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MONITORING AND THREE-DIMENSIONAL NUMERICAL ANALYSIS OF ROCK AND SOIL DEFORMATION DURING CONSTRUCTION

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Abstract. In order to solve the problem of large monitoring errors in settlement deformation in construction engineering, the author proposes rock and soil deformation monitoring and three-dimensional numerical analysis under construction. The author proposes a settlement and deformation monitoring method for pile foundation construction in green building engineering. By setting settlement deformation monitoring points and setting the frequency of pile foundation contour monitoring, a contour line tracking edge monitoring model is constructed to obtain monitoring results, and longitudinal contour correction is used to correct monitoring errors, thus achieving settlement deformation monitoring. The experimental results show that compared with the traditional symmetrical settlement deformation monitoring group and the traditional compression observation settlement deformation monitoring group, the monitoring error obtained by the contour line tracking settlement deformation monitoring group designed by the author is controlled below 1.1. The author's monitoring method has better results, higher accuracy, and smaller errors, and has practical application value.

Key words: Contour line tracking, Green buildings, Engineering design, Construction settlement, Deformation monitoring, Monitoring methods

1. Introduction. With the development of modern society, the scale of engineering construction is gradually increasing. At this time, large-scale buildings will generate huge stress due to their own heavy weight during construction, and the stress will have an impact on the foundation rock and soil of large-scale buildings. If the foundation rock and soil undergo large-scale deformation, it will inevitably affect the stability of large-scale buildings. Therefore, in order to ensure the quality of large-scale buildings, many construction units now attach great importance to the application of rock and soil deformation monitoring technology [1]. The most critical indicator for evaluating the stability of soil and rock and whether buildings can be used reasonably is the deformation of soil and rock. The monitoring results can also verify the accuracy and suitability of the calculated parameter values or calculation methods. The monitoring data of deformation can also serve as a basis for the types of reinforcement methods used in actual engineering practice for rock and soil [2,3]. The author analyzes the current status and development trends of this technology in order to understand its specific applications. Due to the complex and diverse engineering characteristics of soil and rock, if there are omissions or incomplete grasp in survey and design, errors can occur and affect the quality of the project. Therefore, for some major projects with poor geological conditions, soil and rock deformation monitoring can timely and effectively detect problems, take appropriate measures, and ensure the normal and orderly progress of the project. This accumulates valuable practical experience, which has important and far-reaching implications for exploring the relevant fields of soil and rock engineering and improving the level of on-site survey tasks [4].

A large number of on-site engineering monitoring studies have shown that deformation monitoring of rock and soil has the characteristics of complex monitoring objects, long cycles, single means, and serious constraints on the on-site construction environment. The current deformation monitoring of rock and soil mainly uses inductive, resistive, and vibrating wire strain gauges, as well as displacement gauges and image scanners and other related measurement equipment. These sensor sensing components are mostly metal materials and mostly point collection, which are constrained by factors such as sensor material, applicable environment, massive data, signal transmission, etc. They have the disadvantages of easy corrosion failure, low survival rate, poor durability, low accuracy, real-time performance, and low level of intelligent monitoring, and can no longer meet the needs of complex rock and soil deformation monitoring [5,6]. Therefore, global researchers continue to

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explore and develop innovative technologies for monitoring rock and soil deformation. Based on the advantages of monitoring distance and accuracy, distributed fiber optic sensing technology has become the focus of attention for scholars worldwide. In terms of intelligent processing of monitoring data, as some rock and soil deformation monitoring technologies have achieved full real-time monitoring, how to intelligently process the collected massive data and quickly and accurately obtain key information on rock and soil deformation instability has become a bottleneck that urgently needs to be overcome in the development of monitoring technology. Artificial intelligence algorithms can be used to clean and extract massive data, using clustering, fuzzy algorithms, association rules, etc. for data mining, and combining machine learning to establish a deformation trend prediction model for rock and soil. This will be an important research direction for future monitoring and early warning of rock and soil (geological) engineering [7,8].

