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The Process and Key Steps of Constructing Masonry Wells in Road Structural Layers

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Abstract: *This article mainly studies the construction process and key steps of road structure layer masonry wells, in order to improve construction efficiency and quality. By analyzing the shortcomings of existing construction techniques, new construction methods and technical optimization measures have been introduced. The article first introduces the importance of masonry well construction in road structures and the shortcomings of existing research, then, elaborates in detail on key steps including pre construction preparation, wellbore masonry, structural reinforcement of the well chamber, and later inspection and maintenance. Through comparative analysis, it has been proven that the proposed construction plan and technical measures can effectively improve construction speed and structural safety. Four experiments were designed during the experimental phase to evaluate the performance and effectiveness of the research method. In the comparative experiment of construction period, the construction period of modular prefabrication technology was reduced by an average of 11 days. In the quality qualification rate testing experiment, the average quality qualification rate of modular prefabrication technology was 91%. In the long-term performance evaluation experiment, the average maintenance frequency of the masonry well of modular prefabrication technology within 5 years was 1.6 times. In the cost-benefit analysis experiment of construction, modular prefabrication technology reduced the direct construction cost by about 15-20% compared to traditional methods. From the above data conclusion, it can be seen that modular prefabrication technology is significantly superior to traditional construction methods in terms of short construction period, high quality qualification rate, better long-term performance, and better cost-effectiveness.*

Keywords: *Modular Prefabrication Technology, Construction of Masonry Wells, Cost Benefit Analysis, Construction Cycle*

1. Introduction

With the rapid development of urbanization, the construction industry is urgently in need of improving construction efficiency and quality. Especially in the construction of masonry wells, outdated construction methods have been criticized for their long construction time and unstable quality. In recent years, people have begun to pay attention to modular prefabrication technology, which has shown great potential in terms of speed improvement, quality assurance, and cost savings. However, there is still relatively little systematic evaluation research on the application of this technology in masonry well projects and its cost-effectiveness. Therefore, this study explored the practical effects of modular prefabrication technology in masonry well construction through on-site analysis, with the aim of providing a scientific basis for the selection of construction methods in the construction industry.

This article evaluates the differences between modular prefabrication technology and traditional building methods in masonry well projects through four experiments. The results are quite obvious, modular prefabrication technology has advantages in reducing construction time, improving project quality, reducing the frequency and cost of later maintenance. This not only provides direct data support for the selection of masonry well construction technology, but also provides a theoretical basis for applying this technology to more construction projects.

The beginning of this article introduces the background and importance of the research, and points out that the application of modular prefabrication technology in masonry well construction has not yet been studied. Then the article elaborates on how to design and conduct experiments, including comparing construction cycles, testing quality qualification rates, evaluating long-term performance, and analyzing cost-effectiveness. In the results and discussion section, the performance of modular prefabrication technology and traditional construction methods is compared, emphasizing the benefits of modular technology and analyzing and explaining the experimental results. The summary section of the article summarizes the findings and provides some prospects for the future application of modular prefabrication technology.

