehensive recycling technology is proposed to promote scientific and standardized utilization of zinc-containing waste residues as well as provide a theoretical reference for the development of the zinc smelting industry.

2. Comprehensive recycling technology of waste residues in the zinc hydrometallurgical process

2.1. Establishing a thermodynamic model for the zinc leaching residue process

In order to realize the comprehensive recovery and utilization of zinc-containing waste residues, the thermodynamic model of the slag removal process is established. This model is mainly used to analyze the leaching process of the waste residue, the degree of dissolution, and the stability of various elements, so as to determine the equilibrium conditions of the reduction reaction. At a fixed temperature, the volatility of metal vapors increases with increasing pressure. According to the volatility of zinc [7], it is reduced from the leaching residue to steam and condensed to obtain solid metal, so as to realize the separation from other

mineral elements and achieve the purpose of extracting zinc. Gibbs function is used to determine if a reaction can occur spontaneously; its formula is as follows:

$$G = G_0 + \alpha T \ln\left(\frac{p}{p_0}\right)^m \tag{1}$$

In formula (1), G and G_0 represent the reaction and standard Gibbs free energy, respectively; α is a constant; T represents the thermodynamic temperature; P and P_0 represent the reaction pressure and standard state pressure, respectively; M is the stoichiometric number. When G < 0, the reaction is considered to be able to proceed spontaneously; on the contrary, it cannot proceed spontaneously when the value of G is 0, in which the equilibrium state is reached. In the zinc leaching residue, zinc mainly exists in the form of sulfate and oxide, while valuable metals, such as copper, exist in the form of elemental substances. The residue is acid leached with a leaching agent, resulting in a reduction reaction [8]. Zinc enters the solution in a stable ionic state, so the leaching process is a heterogeneous reaction between solid and solution. At the junction of the solid phase and the liquid phase, there is an ion saturation layer through which the dissolved zinc ions diffuse outward, further aggravating the reduction. The degree of reaction can be measured by the leaching rate, and its formula is expressed as follows:

$$\frac{dw}{dt} = -z\lambda \tag{2}$$

In formula (2), w represents the leaching amount of the solid phase; T represents the time; Z represents the unit mass of the leaching material transferred from the solid phase to the liquid phase; λ represents the solid-liquid interaction area. The solid-liquid interaction develops from the surface to the center, which is closely related to the concentration of reactants, temperature, and other factors. When the reaction nucleus appears in the center, the interaction stops, indicating the completion of the leaching process.

2.2. Selecting a waste residue leaching agent

The thermodynamic model shows that the zinc leaching residue process is a multi-intersection and interactive segmental process. In order to improve the leaching speed of the reaction, the major influencing factors need to be controlled. Among them, the waste residue leaching agent has a huge influence on the recovery and utilization of zinc. In this paper, sulfuric acid is selected as the leaching agent in the pickling process. When the acid concentration is low, the dissolution probability of zinc is higher and the degree of enrichment in the solution is higher, while the dissolution probability of other valuable metals is relatively low. In that way, the separation of zinc can be achieved. Generally speaking, the higher the acidity of the leachate, the better the effect, but excessively high acidity will prolong the reaction time. Therefore, it is necessary to control the acidity during the leaching process to ensure a weak acid environment at the end of the reaction, so as to facilitate the leaching of zinc metal [2]. During the leaching process, emulsification inevitably occurs to form an organic phase, which affects the mutual leaching of solid and liquid phases. The organic phase usually appears at the solid-liquid interface and is equivalent to a surfactant. It not only reduces the solubility of the solid phase, but also contaminates the solution. Therefore, it is necessary to prevent emulsification in the leaching process. The organic phase materials can be removed by adding a suitable extractant. In this paper, phosphoric acid extractant is used to purify the leaching solution to realize the separation and cleaning of the organic phase [9-16]. In this paper, the process acidity of the residue leachate is set to pH 3.5, and the termination acidity is set to pH 4 to ensure the effective dissolution and enrichment of metallic zinc.

2.3. Setting the replacement process for comprehensive recovery

After pickling and water washing, there are still some valuable metal elements that have not completely dissolved in the leaching solution. In order to increase the zinc content in the waste residue, it is necessary to comprehensively recycle the waste residue [11]. In this paper, the recovery process of zinc ore is controlled in accordance with the replacement process to ensure a higher leaching rate, so as to complete the comprehensive recovery and utilization of waste residues. The technical flow chart is shown in **Figure 1**.

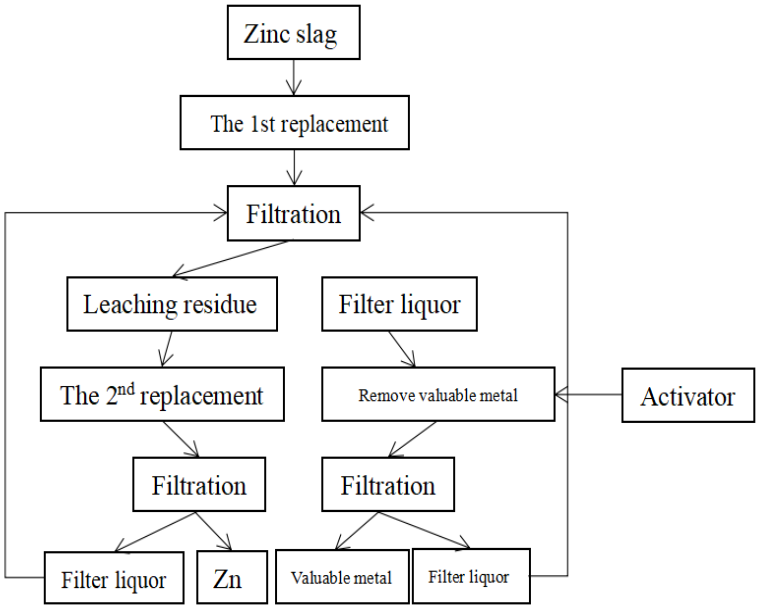

Figure 1. Comprehensive recycling process of waste residues in zinc hydrometallurgy

As shown in **Figure 1**, the comprehensive recycling process mainly includes primary and secondary replacement processes. The aim of the first replacement is to produce crude zinc, in which zinc is directly replaced in the leaching solution of waste residue, and crude zinc is produced after molding. According to the thermodynamic model, the negative migration range of zinc in metal replacement solution is smaller than that of valuable metals, and the difference in terms of their electrical property is about 0.25 V. Therefore, a large amount of zinc ions in the solution are required to achieve complete replacement. In practical engineering, it is impossible to achieve effective recovery by one-time replacement of waste residue, and only the result of coarse zinc condensation can be obtained [3]. The zinc ore filter residue is grounded, pulped, and put into a stirring tank, leached with sulfuric acid, and the changes of temperature and acidity are detected. The temperature of the first replacement process is controlled at 50°C, the time is 1 hour, and the initial acidity and end acidity are 5.3 h, respectively. Under this condition, not only the residual zinc in the acidic solution can be ensured, but also the improvement of the molding success rate. After the first replacement is generated, the acid dissolution process is further carried out. The operation procedure is the same as that of the first leaching, and the second replacement can then be completed. Compared with the primary leaching filtrate, the zinc enrichment rate of the secondary leaching filtrate can reach more than three times, and the success rate of zinc clustering is greatly improved. The temperature of the secondary process is controlled at 85°C, and the time and acidity conditions are consistent with the primary replacement. The filter residue after the reaction comprises of zinc residue. The activator is added several times to the primary leaching solution, and the acidity is controlled at pH 4.5. After the completion of the reaction, the valuable metal is obtained by filtration. On the premise of ensuring the quality of zinc ore, the associated valuable metal resources can be obtained, and the comprehensive recycling of waste residues can be realized.