2. Literature Review. Under the guidance of sustainable development social goals, the number of green buildings is increasing year by year, which will also have a certain impact on traditional engineering buildings and processes. Usually, in the actual construction process, most construction workers pay more attention to controlling the bearing capacity of pile foundations to avoid a series of problems such as construction settlement and deformation to the greatest extent possible. However, due to the novel construction structure and model of green buildings, traditional construction methods are not applicable, which leads to some projects having building defects and being unable to continue advancing, forming obstacles [9]. Therefore, a more flexible monitoring method for settlement and deformation of construction pile foundation should be constructed by combining contour line tracking technology. Ge, C. and others studied a certain tunnel and used the discrete element method to simulate the construction steps of the three-step method and single-sided excavation method with and without systematic anchor support. Analyzed the results of tunnel surrounding rock stress, vertical displacement, and surface deformation under different working conditions, and analyzed the mechanism of system anchor support from a microscopic perspective. The results show that the single-sided excavation method can gradually release the load and deformation, better exerting the support capacity of the lining; The presence of system anchor rods improves the shear resistance of the surrounding rock, enhances the arching effect, and significantly reduces the vertical displacement and surface deformation of the surrounding rock [10]. Li, Z. and others studied the deformation and failure characteristics and acoustic emission response of concrete under dynamic loads under different soaking times. Revealed the failure mechanism and precursor characteristics of acoustic emission response of concrete under drop hammer impact [11]. Yu, X. et al. investigated the relationship between strain energy, volume fraction (VF), confining pressure, and failure mode of backfill surrounding rock through triaxial compression tests, acoustic emission (AE), and microscopic tomography (CT). The research results indicate that total strain energy and elastic energy are positively correlated with two factors (VF and constraint) [12].

The author combines contour tracking technology to construct a construction settlement deformation monitoring method, which measures the actual construction deformation or settlement status in complex environments. Reduce the probability of construction accidents, strengthen the control of the project after completing pile foundation construction, take multiple measures to address deformation or settlement issues, and minimize the increase of additional stress, laying the foundation for subsequent construction.

3. Method.

3.1. Application of three-dimensional numerical analysis. With the continuous improvement of modern technology, more and more monitoring technologies will be developed to provide practical needs. In the future, the engineering safety monitoring information management and monitoring data network system can also be applied to the management and processing analysis of engineering monitoring data, achieving remote real-time sharing of monitoring data and networked management and analysis, this is sufficient to reduce the labor intensity of manual data analysis, improve labor production efficiency, increase mechanized applications, reasonably avoid errors caused by human factors, and enable monitoring results to be timely and accurately returned to relevant survey and design personnel. It plays an important role in avoiding design and construction risks, ensuring construction progress and operational safety, and accurately grasping dynamic changes [13,14]. The combination of rock and soil deformation monitoring technology and computer application operation is relatively close. The signal information obtained through electric pulse signal feedback

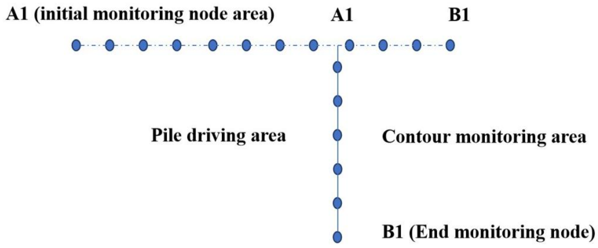

Fig. 3.1: Diagram of pile foundation contour monitoring and pile driving area

is not directly information data that can be translated by humans [15]. Therefore, it is necessary to use the conversion display function of computer technology for data processing, so that the electric pulse signal can be manually interpreted, in order to accurately and accurately explore the relevant changes in rock and soil deformation characteristics.