2. Related Works

In recent years, many researchers have conducted in-depth research on the construction process and key steps of road structural layer masonry wells, aiming to find methods to improve construction efficiency and quality. For example, He Pinjie effectively reduced labor intensity and improved work efficiency by using a car crane to lift prefabricated components. This measure has positive significance for improving the construction of deep vertical shafts in prefabricated concrete structures and has brought certain impetus to the development of related fields [1]. Zheng Zhitao et al. designed a new type of forged semi grouting sleeve based on cold forging and heat treatment processes, and made centering connection specimens and eccentric connection specimens according to the specifications [2]. Prefabrication can become an effective solution to accelerate masonry construction, making it more cost-effective. Therefore, Thambou J attempted to evaluate the effectiveness of prefabricated masonry systems from the perspective of structural characteristics and sustainability in the Australian context [3]. Although extensive research has been conducted since the 1980s, there are still no comprehensive design guidelines for shear wall configurations with required energy dissipation systems. Therefore, Javadi M conducted a comprehensive review of the latest literature, focusing on the design aspects of self-centering shear wall systems [4]. Peruzzi A D P conducted a study comparing the satisfaction of residential building users with two industrial construction techniques, "precast block" and "cast-in-place reinforced concrete wall", and compared them with "traditional techniques" [5]. Ming X explored multiple aspects, including brick and stone arch structures, large-span steel bridges, prefabricated or on-site extruded light steel structures, fiber-reinforced cement-based composite material structures, and the implementation of fiber-reinforced polymer bridge decks [6]. In the event of supply chain disruptions, there have been few studies on the planning of prefabricated component supply chains. Zhang H conducted research, considering the elasticity related to construction schedule and transportation costs, and proposed a multi-objective optimization model [7]. He Qianglong et al. have developed the installation and construction technology of integral prefabricated water collection wells. Through this technology, the visual quality of concrete can be effectively improved, the probability of water collection well leakage can be reduced, and the construction period can be saved, costs can be reduced, and it meets the requirements of green environmental protection [8]. Long Ni analyzed the construction technology of underground pipelines in municipal engineering, including trench excavation preparation, trench excavation work, pipeline foundation construction technology, pipeline laying technology, pipeline installation technology, well chamber masonry construction, and closed water test [9]. Huang Jin summarized the problems encountered during the construction process of inspection wells and conducted in-depth analysis on the problems of traditional masonry wells being unable to be constructed smoothly and the difficulty in ensuring quality in the later stage [10]. Although these studies provide certain solutions, there are generally problems such as limited application scope and difficulty in cost control.

In response to the shortcomings of existing research, this article points out through literature review that in the actual construction process, it is crucial to adopt reasonable construction techniques and processes based on specific on-site conditions. For example, by introducing on-site mixed construction technology, construction speed and structural strength can be effectively improved without increasing too much cost. However, these methods still have shortcomings such as complex operation and high technical requirements. Therefore, this article proposes a mixed construction method that combines prefabrication technology and on-site construction technology, aiming to further optimize the construction process, reduce costs, and improve efficiency.

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3. Methods

3.1. Preparation of Prefabricated Components

In the process of using modular prefabrication technology for masonry well construction, prefabricated components directly affect the efficiency, quality, and final cost of the entire construction project.

Before starting the production of prefabricated components, it is necessary to make a precise design based on the specific needs of the project, which involves the size, shape, weight capacity of the masonry well, and how it can be combined with other building parts. Accurate design is crucial as it ensures that the prefabricated components fully meet the requirements of the project. This study utilizes CAD software and simulation technology to significantly improve the accuracy and efficiency of the design. After the design is completed, the production of prefabricated parts begins in the factory. At this time, it is necessary to strictly follow the quality control standards to ensure that each component can meet the expected performance. Compared to on-site pouring, factory production can better manage the quality of materials, concrete mix ratio, and curing environment, which not only improves the overall quality of components, but also efficiently uses materials and reduces waste. After the prefabricated components are completed, the next step is to safely deliver them to the construction site. During transportation, care should be taken not to damage the components. On site, according to the construction plan and the actual situation on site, placing these components in the designated positions. Considering the volume and weight of these prefabricated components, special equipment may be required for transportation and lifting. If managed properly, not only does it ensure the quality of the components, but it also enables smooth on-site construction [11-12].

The entire process of preparing prefabricated components involves cross departmental communication, supply chain management, and continuous supervision of project progress and quality. By finely planning and executing these preparatory works, the application effect of modular prefabrication technology in masonry well construction projects can be greatly improved, thereby achieving a win-win situation in improving construction efficiency and ensuring engineering quality.