3. Technology improvement

In modern hydrometallurgical zinc smelting process, the comprehensive recovery and utilization of purification slag uses the full wet method as well. On the basis of the mature process, this paper further improves the process of slag purification and improves the leaching rate of valuable metals. The main reason for the lower index of lead slag is the low leaching rate of zinc and cadmium in high cobalt slag. Zinc in lead slag mainly exists in the form of metal zinc and a small amount of zinc sulfate, while cadmium mainly exists in the form of metal cadmium. In the process of purifying and removing copper and cadmium, there are two reaction tanks, and zinc powder is only added in one of the reaction tanks. The distribution ratio of zinc powder is unreasonable, and its reaction and filtration require time. The reaction period is usually 1.5 hours, and it takes approximately an hour to filter the liquid entirely and separate the slag. The longer the contact time of the cadmium slag obtained after the zinc powder replaces cadmium with the solution, the easier it is to reverse-dissolve; that is, the metal cadmium becomes Cd^{2+} and enters the solution again. As a result, the cadmium content in the liquid fluctuates greatly after removing copper and cadmium.

3.1. Improvement of iron removal process

For iron removal, the original method is to add hydrogen peroxide for oxidation and then limestone slurry for neutralization to remove the colloidal precipitate produced by iron. However, the iron hydroxide colloid produced by this method is difficult to filter by pressure, which seriously restricts the production progress. With improvement, limestone slurry is first added to adjust the pH to 5.0, and hydrogen peroxide is then slowly added for oxidation. If the pH is not enough, lime slurry is added to adjust the pH to 5.0. Qualitative methods are used to quickly judge whether the iron content in the liquid after iron removal is qualified. The effect of the improvement is as follows: the slag properties of iron precipitation change, and the formation of $Fe(OH)_3$ colloid becomes goethite-like. With the improvement, the filtration performance of the pulp is significantly improved, the slag is dried, the thickness of the slag cake is significantly increased, and the filtration speed of the iron-removing pulp has doubled, thus meeting the production needs.

3.2. Improvement of one permutation

Before improvement, the hybrid motor is a non-variable frequency motor, and the speed cannot be adjusted. From adding zinc powder to the end of the reaction, its operating frequency is high. Before adding zinc powder, the pH value is not adjusted, and zinc powder is added directly to replace at a pH of 5.0. In that case, the activity of zinc powder is not high. When grooving, compressed air is supplied from the bottom, and after one-time replacement, the cadmium content in the solution is controlled at about 500 mg/L. Due to the above factors, the prepared cadmium sponge is finely crushed, and it is not easy to be pressed into a group. The quality of extruded cadmium cake is poor, with cadmium less than 80%, and the recovery rate of sponge cadmium is as high as 50%. With improvement, the motor is replaced with a variable frequency motor; the speed is reduced when adding zinc powder and increased slightly after adding zinc powder. Before adding zinc powder, the pH value is adjusted to 3.0 to improve the activity of zinc powder. The bottom compression air inlet is stopped, and the cadmium content in the liquid is increased after one replacement and controlled to 1 g/L to 2 g/L. The effect of the improvement is as follows: the cadmium sponge produced is significantly larger, the cadmium sponge is easier to suppress, the quality of the cadmium cake is better, including cadmium more than 85%, the recovery rate of the cadmium sponge is reduced to less than 10%, and only a small amount of material extruded by the molding machine needs to be returned.

3.3. Improvement of secondary replacement

In the original method, after the first replacement, the liquid is pumped into the second replacement tank,

stirred continuously, and a sample is taken to detect the cadmium content before the second replacement. After the results are in, zinc powder is added to remove cadmium. The excess coefficient of zinc powder is as high as 1.8 times the theoretical value, but when it is lower than 50 mg/L, cadmium cannot be removed, which seriously increases the production cost. During the second replacement process, steam is always used for heat preservation, and the temperature is controlled at about 65°C. With improvement, stirring should be started five minutes before sampling and stopped after sampling. After obtaining the liquid cadmium detection results, zinc powder should be added before secondary replacement. The reaction temperature is then lowered and controlled at 55℃ to 60℃. The effect of the improvement is as follows: the excess coefficient of the secondary replacement zinc powder is reduced from 1.8 times of the theoretical amount to 1.2 times, and the cadmium content in the post-liquid is stably reduced to below 50 mg/L, which significantly reduces the cost.

3.4. Improvement of cobalt removal

Before improvement, the cobalt removal agent is directly added to the cobalt removal tank in powder form, resulting in uneven addition, yellow smoke, and a large amount of cobalt removal. In addition, the pH value is not adjusted before adding the cobalt removal agent. The pass rate of the slot is about 50%, and frequent secondary slotting is required, which reduces the production efficiency. With improvement, the pH value is adjusted to about 4.0 before adding the cobalt removal agent. After mixing mud and water, the cobalt removal agent is added. The effect of the improvement is as follows: the yellow smoke problem before the improvement is solved, and the amount of cobalt removal agent is reduced. The dose is reduced from 14Co + 6Ni + 3Cd to 12Co + 6Ni + 3Cd. The cobalt removal effect is stable, and the success rate of one-time slotting is increased to more than 85%.

4. Conclusion

In conclusion, after optimizing the valuable metal extraction process during residue purification in zinc hydrometallurgy, the filtration performance of the iron removal slurry has significantly improved, increasing to 85%, and the return rate of cadmium has decreased from 50% to 10%, greatly improving the leaching rate of cadmium; the amount of zinc powder added has reduced from 1.8 times to 1.2 times theoretically, while the content of cobalt has also reduced from 14 times to 12 times; the efficiency of removing cobalt from the filtrate has improved significantly, which is a noteworthy accomplishment.

Disclosure statement

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Countermeasures for the Maintenance Management of Expressway Bridges and Tunnels

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Abstract: In order to improve the maintenance of expressway bridges and tunnels as well as to maximize the utilization rate of expressway bridges and tunnels, this paper studies the countermeasures for the maintenance management of expressway bridges and tunnels. Through theoretical analysis, this paper expounds the problems existing in the maintenance management of expressway bridges and tunnels as well as proposes corresponding solutions to these problems. By implementing the countermeasures for the maintenance management of expressway bridges and tunnels, it is possible improve the maintenance effect of expressway bridges and tunnels as well as ensure the smooth and safe operation of expressway bridges and tunnels.

