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Research on the application of GPS, total station and CAD Technology in architectural Grid

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Abstract: In the field of contemporary construction project management, the integrated operation of global positioning system, measurement station equipment, and computer-aided design technology has become a core tool to improve construction efficiency and accuracy. This article analyzes the application of these advanced technologies in building layout and discusses their practical effectiveness in on-site surveying, construction positioning, and deformation monitoring. Global positioning system technology can provide accurate geographic location information, improving the efficiency of construction site surveying and construction positioning. The measuring station equipment plays a crucial role in monitoring construction progress, ensuring construction quality, and conducting safety supervision. Computer aided design technology, with its efficient design capabilities and structural analysis functions, provides strong support for the rapid updating of architectural design and the improvement of construction accuracy.

Keywords: Building grid; GPS technology; Master station instrument technology; CAD technology; Architectural surveying.

1. Introduction

The development of the construction industry cannot be separated from technological innovation, especially the widespread application of technologies such as Global Positioning System (GPS), central station equipment, and Computer Aided Design (CAD), which have improved the efficiency and accuracy of planning, construction, and supervision of construction projects. The integration and application of these technologies in building and managing building networks have achieved rational allocation of resources and enhanced the tracking and management capabilities of construction processes. GPS technology optimizes the measurement and construction positioning of construction sites with its precise positioning capability. Total station technology plays a key role in monitoring construction progress and ensuring quality and safety. The application of CAD technology enhances the flexibility of design schemes and improves the accuracy of construction guidance. This article will analyze the practical application and positive impact of these technologies in building grids.

2. Concept of Building Grid

2.1. Definition of Building Grid

Grid system is a core positioning technology in the field of architecture, which achieves accurate positioning of building components by drawing equidistant or non-equidistant coordinate lines on building plans and elevations. This system plays a guiding role in the arrangement and positioning of the main structures of buildings, such as pillars, beams, walls, and doors and windows. During the construction process of buildings, it provides a reliable benchmark for the accurate installation of various components. Building grids can be presented in two-dimensional or three-dimensional models. Faced with complex building structures or high-rise buildings, grid systems create a unified coordinate system for designers, engineers, and construction personnel, improving the organization and accuracy of design, construction, and later maintenance. In the field of modern architecture, this grid system has become an essential auxiliary tool, promoting the improvement of construction quality and efficiency.

2.2. Application Fields of Building Grid

The building grid system plays an indispensable role in the field of architecture, with a wide range of applications covering building design, structural layout, construction organization, and post maintenance. In the initial stage of design, the system serves as the skeleton of the design, assisting the designer in scientifically planning the space and reasonably dividing the functional areas of the building. The construction design phase of the building grid system provides designers with an accurate benchmark, ensuring the precise positioning and arrangement of structural components such as beams, columns, and support walls. The system improved the efficiency and safety of construction during the construction phase, and the construction team quickly determined the structural position through grid coordinates to ensure construction accuracy. The grid system also shows advantages for maintenance work after the completion of the building, helping maintenance personnel quickly find and determine the components that need to be repaired or updated, and improving the efficiency and accuracy of maintenance work.

3. Application of GPS Technology in Building Grid

3.1. Construction site measurement

GPS technology has become a key tool for site surveying in the field of architecture. In the past, surveying and mapping work relied heavily on manual operations and optical equipment, and the process was lengthy and easily affected by terrain and climate. GPS technology, relying on the global satellite positioning system, quickly provides accurate three-dimensional coordinates, improving the speed and accuracy of site surveying. Technology quickly locks in the precise location of measurement points through the collaborative work of satellite signals and ground receivers. The application of this technology allows designers and engineers to have a deep understanding of the site terrain and develop better design solutions in the early stages of the project. GPS technology can fill the gap in traditional surveying and provide more detailed terrain data when dealing with large or complex terrain projects. The accuracy of GPS site surveying can reach millimeter level, providing a stable guarantee for design and construction. GPS technology supports real-time data transmission, allowing project teams to quickly respond to the latest site information at any time. This fast and accurate surveying method significantly shortens the project planning cycle, reduces errors and uncertainties [1].

3.2. Construction layout

Building construction layout refers to the process of accurately transferring the layout of the building plan and the position of structural components from the design drawings to the construction site. This step is crucial for ensuring project quality and construction accuracy. The traditional homework method overly relies on manual measurement and optical equipment such as theodolites, levels, etc. These methods can meet the needs to a certain extent, but due to the complexity of operation, susceptibility to external interference, low efficiency, and large errors. With the application of Global Positioning System (GPS) technology, building positioning operations have been significantly improved. GPS construction personnel can quickly and accurately convert the coordinate information on the drawings into specific location points on site. With the help of satellite signals, GPS devices can provide precise geographic location information up to centimeters, which is particularly suitable for large or complex terrain construction projects, improving positioning efficiency and reducing manual operation errors. The application of GPS technology in building positioning operations includes the following steps [2]. Input the grid coordinate information involved in the construction design into the GPS positioning system. Construction personnel use GPS devices to accurately locate every key point on site, ensuring the accurate placement of structural components such as foundations, pillars, and beams. GPS devices can also provide real-time feedback during the construction process. Once the design is adjusted or changed, construction personnel can quickly update the positioning points to ensure that the construction progress matches the accuracy. The introduction of GPS technology has improved the efficiency and accuracy of positioning operations, reducing rework and material loss caused by inaccurate positioning. Especially in projects such as high-rise buildings and bridges that require high precision, the role of GPS technology is more prominent, providing solid technological support for construction operations.