3.2. Wellbore Masonry and Reinforcement

The first step in wellbore construction is to accurately install prefabricated components, which requires the use of lifting machinery to accurately place the prefabricated wellbore components on the prepared foundation according to the design drawings. In this process, ensuring tight docking between components, stability, and accuracy are crucial as they directly affect the overall structural robustness. In order to improve the accuracy and efficiency of installation, professional equipment and technologies such as laser ranging and guidance systems are commonly used during installation. After the prefabricated components are placed, the joint treatment step involves filling the joints and cracks with specialized sealing materials, and may use reinforcement bars or steel bars to strengthen the joints, improving the stability and waterproofing of the structure. Choosing the right sealing and reinforcement materials is crucial as it helps with waterproofing and prolongs the service life of the structure. In addition, the bearing capacity and durability of the wellbore can be further enhanced through peripheral reinforcement frames or prestressing techniques. The evaluation of unsealing performance can be expressed by formula (1):

$$\mathrm{SSP} = \frac{L_{sealed}}{L_{total}} \times 100\% \tag{1}$$

In formula (1), the length of the successfully sealed joint is L_{sealed}, and L_{total} is the total length of the joint in the wellbore. After completing the masonry and reinforcement work, it is necessary to check the straightness, roundness, and joint treatment of the wellbore structure to ensure that each part meets the design requirements and safety standards. If any problems are found during the inspection process, they need to be adjusted or redone in a timely manner to ensure the integrity and functionality of the structure without any problems. Through the above process, the masonry and reinforcement work of the shaft can be truly and effectively completed, laying a solid foundation for subsequent construction activities and long-term use of the shaft [13].

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3.3. Waterproof Treatment and Quality Inspection

Masonry wells are often exposed to groundwater and rainfall, and as an important component of urban infrastructure, their waterproof performance is crucial. This not only prevents water infiltration and reduces internal corrosion, but also extends its service life. For modular prefabricated masonry wells, waterproofing treatment is divided into two parts: the prefabrication stage and the on-site installation stage. During the prefabrication stage, the waterproofing ability of the components is improved by using high waterproof concrete and waterproofing agents; during on-site installation, special attention should be paid to waterproofing of the joints and connecting parts, and materials such as sealing tape, waterproof coating, or grouting are commonly used to seal the joints. After waterproofing treatment, a comprehensive quality inspection must be carried out to ensure that the masonry well meets the design and construction standards. This includes visual inspection, water pressure testing, and joint sealing testing to ensure that there are no obvious defects, the waterproof effect is good, and the joint waterproofing treatment is in place. The formula for quality inspection qualification rate QIPR can be represented by formula (2):

$$\mathrm{QI}PR = \frac{N_{pass}}{N_{total}} \times 100\% \tag{2}$$

In formula (2), N_{pass} represents the number of items evaluated as qualified in quality inspection, and N_{total} represents the total number of items inspected. It is recommended not only to conduct quality inspections in the initial stage, but also to regularly test and maintain the waterproof performance of masonry wells. This can timely detect and repair any potential waterproof problems, and prevent problems caused by long-term water damage. Waterproofing treatment and quality inspection are extremely important steps in the construction of modular prefabricated masonry wells. By implementing effective waterproofing measures and conducting strict quality inspections, the performance and durability of masonry wells will be significantly improved, ensuring their long-term stable operation in urban infrastructure [14].

4. Results and Discussion

4.1. Comparison Experiment of Construction Period

In the construction cycle experiment, the difference in construction cycles between traditional masonry well construction methods and modular prefabrication technology in practical applications was compared. In the experiment, the completion time of 10 similar engineering projects under two methods was collected and analyzed, and the experimental results were visually displayed in scatter plots and average construction period line graphs. The construction cycle savings ratio formula is used to quantify the differences between traditional construction methods and research methods, and can be represented by formula (3):

$$\mathrm{CD}SR(\%) = (\frac{D_t - D_p}{D_t}) \times 100\% \tag{3}$$

In formula (3), D_t represents the time required for traditional construction methods to complete the same project, and D_p represents the time required for research methods to complete the same project, as shown in Figure 1.