Keywords: Expressway; Bridges; Tunnel; Maintenance management

Online publication: May 30, 2022

1. Introduction

In China, the expressway is an important part of the road network system, which guarantees people's safety while travelling. However, with the ongoing development of various domestic expressways, the pavement of many expressway bridges and tunnels has developed defects of varying degrees after being put into operation, such as cracks and water damage, thus significantly increasing the traffic risk. Therefore, maintenance measures must be taken to effectively improve the structural quality of these pavements and ensure people's safety while travelling [1-8]. Chen Tao believes that with the increase in traffic flow and vehicle speed on the expressway, the risk of pavement rutting, cracks, pits, and other defects is also increasing, thus traffic safety cannot be guaranteed [9]. Therefore, some feasible maintenance measures should be applied, such as paving technology, local filling technology, and overlay maintenance technology, so as to ensure structural safety. The engineering construction quality of expressway bridges and tunnels is of great significance to promoting the development of China's infrastructure and ensure the safety of people's lives.

2. Problems existing in the maintenance management of expressway bridges and tunnels

2.1. Backward maintenance management mode

China has a large highway bridge and tunnel system; hence, a lot of energy and money need to be invested in the maintenance management of highway bridges and tunnels. The maintenance management mode is still backward. At present, there is no advanced concept and effective solution for the maintenance of highway bridges and tunnels. The maintenance mode is backward, and it lacks scientific and reasonable maintenance measures, effective maintenance specifications, as well as practical maintenance methods for employees.

2.2. Low overall quality of maintenance personnel

The maintenance management personnel are closely related to the use and management of highway bridges and tunnels. They not only implement the decisions of their superiors, but also have direct contact with the system. Therefore, the maintenance management personnel are responsible for the maintenance of highway bridges and tunnels. Their overall quality directly determines the quality and efficiency of their work. A low overall quality will have a great impact on the maintenance management of highway bridges and tunnels. For the maintenance management of highway bridges and tunnels, many employees do not maintain quality or inspect carefully. In addition, the maintenance manager's attitude towards the overall technical problems, the way of thinking about work, and learning new maintenance modes are also important factors that restrict the advancement of maintenance operation.

2.3. Lack of sound and efficient maintenance management mechanism

A sound maintenance mechanism is the basis for the smooth and efficient completion of work. Without a sound maintenance management mechanism, there will be many loopholes in the maintenance of highway bridges and tunnels. With the passage of time, these loopholes will continue to accumulate, causing damage to highway bridges and tunnels as well as seriously affecting the service life of these bridges and tunnels. In addition, the maintenance management mechanism with ambiguous rights and responsibilities will cause confusion in work management between departments and employees, as well as reduce work quality and efficiency. At present, China still lacks an ideal and efficient maintenance mechanism. Due to the long-term influence of maintenance methods and habits, departments and employees at all levels lack awareness of the importance of innovation and keeping pace with the times, in completing work scientifically and orderly, as well as in establishing and perfecting the maintenance mechanism. These rules and regulations have seriously restricted the development in maintenance of highway bridges and tunnels in China.

3. Countermeasures for the maintenance management of expressway bridges and tunnels

3.1. Preparation and improvement of the maintenance system

In the process of maintenance, it is important to first strengthen and implement the bridge management system and inspection system. Technicians and professional maintenance personnel should regularly and timely identify road, bridge, and time issues. At the same time, strengthening the resolution of existing highway bridge defects and formulating preventive measures for large-scale highway bridge defects and safety accidents are also important. In addition, the maintenance department should establish a reasonable bridge inspection system to carry out special inspection on highway bridges to prevent the occurrence of other defects. The maintenance management department should also establish a highway and bridge maintenance report system to ensure that professional technicians and maintenance personnel record down the defects and follow up with equipment maintenance, so as to provide strong data support for the continuous maintenance work in the future [2]. Finally, the safety management responsibility system should be implemented to ensure a clearer division of responsibilities and work requirements of technical and management personnel. Each road and bridge should be managed by an assigned person, so that the person in charge of each road section will be able to detect the defects in a timely manner. Therefore, the construction and improvement of the technical management system of highway bridges can lay a foundation for ensuring the continuity and integrity of bridge maintenance, implementing various maintenance and management actions, as well as improving the maintenance quality of highway bridges.

3.2. Road cracks repair

Load cracks not only affect traffic safety, but also may cause fatal damage to the durability of the bridge. Therefore, relevant units and maintenance management departments should attach great importance to and

adopt corresponding maintenance schemes for different types of load cracks. At the level of structural defects of the bridge itself, measures such as steel plate adhesion, prestressed reinforcement tensioning, and original structure reinforcement can be adopted to effectively solve the problems of load cracks and insufficient bearing capacity of the original structure, which can be confirmed by a load test [3]. In addition, in view of the load cracks and main reinforcement corrosion caused by the insufficient bearing capacity of the main beam, adhesives or anchor steel plates can be used at the tensile edge of the structure and weak parts of the bridge to form a relatively stable structure, so as to effectively solve the cracks and other defects caused by the increasing load on the bridge. These methods can improve the original structural stress state of the bridge to a certain extent.

3.3. Bridge deck maintenance

In terms of preventive measures, in order to effectively prevent the damage to highway bridge deck concrete, the maintenance unit must reasonably arrange the bridge deck pavement. First, before paving asphalt concrete materials, tools such as iron brush should be used to clean up road dust and sundries. The compaction of asphalt concrete can control the water permeability within a range and the slump of concrete to ensure the continuity and high strength of concrete materials.

In terms of maintenance measures, at this stage, the general maintenance and reinforcement scheme mainly includes local maintenance, overhaul, etc. Local repair mainly involves milling, supporting, melting rusty materials, and other processes for the damaged asphalt pavement of the bridge deck, followed by paving. A new pavement layer can be used to ensure that the laying thickness and weight meet the design load [4]. In addition, for bridges with potential safety hazards, such as large bridge deck damage, large span, and multiple pits, a backfill maintenance scheme should be formulated. Recasting requires the use of technology to remove the old road surface, smooth the surface, and fix the short rod. At the same time, it is necessary to lay an appropriate amount of wire mesh to strengthen the safety of the bridge deck, and finally pour concrete with appropriate thickness.

3.4. Drainage system maintenance

When the bridge drainage system is damaged or blocked, water will fill the bridge area, causing vehicles to slip and adversely affect the safety of drivers. This is also an important factor leading to traffic accidents. When ponding enters the concrete structure through the cracks of the drainage system, it not only corrodes the bridge deck, but also affects the service performance of the bridge deck. Therefore, if the drainage pipes and gutters on the bridge deck are blocked, they must be unclogged to ensure a smooth drainage system.

In addition, the damaged drainage pipe should be repaired in time. If the joint falls off or is not firm, it should be reinstalled and replaced. In real-life scenarios, the bridge deck drainage pipe joint may be damaged, causing water to seep into the beam floor when snow melts, which leads to the freezing of the beam floor concrete [8].