3.3. Monitoring of Building Deformation

During the construction and use of buildings, the structure may undergo deformation due to multiple factors such as load fluctuations, crustal movements, and climate conditions. Monitoring deformation is a key step in ensuring the safety of building structures and extending their service life. The Global Positioning System (GPS) provides a convenient, continuous, and accurate technical means for deformation monitoring. Compared with the traditional monitoring method that relies on fixed measurement points for periodic measurements, this traditional method is difficult to quickly detect problems due to the long-time interval. GPS technology can monitor real-time displacement of key parts of buildings, achieving accurate three-dimensional displacement data acquisition around the clock. This promotes the monitoring of building deformation not only during the construction phase, but also during the operational period of the building. Engineers can analyze the deformation trend of buildings in a timely manner through long-term data collection, and take reinforcement or maintenance measures to avoid potential structural safety hazards. Especially in high-rise buildings, cross river bridges, major infrastructure projects, etc GPS technology can accurately capture small deformations, providing solid technical support for managers and ensuring the safety and stability of buildings. This high-precision and real-time monitoring method enhances the safety of construction and provides a solid guarantee for the long-term operation of buildings [3].

4. Application of 3 main station instrument technology in building grid

4.1. Construction progress monitoring

Effective monitoring of construction progress is crucial in ensuring timely and high-quality delivery of projects in the field of architecture. The central station instrument provides solid technological support for project progress monitoring with excellent measurement accuracy. The master station instrument can accurately capture multidimensional data of the construction site, such as spatial distance, angular positioning, and height information, enabling project management to instantly grasp the matching degree between the current situation of the construction site and the design blueprint. With the help of the main station instrument, the construction team can periodically track the progress of key construction points, ensuring precise execution of each link. Whether it is earthwork excavation, foundation construction, or main structure construction, effective supervision can be implemented at each construction stage through the use of central station instrument technology to ensure that all operations are carried out according to the predetermined plan. The main station instrument can also monitor the position and operation status of construction machinery, ensuring accurate positioning and operation of mechanical equipment. This enhances the controllability of construction progress and reduces the possibility of human errors. The real-time data collection capability of the main station instrument allows construction managers to compare the on-site construction progress with the plan, optimize the construction plan in a timely manner, and prevent delays in the construction period caused by schedule delays. This efficient construction progress monitoring method plays a key role in ensuring the smooth implementation of construction projects and ensuring timely delivery of the project.

4.2. Quality Monitoring

Ensuring the safety and durability of construction projects through quality monitoring is crucial in the field of architecture. In this stage, the central station instrument technology plays an important role in monitoring work, demonstrating outstanding performance in ensuring the accuracy and uniformity of building structures. By utilizing the precise measurement capability of the central station instrument, the construction team can monitor the size, angle, and horizontal status of various parts of the building in real time, ensuring compliance with design specifications. During the quality monitoring process, the central station instrument accurately measures the verticality, horizontal status, and symmetry of the building. For example, in the construction of super high-rise buildings, the assistant engineer of the main station instrument tracks the floor height and the verticality of the pillars to ensure the stability and safety of the overall structure. The main station instrument is also suitable for measuring the dimensions of concrete structures, ensuring that key components such as walls, beams, and columns are completely consistent with the design drawings, and preventing construction errors. With the help of master station technology for quality monitoring, construction teams can promptly identify and correct quality issues during construction, reducing the need for rework and repairs in the later stages. The central station instrument can also be used for providing accurate data in the quality acceptance process after the completion of the project, ensuring that the building meets the design standards. This efficient and accurate real-time monitoring method provides solid support for the high-quality construction of construction projects [4].

4.3. Safety Monitoring

The safety monitoring of engineering construction is fundamental to the smooth progress of the project, and the central station instruments play a key role in the field of construction safety monitoring. With the high-precision detection of the main station instrument, the construction team can closely monitor various safety factors on the construction site, such as ground subsidence, structural deformation, and the movement of important components. The real-time data output by the central station helps managers quickly identify potential security risks and deploy protective measures in advance. Especially in the process of deep excavation and high-rise building construction, the stability of the foundation and the overall safety of the building are particularly critical. The main station instrument can continuously monitor the subsidence of the ground, ensuring the stability of the foundation during construction. Once unusual settlement is detected, the central station instrument will trigger an alarm, allowing the construction team to quickly modify the construction strategy based on real-time data and avoid structural safety accidents. The central station instruments have the ability to continuously monitor the core structural positions of buildings, such as the supports of bridges and the arch structures of large span buildings, ensuring the safety and stability of these critical parts during construction and use. With the technical support of the central station instruments, the construction team was able to build a comprehensive safety monitoring system to keep abreast of the safety dynamics of the construction site at all times. This systematic and intelligent safety monitoring method enhances the safety factor of the construction process, laying a solid foundation for the long-term safe use of buildings [5].