3.2. Layout of settlement deformation monitoring points. Usually, in order to improve the overall quality and effectiveness of green building construction, a certain number of additional measurement nodes are selected in certain areas, with the aim of obtaining numerical information of buildings in corresponding positions and providing theoretical basis for subsequent construction [16]. In order to meet the construction requirements of green building projects, it is necessary to first delineate the corresponding monitoring area and calculate the unit monitoring distance, as shown in formula 3.1.

$$H = (0.5k - \sum_{i=1} b^2 i \times \beta_1) + \beta_2 \tag{3.1}$$

In formula 3.1: H represents the monitoring distance of the unit, k represents the observation range, i represents the number of observation markers, b represents the depth of error, β_1 represents the preset number of nodes, and β_2 represents the measured number of nodes. Through the above calculation, the actual unit monitoring distance can be obtained. According to the specific monitoring scope defined, the fuzzy settlement position of the engineering construction is clarified, and the specific settlement points of the pile foundation are marked using precision leveling observation method and directional settlement monitoring method, arranged symmetrically in pairs. At this point, it is necessary to drill holes at the edge of the pile foundation, bury corresponding quantities of Φ25 type steel bars at the marked positions, and use high-strength concrete for reinforcement. At the same time, the monitoring device should be placed according to the number of deployed nodes, linked to the monitoring platform, to achieve the deployment of settlement monitoring nodes.

3.3. Frequency setting for pile foundation contour monitoring. After completing the layout of settlement monitoring points, the corresponding frequency of pile foundation contour monitoring should be set according to the actual engineering construction needs [17]. The monitoring frequency is a monitoring program set for the current construction situation, which is generally not fixed and changes accordingly with the progress of construction. The management level is level four. Firstly, determine the local pile driving area, as shown in Figure 3.1.

According to Figure 3.1, the setting of the pile foundation contour monitoring and driving area can be completed. At the same time, within the calibrated range, corresponding indicator parameters are set according to different pile driving soil layers, as shown in Table 3.1.

According to Table 3.1, it is possible to set the monitoring index parameters for the pile foundation profile. Next, based on the acquisition and summary of monitoring values and information, a specific frequency of change is set. When the equivalent value of the compression modulus is 0.972, the monitoring frequency is most balanced. Based on the empirical coefficient of pile foundation settlement, the standard monitoring mean is calculated, as shown in equation 3.2.

$$u = \alpha^3 + \int (m + n) \times \frac{m_1 m_2 - 1}{2} \tag{3.2}$$

Table 3.1: Setting of Monitoring Index Parameters for Pile Foundation Profile

Building monitoring of soil layers	depth/m	Reverse monitoring frequency ratio
Silty clay	10.14	1.02
Silty sand	11.23	1.25
Clay	11.56	1.16

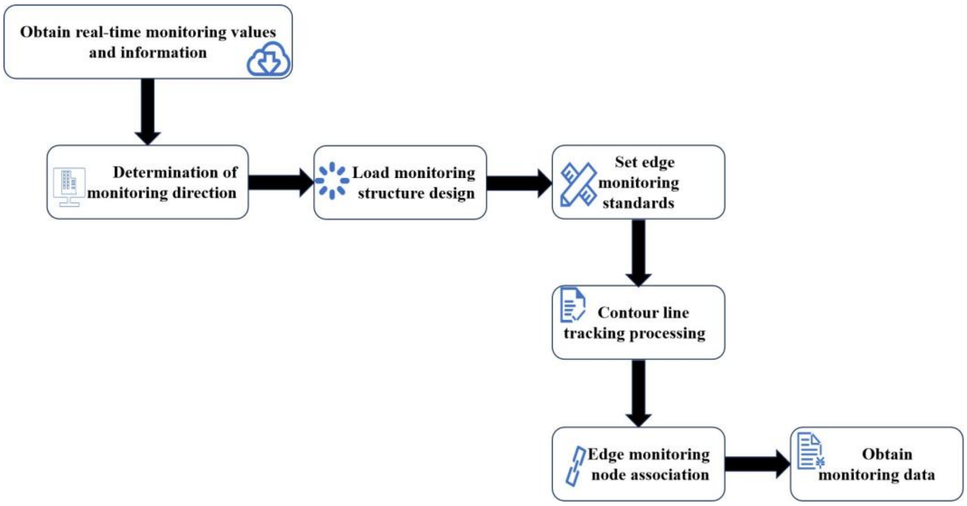

Fig. 3.2: Structural diagram of contour line tracking edge monitoring model

In Formula 3.2: u represents the monitoring mean, α represents the settlement coefficient, m_1 represents the monitoring distance of unit markers, m_2 represents the compression distance, and n represents the error distance. Through the above calculation, the actual monitoring mean can be obtained, and the specific balance monitoring frequency can be achieved.