3.5. Expressway expansion joint maintenance

The bridge deck's expansion joint is usually found in the weakest area of the beam end, which plays an essential role in repeated traffic. Therefore, the regular maintenance of the bridge expansion joint should be strengthened, the garbage generated by the expansion joint should be cleaned regularly, and the bolts should be tightened to ensure normal functioning. However, if the expansion joint is damaged or defective, the maintenance personnel should determine the cause and repair or replace it with a new one. In terms of preventive maintenance, the time with the largest benefit-cost ratio is usually selected as the best maintenance time. When curing at different times, the benefit-cost ratio also varies [4].

3.6. Pier foundation maintenance

The basic purpose of pier foundation maintenance is to ensure the stiffness and stability of the bridge structure as well as to reduce the abrasion of running vibration by snow and water. The code for the maintenance of expressway bridges stipulates that the maintenance of pier foundation should focus on five aspects [5-10].

(1) Before maintenance, pollutants should be removed to keep the surface of pier and abutment clean and tidy.
(2) It should be emphasized once again that the contaminated working structure has been eroded by snow as a result of low temperature over a long period of time.
(3) When the bridge deck concrete has eroded, defects such as honeycomb and scratched surface, as well as the surrounding chisels should be cleaned and then troweled with cement mortar.
(4) If the veneer of block masonry has been damaged or weathered, it should be supplemented with stone and precast concrete blocks.
(5) If the pier foundation has no runoff slope and the slope surface is uneven or cracked, cement mortar or concrete should be used to form a horizontal slope surface to facilitate drainage.

3.7. Portal maintenance

In the process of expressway construction and development, the end wall is the main structure of the tunnel portal, and the problem is usually targeted on this structure. For example, the problems of water leakage, cracking, and falling off of end wall decorative coating are under the category of common problems in civil structure construction, which increases the incidence of expressway tunnel operation risk. Due to the insufficient performance reliability of waterproof facilities and the actual effect of drain holes, the construction quality of tunnel civil structure is potentially threatened, resulting in cracks and uneven settlement, reducing the construction level of civil structure, burying potential safety hazards in the construction and application of expressway tunnel, as well as hindering the role of civil structure.

3.8. Lining structure maintenance

In the process of formulating and implementing the civil structure construction plan of expressway tunnels, the construction status of the lining structure will affect the application effect.

(1) Due to longitudinal cracks, annular cracks, and oblique cracks, the stability of the lining structure is reduced. Under the influence of seepage, the application rate of the lining structure in practice is increased, which hinders the improvement of its construction level.
(2) Due to the lack of scientific analysis of the geological structure and the application level of the lining of expressways, it is difficult to meet the requirements of the construction process of the tunnel lining.

3.9. Repair track maintenance

The channel facilities formed by the cable trench cover plate on the tunnel maintenance road will affect the quality in practice, increase the problems in the civil structure construction of expressway tunnels, adversely affect its application quality and tunnel construction effect, as well as threaten the application safety of expressways in practice. At the same time, influenced by inspection and repair issues, the hidden dangers in expressway tunnels are not handled in time, which reduces its construction quality level and leads to the application of civil structure of expressway tunnel.

3.10. Strengthen the construction of information platform

3.10.1. Improve work efficiency by using the disease database

The main tasks of maintenance informatization are data collection, query and management, data

configuration and management, as well as the establishment of shared database. The traditional daily maintenance management uses manual way to query, navigate, and reuse all kinds of data and pictures generated by maintenance management tasks, which are time-consuming and laborious. The maintenance information platform takes the disease database as the core and uses the database technology to classify, store, and organize maintenance data to form an information sharing platform [10-14]. The platform allows administrators at all levels to query, retrieve, and reuse these maintenance data based on different access permissions, as well as export various maintenance daily worksheets, including daily maintenance and maintenance project plan, project progress report, and project settlement. It is necessary to quickly calculate the workload completed on time and avoid duplicate records, duplicate forms, and duplicate inspection records. At the same time, the high efficiency and reliability brought by automation help prevent errors and omissions of manual statistics as well as improve the level and efficiency of maintenance.

3.10.2. Support the establishment of a maintenance decision model

By importing various regular inspection data and test data into the maintenance information platform, it is possible to automatically evaluate road conditions, PQI, SCI, and other facilities, establish a long-term maintenance data management system, and regularly monitor the dynamic conditions. At the same time, big data should be used to mine all kinds of maintenance data, identify laws in massive data, establish damping models for technical status indicators of various facilities, predict the results of maintenance projects as well as medium and long-term maintenance decision-making and analysis models, change the current maintenance mechanism from manual to active, as well as improve highway maintenance in a more scientific and intelligent manner. Conservation data can genuinely assist in decision-making.

3.10.3. Active risk management

Maintenance informatization uses the maintenance data of traffic safety facilities such as railings to actively manage highway risks. If there are multiple maintenance records of traffic safety facilities in a certain section within a period of time, the system will automatically select them as risk candidates, prompt the maintenance personnel to complete the risk-closed loop, and remove risk information from the platform [15].

3.11. Strengthen the emergency plan management

In order to ensure the orderly development of highway emergency rescue work and the improvement of safety management level in the rescue construction, it is necessary to enhance the awareness of emergency rescue safety management. Actions are guided by thoughts. Therefore, the highway management department should encourage relevant personnel to study relevant laws, regulations, and rules before carrying out emergency rescue work, so as to improve their ideological level. Through learning, the on-site construction personnel and management personnel can effectively improve their safety awareness, ensure the orderly implementation of civil air defense, material defense, and technical prevention, prevent disasters from occurring in the first place, as well as minimize the impact of human factors and natural disaster factors as much as possible. During the emergency rescue construction, the road administration department and the traffic police department should clean up along the way to ensure the smoothness of the road and control the impact of natural disasters within a controllable range. In engineering practice, it is crucial to put the basic interests of the people first, establish a high-standard, people-oriented safety management system, and ensure an efficient implementation of emergency rescue work. At the same time, a 24-hour manned system should be established to enhance the investigation of potential on-site safety hazards. Once problems are found, even minor problems should be handled in time to avoid further aggravation of the situation and unnecessary losses [16].

4. Conclusion

In conclusion, expressway bridges and tunnels play an important part in transportation in China. In the maintenance management of expressway bridges and tunnels, the management mode is backward, the overall quality of the maintenance personnel is poor, and there is a lack of effective safety maintenance management mechanism. Several measures can be taken to improve the maintenance management of expressway bridges and tunnels, including preparing and improving the maintenance system, repairing load cracks on the bridge deck, maintaining the bridge deck and the drainage system, and strengthening the maintenance of the expansion joint and foundation, the tunnel portal, the lining structure, the access road, the construction of a maintenance platform, and the management of emergency plans.

Disclosure statement

The author declares no conflict of interest.

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Application of Green Design Concept in Interior Design Practice

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Abstract: Parallel with the increasing development of China's social economy, many people are paying attention to the high-level design quality of interior design and the aesthetics and environmental protection of interior design. Therefore, the concept of integrating green design has become the focus of designers in the works of interior design. Based on the overview of green interior design concept, the author introduces the role and principles of green design concept in interior design, and discusses in detail the key applications of green design concept in interior design, hoping to provide reference and guidance for interior design practitioners.