As shown in Figure 1, the median construction period of modular prefabrication technology is 23.5 days, ranging from 20 to 27 days, while the median construction period of traditional methods is 34.5 days, ranging from 30 to 40 days. From the above data conclusion, it can be seen that modular prefabrication technology can significantly shorten the construction period, reducing the average construction time by about 11 days. Therefore, adopting modular prefabrication technology can not only accelerate project progress, but also improve the stability and controllability of the construction process.

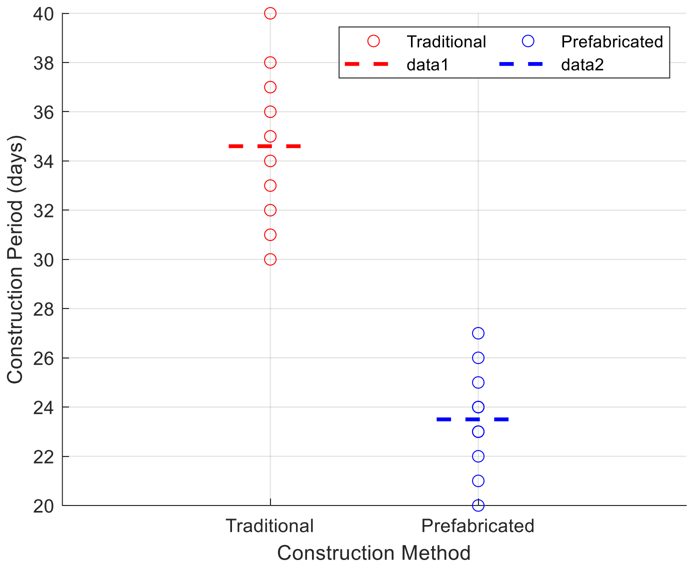

Figure 1: Comparative experimental evaluation of construction period

4.2. Quality Qualification Rate Testing

In the quality qualification rate testing experiment, the quality qualification rates of traditional construction methods and modular prefabrication technology were compared in 10 different masonry well engineering projects. This is to explore the effectiveness of two methods in ensuring engineering quality. The experiment plots the quality qualification rates of two methods to visually demonstrate the performance differences between the two methods.

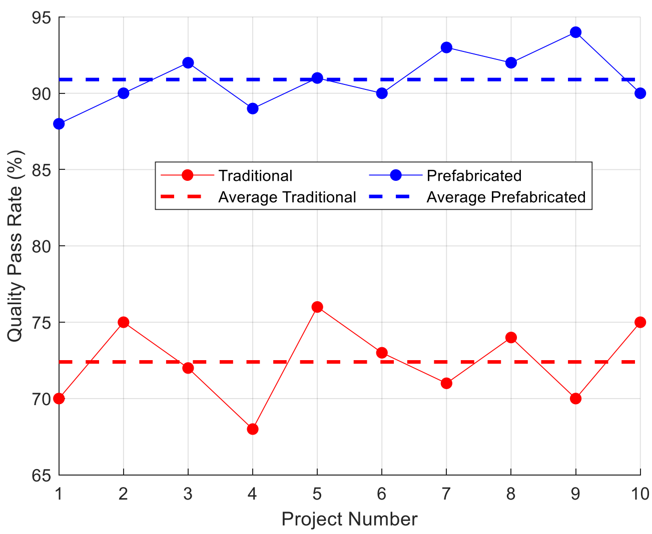

Figure 2: Quality Qualification Rate Test Evaluation

From Figure 2, it can be seen that after comparing 10 projects using traditional construction methods and 10 projects using modular prefabrication technology, the average project qualification rate of traditional methods is 71.8%, with fluctuations ranging from 68% to 76%. The average qualification rate of projects using modular prefabrication technology is 91%, with a fluctuation range of 88% to 94%. From the data conclusion, it can be seen that modular prefabrication technology has advantages in ensuring project quality, indicating that it is an effective method to improve the success rate of engineering projects, as shown in Figure 2:

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4.3. Long Term Performance Evaluation

In the long-term performance evaluation experiment, the performance of traditional construction methods and modular prefabrication technology after long-term use is comprehensively evaluated and compared, especially in the two key indicators of maintenance frequency and cumulative maintenance cost. In the experiment, relevant data of the masonry wells constructed by two methods during the observation period were collected, and these data were plotted. The specific data situation is shown in Figure 3:

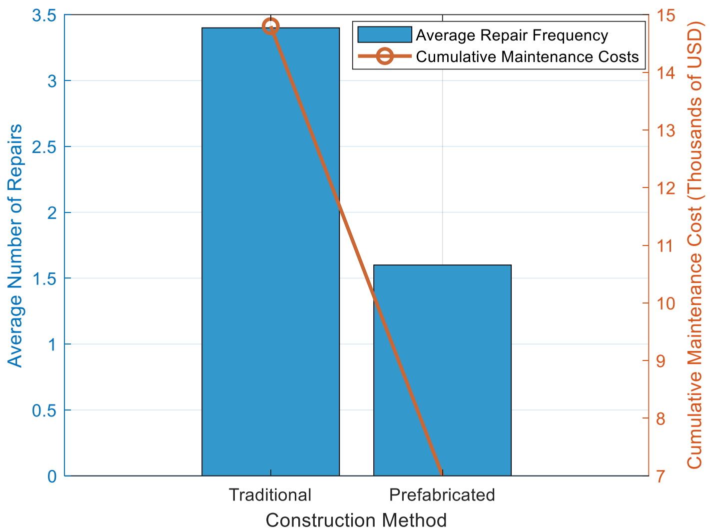

Figure 3: Long term performance evaluation

From Figure 3, it can be seen that the average maintenance frequency of modular prefabrication technology for masonry wells is 1.6 times, while the traditional method is 3.4 times. During the same period, the cumulative maintenance cost of modular prefabrication technology is $7000, much lower than the traditional method's $14.8000. From the above data conclusion, it can be seen that modular prefabrication technology has significant advantages in improving the long-term durability of masonry wells and reducing maintenance costs, proving its significant superiority over traditional construction methods in maintaining sustained performance.

4.4. Evaluation of Intelligent Analysis Effect

Table 1: Evaluation of Intelligent Analysis Effectiveness

Project ID	Direct Cost Traditional	Direct Cost Prefabricated	Maintenance Cost Traditional	Maintenance Cost Prefabricated
1	120	100	30	15
2	130	105	32	16
3	125	103	35	14
4	135	98	31	17
5	140	107	33	15
6	130	102	34	18
7	128	104	36	13
8	132	99	30	16
9	138	101	29	14
10	137	100	37	15

The intelligent analysis effect experiment analyzed and compared the cost-effectiveness of traditional construction methods and modular prefabrication technology in masonry well construction projects. Conducting a comprehensive evaluation of the direct construction cost, construction period, maintenance frequency, and cumulative maintenance cost of two construction methods, and plot these data into a table for display, as shown in Table 1:

From Table 1, it can be seen that the construction project of masonry wells using modular prefabrication technology has an average lower direct construction cost than traditional methods, about 15-20%, and a reduction of about 50% in long-term maintenance costs. From the data, it can be seen that although modular prefabrication technology may require higher initial investment, it provides lower total costs throughout the entire project lifecycle, demonstrating significant cost-effectiveness advantages.

5. Conclusion

This study comprehensively evaluated the performance of modular prefabrication technology in masonry well projects, and the results were also satisfactory. Compared to traditional methods, research methods have shown significant improvements in several key areas. Specifically, research can significantly shorten construction time, reduce the frequency and cost of long-term maintenance, and reduce maintenance costs by half. This validates the effectiveness of modular prefabrication technology in improving efficiency, ensuring quality, and reducing maintenance costs, bringing practical benefits and references to the construction industry. However, this study also has its limitations, such as the experimental data may be too simple, and practical operations may encounter various problems. Future research can continue to delve deeper into the performance of modular technology in different situations, exploring how to further improve construction processes and material usage, achieving wider applications and greater economic benefits. In addition, researching how to combine this technology with other emerging technologies is also a direction worth exploring in the future.

Acknowledgement

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