5. Application of CAD Technology in Building Grids

5.1. Optimization and modification of architectural design schemes

Computer aided design (CAD) plays a crucial role in optimizing and modifying building blueprints in the field of architecture. With the help of CAD systems, designers can shape building prototypes in a virtual 3D environment, ensuring their functionality, attractive appearance, and cost-effectiveness through continuous version updates. In the process of improving design schemes, numerous factors need to be considered, including building material selection, spatial planning, load-bearing capacity, etc. By utilizing CAD technology, designers can analyze and adjust these factors using advanced optimization algorithms and mathematical models to achieve the optimal design state.

The basic process of architectural design optimization can be expressed as the following formula:

$$Z = f(x_1, x_2, \dots, x_n)$$

Z is the optimization objective (such as minimizing costs, maximizing space, etc.), $(x_1, x_2, \dots x_n)$ are adjustable variables in the design (such as material selection, structural dimensions, room layout, etc.). By repeatedly adjusting these variables, CAD software can automatically generate multiple alternative design solutions and evaluate their performance indicators in real-time. Designers can choose the design scheme that best meets the project requirements based on the feedback information from the system. CAD technology allows designers to make real-time design modifications at any stage and quickly update all relevant building grid information through automated calculation functions. This accelerates the process of design optimization and reduces errors and delays caused by manual modifications, ensuring that architectural design can quickly respond to changes in project requirements and conditions [6].

5.2. Analysis and Calculation of Building Structures

CAD technology plays an important role in architectural design and is widely used in structural analysis and calculation. By integrating with structural calculation tools such as finite element analysis (FEA), CAD software can accurately simulate the performance of building structures under different load conditions and provide engineers with detailed data on stress, strain, deformation, etc optimizing the safety and economy of building structures.

The analysis of building structures usually involves load calculation formulas, as shown below:

$$\delta = \frac{F}{A}$$

Among them, δ represents stress, ***F*** is the applied load, and ***A*** is the area under stress. Through this formula, CAD systems can quickly calculate the stress distribution of building structures under external loads, helping engineers determine whether the building can withstand design loads. If the calculation results show that the stress exceeds the safe range of the structural material, CAD software can help engineers adjust design parameters, such as increasing the cross-section of the component, changing material selection, etc to ensure the safety of the structure. CAD technology can also automatically generate and update mesh models of building structures, and perform structural calculations and analysis through integrated calculation modules. This automated process reduces manual calculation time, lowers the possibility of errors, and provides strong support for building structural design.

5.3. CAD drawing provides construction guidance for construction personnel

The application of CAD technology in the construction phase is equally indispensable, providing guidance to construction personnel by generating detailed architectural drawings to ensure the precise implementation of design schemes. Construction drawings usually contain detailed information such as dimensions, materials, construction steps, and the location of key nodes, helping construction teams accurately locate the position of each component in the building grid and strictly follow the design requirements for construction [7].

Table 1. Construction Guidance Building

Component number	Component type	X coordinate	Y coordinate	Z coordinate	Material	Notes
001	Foundation column	10.0	15.0	0.0	concrete	support structure
002	wall	12.0	18.0	3.0	brick	External wall structure
003	beam	8.0	20.1	6.0	steel structure	Floor load-bearing capacity
004	floor	12.5	15.5	9.0	Precast slab	Ground structure
005	Roof beam	15.0	20.0	12.0	steel structure	Roof support

With the help of this table, construction personnel can clearly grasp the exact coordinates, material categories, and construction details of each component. For example, component 001 is a fundamental pillar located at coordinates (10.0, 15.0, 0.0), made of concrete material and installed as a load-bearing part. These detailed location data ensure that construction personnel can carry out precise construction according to the design drawings, ensuring the accuracy of the building layout. The information contained in the table can also assist the construction team in quickly comparing the construction progress during the construction process, detecting and resolving potential deviations or problems in a timely manner, and improving construction efficiency. The clear guidance of CAD drawings lays the foundation for quality supervision and acceptance of the project, ensuring its smooth completion.

6. Conclusion

Through exploration and analysis, it was found that the application of global positioning systems, measurement stations, and computer-aided design technology in building network layout has had a very positive promoting effect on contemporary construction project management. These advanced technologies have improved every aspect of construction projects from design to construction, and through precise data support and efficient construction supervision, ensure the control of project progress and quality. With the continuous upgrading and integration of technology, the management of building networks is developing towards intelligence and automation, which has improved the overall strength and market competitiveness of the construction industry. The integrated use of GPS, measurement stations, and CAD technology has become an important technical support for promoting the modernization process of the construction industry.

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