Keywords: Green design concept; Interior design; Application

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1. Introduction

The advent of "great environmental protection" era requires interior designers to scientifically integrate the concept of green design into the practice of interior design, and infuse the green environmental protection design for heating, ventilation, and air conditioning (HVAC) system design, ventilation design, indoor layout and furniture furnishings, so as to create a healthy, comfortable, environment-friendly and healthy living space. Qiao [1] analyzed the practice of interior design based on the concept of green design, pointed out the problems existing in interior design at this stage, such as overemphasis on luxury and novelty, excessive use of synthetic building decoration materials, and serious material waste caused by excessive pursuit of popularity in design, and believed that in order to achieve environmental protection to a greater extent and well-being of interior design, we should fully integrate the concept of green design under the advocacy of the concept of green environmental protection, so as to further reduce energy consumption and improve indoor comfort and environmental protection, as well as maximize the development of China's interior design industry toward green and environmental protection.

2. Overview of green interior design concept

Interior design is not only the extension of architectural design, but also the re-creation of indoor space and environment. Therefore, its main goal is to create a healthy and comfortable living environment for people through the practice of green design and meet the physiological and psychological needs of owners. The practice of interior design based on the concept of green design can make interior design more economical, with richer design elements and more environmental protection benefits. Therefore, all designers are called on to realize the harmonious coexistence between man and nature through the scientific application of green materials and new, advanced technology, so as to create a pleasant ecological living space [1].

3. Practical significance of interior design based on green design concept

3.1. Improving the utilization rate of effective living area of indoor space

Interior design based on green design concept can effectively improve the utilization rate of indoor space. In the process of interior design, designers can employ the green design concept into all aspects. At the same time, they can also divide the interior space according to the golden section principle to avoid the waste of interior space [2]. Optimizing the indoor area utilization can not only facilitate the selection of furniture, but also make the space arrangement more reasonable. During interior designing, designers need to adjust the internal layout in combination with people's indoor movement track and living habits, so as to ensure humanization of interior design and promote the improvement of indoor environmental comfort [3].

3.2. Enhancing the practicability of indoor space

During interior designing, designers scientifically integrate the green design concept in combination with the characteristics of building structure, which must be based on its practicability. In the specific design practice, designers should pay attention to the layout of indoor façade and ground, and ensure that the range of indoor available space is further increased by adjusting the size of building decoration materials. In addition, we should select a good interior decoration to ensure that the interior design meets the needs of people's daily life and reduce pollution. For example, when using green plants for interior decoration, it can not only purify the air and reduce pollution, but also effectively avoid the waste of resources and effectively improve the use value of houses [4,5].

3.3. Improving the safety of indoor space

When designers carry out interior design according to the green design concept, they must take safety into account. The interior design of green design concept is mainly reflected in the quality of decoration materials and furniture. First of all, driven by the concept of green design, we should try to choose green environmental protection materials in the selection of home decoration materials. These materials should contain trace formaldehyde or better, zero formaldehyde, so people can live at ease. Secondly, in the selection of furniture, we should weigh less on the price of furniture, but instead, choose furniture with good quality and environmental protection performance as well as high safety performance [6].

3.4. Creating a more comfortable and healthy living environment

Interior design based on green design concept requires designers to reduce the application of harmful materials to human body as much as possible when selecting interior decorations, so as to create a natural, fresh, simple, elegant and low-carbon living space. In addition, the main intention of having an interior space based on the green design concept is to relieve people's emotions, create a more comfortable and pleasant environment, and play a positive role in promoting people's happiness [7].

3.5. Improving the ecological environment

At present, China's interior design is still in the initial stage of development. It often makes designs contrary to the ecological concept in interior design, which leads to not only excessive decoration, but also causes certain environmental pollution. Therefore, designers are called upon to strengthen the understanding of green design, pay attention to the integration of green concept in interior design, try to take green environmental protection as the premise in the formulation of design scheme and the selection of decoration materials, and improve the ecological environment on the basis of fulfilling people's living needs [8].

4. Basic principles of green interior design

In order for the interior design to meet the development needs of green buildings, we should improve the design requirements, that is, carry out the design work on the premise of meeting the basic principles of green environmental protection, energy conservation and consumption reduction, recycling and so on.

4.1. Green environmental protection

Environment friendly society is the general goal and requirement of architecture put forward by contemporary people under the condition of serious environmental pollution. Under this objective, the interior design should meet the requirements of green environmental protection and create a natural, comfortable and environment-friendly indoor environment [9]. Firstly, in terms of material selection, the application of chlorofluorocarbons should be reduced as much as possible to reduce the environmental pollution caused by refrigerants and urban heat island effect. Secondly, it is necessary to strengthen the application of green building decoration technology and adopt high-tech modern building decoration technology to achieve the goal of green environmental protection in interior design.

4.2. Energy saving and consumption reduction

The operation of indoor building system consumes a lot of energy and aggravates the phenomenon of energy depletion. In order to properly solve such problems, we should apply renewable energy as much as possible in the design, such as solar energy, geothermal energy, etc. At the same time, we should focus on the application of energy-saving technologies, such as frequency conversion technology and intelligent technology, and adjust the operation parameters of the air conditioning system according to the building environment and climate conditions to avoid the full-load running of the indoor facilities and equipment, thereby achieving the goal of energy conservation and consumption reduction [10].

4.3. Recycling

In order to meet the requirements of green interior design, designers can divide the interior into different functional areas and then implement independent design. The advantage of this approach is that even if there is equipment failure in one functional area, other functional areas will not be affected. Aged components can be recycled and reused, which effectively improves the utilization rate of decoration materials [11].

5. Applications of green design concept in interior design

In order to make the interior design of housing more ecological, we should pay attention to the integration of green ideas (such as in the aspects of decorative materials, indoor space layout and renewable resources utilization), realize the building functions, fulfill people's living needs, and improve the environmental protection benefits of buildings.

5.1. HVAC system design

The main function of HVAC is to realize indoor heating, ventilation and air conditioning. Therefore, the design level will directly determine the comfort of indoor space. Generally speaking, the energy-saving design of indoor space HVAC also has the following advantages: (i) It can promote the effective improvement of the owner's quality of life and make people's work and life convenient; and (ii) The development of HVAC energy-saving technology is closely related to the national energy conservation and emission reduction work. In the design of HVAC system, in order to ensure the accuracy and reliability of the design scheme, designers should strengthen the low-temperature radiant floor heating technology and improve the energy-saving effect on the basis of ensuring the efficient and economic operation of the air

conditioning system. For example, the application of traditional air-conditioning system requires the exchange of human temperature and humidity to have even effect on the whole room; therefore, there are high requirements for air temperature. However, the use of energy-saving air-conditioning system makes it possible to achieve the energy-saving goal of building HVAC system as the air temperature drops significantly, and the radiant heat also has energy-saving function. In the past, the building HVAC system mainly used three-dimensional radiator heating. Because the radiator is close to the wall and far from the center of the room, the heating in the room is uneven. Through the scientific application of low-temperature radiant floor heating technology, the coil is buried under the floor. After starting the system, the whole room is evenly heated, and the heat is increased by convection, which makes people feel comfortable, warms people's feet, and have a positive impact on human health [12].

Renewable resources are inexhaustible and have tremendous environmental benefits. Therefore, the development and application of clean renewable resources should be strengthened in the design. There are many kinds of renewable resources, including solar energy, wind energy, and geothermal energy. Solar energy has the function of providing heat energy to the building interior. With the continuous development of solar heat collector, the application of active solar heating system becomes possible. The function of natural air cannot be ignored. When there is a large difference between indoor and outdoor temperatures, the HVAC system can be started to realize the exchange of indoor cold and warm air. When the outdoor temperature is lower than the indoor temperature, the heating scheme should be started to collect the outdoor air source, or make cool storage at night [13]. The scientific utilization of natural wind can not only save electric energy and reduce pollution, but also effectively improve indoor air quality. Therefore, paying attention to the application of wind energy is also an effective way in the energy-saving design of building HVAC. The application of groundwater is based on the thermal insulation characteristics of groundwater bottom layer. Groundwater is used as a cold source, and the surface shallow water source is used to absorb solar energy and geothermal energy, so as to form low-temperature and low-level thermal energy, and then realize energy conversion through a small amount of high-risk electric energy input. However, in the conversion process, attention should be paid to water quality protection and the application of reinjection technology.

5.2. Indoor ventilation design

As people pay more and more attention to residential safety, interior designers should strengthen the green design in indoor ventilation design to improve the level of indoor air quality. In order to achieve this goal, designers should scientifically integrate the green design concept, fully consider the ventilation requirements, flexibly select the design scheme according to the indoor space pattern, and give full play to the advantages of natural wind. When the interior design work is limited by space, it is necessary to fully rely on auxiliary equipment to create a good air environment for the interior space.

5.3. Treatment of indoor light environment

People mainly realize information acquisition through the visual system. However, in order to make the visual system work, we must rely on light. Therefore, in the practice of interior design, we need to deal with the indoor light environment scientifically and reasonably. The indoor light environment is mainly composed of natural light and artificial light. Through the analysis of the practical experience of indoor design, natural light plays a positive role in promoting human health and has the advantages that artificial lighting does not possess. In the past, it is necessary to make full use of the natural light in the process of indoor lighting. Therefore, it is necessary to make the greatest use of the natural light in the process of indoor lighting [14].

For the environmental treatment of artificial lighting, firstly, it is necessary to reasonably arrange the lamps and pay attention to the selection of energy-saving lamps. Secondly, it is necessary to improve the lighting control mode to cut down excessive heat generation so as to save energy and meet the requirements of green environmental protection design concept.

5.3.1. Arranging lamps reasonably

Reasonable illuminance should be determined first in lighting design. Reasonable lighting mode should be selected in the layout of lighting lamps. General lighting, local (or key) lighting, uniform and symmetrical layout, appropriate distance-height ratio and so on should be adopted according to zoning, grouping, business, non-business, day and night. Places with good natural lighting should make full use of natural light. The lamps should be arranged in zones according to the characteristics and time periods of lighting use, and the number of lighting switches should be appropriately increased in order to adopt zone time-sharing control mode.

5.3.2. Improving lighting control mode

According to the building characteristics, building functions, building standards, use requirements and other specific conditions of the building, the lighting system should be controlled in a decentralized, centralized, manual, automatic, economical, practical, reasonable and effective manner, so as to ease the application and create conditions for power saving [15].

(i) For rooms with small area, one lamp and one control or two lamps and one control should be adopted. For rooms with large area, the mode of multiple lights and one control should be adopted. When the room has uniform illumination requirements, the mode of control one between two can be adopted. When there is no uniform illumination requirement, it can be controlled by zones.

(ii) The lighting of staircases and walkways in residential buildings should be controlled by energy-saving self-extinguishing switch. The energy-saving self-extinguishing switch should apply the infrared mobile detection and optical control switch, and the emergency lighting should have the feature of forced lighting in case of emergency. The lighting of public buildings, such as corridors, halls, staircases, and other public places, such as schools, office buildings, hotels, shopping malls and other buildings, should be controlled centrally, and zoning and grouping control measures should be taken according to the building use conditions and natural lighting conditions. The lobby, elevator lobby and guest room floor corridor of the hotel adopt automatic dimming devices that regularly reduce the illumination at night. Control measures that can turn off some lamps or reduce the illuminance should be taken for the aisle of the hospital ward at night.

5.4. Reasonable layout of indoor space

The most important aspect in interior design is interior space, which is the key point in the whole design work. With the further improvement of people's awareness of environmental protection, people should scientifically integrate the concept of green design into the process of interior design, do a good job in the reasonable layout of interior space that combines people's living needs and habits, and pay attention to the "development" of interior space on the basis of people-oriented principle. For example, some space needs are only temporary, such as the decoration design of children's bedroom. The children's room will no longer be intended for taking care of children when they grow up. Therefore, in the design, we should pay attention to flexible design, make reasonable layout of indoor space, and constantly optimize the design scheme to meet the temporary and long-term functional needs [16].

5.5. Paying attention to the selection of indoor furnishings

In interior design, we should pay attention to the degree of green environmental protection of relevant furnishings and change the traditional concepts of paying too much attention to price, style and so on in the process of selecting interior furnishings. In terms of furniture selection, we should choose green furniture that is harmless to human health, such as solid wood furniture. We should also choose healthy and simple interior decoration, which can not only highlight the owner's aesthetic sense, but also deliver the environmental protection effect.

6. Conclusion

In short, the interior design based on the green design concept is the future development trend of the design industry under the background of the deteriorating ecological environment, and it is also the basis to ensure the green environmental protection benefits of interior design. Therefore, the related design personnel should fully understand the connotation of the concept of green interior design, according to the green environmental protection, energy saving, recycling and other principles of indoor air conditioning system, ventilation system, lighting system, space layout and furnishings for reasonable design. Through a variety of advanced technology and the application of green environmental protection material, we can promote a sustainable development of interior design.

Disclosure statement

The author declares no conflict of interest.

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Research on the Integration of Structural Design and Material Parameters of Long-life Asphalt Pavement

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Abstract: In order to reduce the disease risk stemming from asphalt concrete pavement and ensure the safety of road operation, we should pay attention to the structural design of long-life asphalt pavement, strengthen the selection of long-term pavement materials, scientifically set the pavement mechanical performance indexes based on the calculation results of pavement structure thickness combination and modulus combination, and ensure the stability and durability of road pavement structure through the real-time establishment of three-dimensional finite element calculation model, as well as the integrated design that takes into consideration the aspects of road subgrade, semi-rigid base and asphalt layer.

Keywords: Long life asphalt pavement; Modulus combination; Thickness combination; Structural design

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1. Introduction

In the environment of accelerating socialist economic development, the stability and durability of road engineering pavement structure will have a direct impact on national production efficiency. In recent years, the economic and trade exchanges between cities have become more frequent, and the number of road traffic running vehicles and the road load pressure have increased, resulting in the frequent occurrence of road pavement diseases and serious potential safety hazards for the safety of travelers. Therefore, it is of great significance to explore the scientific methods of long-life pavement structure design and construction. In fact, long-life asphalt pavement is to improve the durability of road pavement structure through the scientific selection of construction materials as well as the reasonable design of mixed materials and pavement structure. This study adopts the design of semi-rigid base asphalt pavement to realize the construction of long-life pavement, makes a scientific analysis on the structural design of each layer of pavement and the selection of pavement materials, and provides technical guidance for the efficient construction of similar projects.

2. Overview of long-life asphalt pavement

Long-life asphalt pavement refers to an innovative pavement with a theoretical service life of more than 40 years. During the design and construction of long-life road pavement, attention should be paid to its outstanding flexibility and durability characteristics, so as to avoid rutting, cracks, and other diseases under the influence of vehicle load and external stimulation factors [1]. Therefore, relevant construction units and designers should fully understand the design connotation of long-life asphalt pavement, accurately calculate

the thickness combination and modulus combination of asphalt pavement structure, and then apply scientific construction technology to realize the scientific control of road pavement structure diseases.

3. Selection of mechanical performance indexes of long-life asphalt pavement structure

The release of the code for design of highway asphalt pavement (JTGD50-2017) puts forward new requirements for the mechanical performance indexes of asphalt pavement. It requires designers to take into consideration the tensile stress at the bottom of asphalt layer, surface deflection and surface shear stress as the main indexes for the design of new road asphalt pavement in order to control the fatigue damage of pavement and improve the overall stiffness of pavement.

In fact, the fatigue life of asphalt layer is mainly affected by tensile stress. Therefore, the fatigue characteristics of asphalt layer can be accurately reflected by using tensile strain instead of tensile stress. In terms of ensuring the overall stiffness of the pavement, we should not only pay attention to the deflection design of the road surface, but also pay attention to the stress design of the stress surface. Through systematic research, Bi [2] found that the maximum shear stress of asphalt pavement in road engineering plays a decisive role in the early longitudinal crack shear damage of rutting and wheel track belt. Therefore, in this study, the pavement surface deflection, the tensile strain at the bottom of the asphalt layer, the compressive strain at the top of the foundation, and the maximum shear stress of the surface layer are used as the mechanical analysis indexes of the pavement structure.

4. Design of structural surface course of long-life asphalt pavement

In the structural design of long-life asphalt pavement surface, the main consideration should be the protection of pavement base crack and dry crack. Designers should effectively control the subgrade design, semi-rigid design and asphalt layer thickness design, so that the semi-rigid base that has not been cracked can be scientifically protected, so as to improve its overall durability and ensure that the service life of the pavement can be moderately extended.

4.1. Roadbed design

Under the action of vehicle load, the asphalt pavement structure will deform, and the bottom surface of the surface course will produce the phenomenon of joint strain, which will seriously affect the safety of the road pavement, which will not only bring inconvenience to the driving comfort, but also further damage the pavement fatigue. Based on this, designers should focus on controlling the permanent deformation of pavement structure in the process of road pavement design. One way is to accurately analyze the permanent strain inside by constructing the prediction model, and determine the design conditions and actual deformation by calculating the cumulative deformation [3]. The other way is to limit the profitability of subgrade soil and reduce shear failure, so that the permanent deformation of pavement under repeated load is always in a stable state, so as to avoid diseases such as car river and crack during road operation.

4.2. Semi rigid base course

In the practice of structural design of long-life asphalt pavement, the construction unit shall mainly design the semi-rigid base course with rigid materials, which have high quality and high compressive strength for the overall structure. Even under the load of heavy-duty trucks, the compressive stress can reach 1 MPa, and the stress transmitted to the surface of the base course is smaller, meeting the durability requirements of road pavement [4].

4.3. Asphalt layer

In order to ensure that the asphalt pavement has been operated for 40 years without fatigue damage, the

concept of long-life construction should be scientifically integrated into the pavement structure design, and all details should be strictly controlled. For example, in the selection of asphalt materials, it is necessary to check the pavement fatigue during the road design life, and then formulate a scientific construction scheme based on the road design standard. Meanwhile, it is required to strictly follow the established scheme in the subsequent construction to ensure that the quality of the road pavement structure meets the long-life application standard [5].

5. Calculation and analysis of pavement structure thickness combination

5.1. Structure thickness combination and material parameters

In order to control the pavement elevation scientifically, the total thickness of pavement structure should be kept unchanged during calculation, and the flexible base course should be replaced by asphalt surface course. The thickness of the surface course should be strictly controlled, and the thickness of the corresponding base course should also be controlled within the allowable variation range, generally 10 – 40 cm. High-quality asphalt mixing beam should be adopted for each layer of asphalt, the modulus should reach 1400 MPa, and the Poisson's ratio should be set to 0.35. The base modulus is set to 400 MPa and the Poisson's ratio is set to 0.35. The modulus of soil foundation is 45 MPa and the Poisson's ratio is 0.40 [6]. The calculation and parameters of pavement structure are shown in **Table 1**.

Table 1. Pavement structure and parameters with varying thickness of structural layer

Pavement structure	Thickness (cm)	Modulus (MPa)	Poisson's ratio
Asphalt surface course	32-62	1400	0.35
Basic level	42	400	0.35
Soil base		45	0.40

5.2. Result analysis

Various parameters are input into the general finite element calculation program for calculation, and the obtained mechanical indexes are shown in **Table 2**. Reading **Table 2**, we can draw the following conclusions:

(i) The flexural tensile strain of asphalt pavement structure will increase with the increase of asphalt layer thickness, while the flexibility will gradually decrease with the increase of asphalt layer thickness. The maximum shear stress also showed an insignificant growth trend.

(ii) With the increase of the thickness of base course, the total deflection of asphalt pavement will decrease obviously.

Through the combination calculation of asphalt layer and flexible base course with different thickness, it is found that the deflection value for testing the overall deformation capacity of pavement structure changes greatly, while the maximum shear stress value affecting the local shear failure of surface layer and the maximum flexural tensile strain of fatigue crack of asphalt layer are not obvious [7].

Relevant research results show that the construction of thick asphalt surface on semi-rigid foundation can significantly reduce the maximum shear stress and bending tensile stress at the bottom of the layer, while the construction of thick asphalt surface on flexible base will not significantly change the maximum shear stress and bending tensile strain, indicating that without considering the nature of the base, blindly increasing the thickness of asphalt surface may lead to a significant increase in the shear failure ability of pavement structure and the overall failure ability of pavement. Therefore, designers should fully consider the adverse impact of base course properties on pavement structure when implementing the thickness combination design of pavement structure [8].

Table 2. Mechanical indexes calculated when the thickness of structural layer changes

Surface thickness (cm)	Base course thickness (cm)	Maximum shear strain (Ma)	Maximum bending tensile strain (μ ε)	Deflection / 0.01 mm
32	40	1.93E+05	25.72	29.82
34	38	1.95E+05	32.35	29.80
36	36	2.69E+05	41.05	29.82
38	34	2.04E+05	25.61	29.84
40	32	1.78E+05	32.99	29.59
42	30	2.42E+05	68.74	28.42
44	28	2.70E+05	29.99	29.09
46	26	2.38E+05	21.98	28.75
48	24	2.16E+05	30.01	28.32
50	22	2.61E+05	39.20	27.97
52	20	2.23E+05	41.64	27.32
54	18	2.19E+05	52.78	27.37
56	16	2.05E+05	54.75	27.04
58	14	2.37E+05	45.85	26.52
60	12	2.51E+05	68.49	25.87
62	10	2.80E+05	43.01	16.13

6. Calculation and analysis of pavement structure modulus combination

6.1. Structural modulus combination and material parameters

The main feature of long-life pavement structure is that the surface layer and intermediate layer can diffuse the load and prevent pavement damage. The main function of the base course is to eliminate fatigue damage. Pavement foundation plays a positive role in promoting pavement deformation and frost resistance. Therefore, the surface course adopts high-quality asphalt mixture, the base course adopts low modulus flexible material, and the soil foundation adopts stable soil material. In order to find out the important influence of asphalt mixture surface course and low modulus base course on pavement structure, it is necessary to accurately calculate the modulus combination of pavement structure [9-12]. The specific performance is as follows: The thickness of each surface course remains unchanged, and the modulus of asphalt layer is controlled in the range of 1200 – 1600 MPa. The low modulus base course should be controlled at 1000 – 200 MPa. The modulus of soil foundation is 45 MPa. The pavement structure and parameters are shown in **Table 3**.

Table 3. Pavement structure and parameters with varying structural layer modulus

Pavement structure	Thickness (cm)	Modulus (MPa)	Poisson's ratio
Asphalt surface course	32	1200 – 1600	0.35
Basic level	40	1000 – 200	0.35
Soil base	N/A	45	0.40

6.2. Result analysis

By inputting the parameters into the finite element program, the mechanical indexes can be obtained. The results are shown in **Tables 4**, **5** and **6**.

Table 4. Maximum flexural tensile strain when the modulus of structural layer changes

Surface layer	MPa	1200	1300	1400	1500	1600
Base course (MPa)	200	23.32	19.63	16.59	14.13	12.01
	400	33.74	29.44	25.73	22.70	19.96
	600	41.10	35.52	31.43	27.98	25.14
	800	48.11	42.09	37.11	32.90	29.20
	1000	43.43	47.13	41.88	36.37	33.64

Unit: με

Table 5. Maximum shear stress when the modulus of structural layer changes

Surface layer	MPa	1200	1300	1400	1500	1600
Base course (MPa)	200	194811	194917	194992	195069	195152
	400	194.79	194183	194279	194361	194443
	600	193621	193722	193818	193903	193979
	800	193309	193403	193485	193579	193661
	1000	193082	191839	193249	193332	193409

Unit: Pa

Table 6. Maximum deflection value when the modulus of structural layer changes

Surface layer	MPa	1200	1300	1400	1500	1600
Base course (MPa)	200	35.53	34.38	33.52	32.63	31.87
	400	31.44	30.61	29.83	29.09	28.51
	600	29.12	28.40	27.74	27.14	26.48
	800	27.64	26.91	26.26	25.73	25.22
	1000	26.49	25.78	25.17	24.68	24.24

Unit: 0.01 mm

Through the analysis of relevant data in **Tables 4**, **5** and **6**, the following changes can be found:
(i) The maximum shear stress of pavement structure increases with the increase of asphalt surface modulus. The maximum flexural tensile stress is inversely proportional to the completion value and the increase of surface modulus, that is, the modulus increases, and the maximum shear stress and deflection value gradually decrease.
(ii) The maximum strain of pavement structure will increase with the increase of flexible base modulus. The maximum shear stress and deflection decrease with the increase of flexible base modulus.

Relevant research results show that the application of flexible base material can help the rapid diffusion of road surface stress. However, the application of flexible base can significantly improve the maximum flexural tensile strain and deflection [13-16]. It is not advisable to increase the modulus of flexible base material. High-quality asphalt pavement can significantly reduce the maximum flexural tensile strain, enhance the fatigue cracking resistance of road pavement structure, and effectively improve the deformation resistance of pavement structure. It can be widely used in engineering design practice. It should be noted

that in the application practice of modulus flexible materials and asphalt surface materials, materials should be selected first, and the maximum shear stress and deflection of materials are required to meet the design standards [17,18].

7. Conclusion

In short, the long-life asphalt pavement structure is the inevitable trend of the construction and development of road pavement engineering in the future. Relevant personnel should apply high-quality thick asphalt pavement and high modulus flexible base material in the structural design and material selection of long-life asphalt pavement, and make use of its significant mechanical index advantages to continuously improve the stability and durability of road pavement structure and ensure the safety of road operation.

Disclosure statement

The author declares no conflict of interest.

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Journal article (print) with one to three authors

[1] Yao Y., Xia B. Application of Phase Frequency Feature Group Delay Algorithm in Database Differential Access. Computer Simulation, 2014, 31(12): 238-241.

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[4] Hargreave M., Jensen A., Nielsen T.S.S., et al. Maternal use of fertility drugs and risk of cancer in children—A nationwide population-based cohort study in Denmark. International Journal of Cancer, 2015, 136(8): 1931–1939.

Book

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No author

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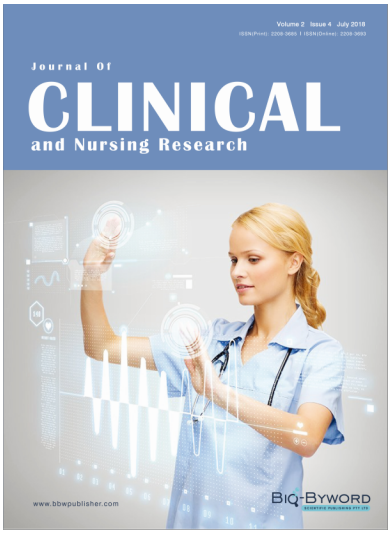

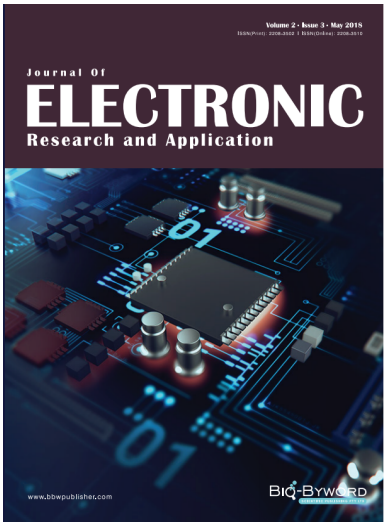

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