3.4. Construction of contour line tracking edge monitoring model. After setting the monitoring frequency for the pile foundation contour, it is necessary to combine contour line tracking technology to construct a more diverse and flexible edge settlement deformation monitoring model. Edge monitoring is actually a means of obtaining numerical values, information, and images. Based on the changes in the grayscale values of the scenery and background during construction, associate the corresponding monitoring nodes set up. At the same time, set more intuitive and quantitative edge monitoring points based on the real-time data transmitted back from the monitoring nodes, combined with contour tracking technology. At this point, the variation vector ratio for measuring building settlement deformation is generally controlled between 1.03 and 5.2. Using C50 prefabricated concrete slabs, they are placed at the location of settlement deformation, and a total of 5 pressure bearing segments need to be set longitudinally to achieve multi-dimensional assembly monitoring. Subsequently, in order to expand the detection range of green buildings, the monitoring specifications can be adjusted and a specific monitoring model can be constructed, as shown in Figure 3.2.

According to Figure 3.2, the design of the contour line tracking edge monitoring model structure can be completed. Use the model to plan the corresponding monitoring structure, and at the same time, use monitoring nodes to achieve short distance monitoring control and obtain monitoring results. However, it should be noted that for local construction monitoring areas, centralized monitoring should be adopted to maximize the overall monitoring accuracy and better integrate with contour line tracking technology. With the assistance of edge monitoring points, a multi-dimensional contour line tracking edge monitoring model should be further constructed. Based on this, as the monitoring area changes, it is necessary to adjust the corresponding monitoring nodes at a distance of 300cm. Can complete the design and adjustment of the

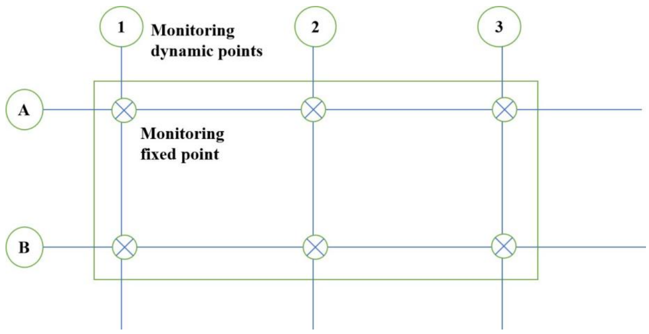

Fig. 3.3: Layout diagram of vertical contour correction piles

monitoring node position adjustment structure. Subsequently, within the determined green building, a related auxiliary framework is constructed, with specific monitoring cycles set. Based on the settlement and deformation status of the building, the monitoring position and effective area are adjusted, thereby optimizing and improving the overall ability of the monitoring model and expanding the actual monitoring range.

3.5. Longitudinal contour correction for settlement deformation monitoring. After completing the design of the contour line tracking edge monitoring model, combined with the longitudinal contour correction method, better settlement deformation monitoring can be achieved [18]. Using contour line tracking method for multi-dimensional monitoring correction processing. Using the WHPB platform, set 6 steel pipe piles at the designated positions, and each steel pipe pile needs to be equipped with a corresponding monitoring device and correlated with each other. The size of the pile type is D1.24m x 123.82m. The monitoring piles need to be inclined towards the interior of the building platform, with a depth of 101m. The actual depth is 90.51m, and the exposed length of a single pile is about 20.31m. The monitoring pile position is set, as shown in Figure 3.3. According to Figure 3.3, the layout and construction of longitudinal contour correction piles can be completed [19]. At the same time, combining contour line tracking technology, a longitudinal correction monitoring program is set up, a monitoring model is adopted, and a cyclic monitoring mechanism is formed. As the monitoring nodes change, the monitoring area is also constantly adjusted, achieving multi-dimensional dynamic correction monitoring.

3.6. Experimental preparation. The main purpose of this study is to analyze and study the practical application effect of the settlement and deformation monitoring method for green building pile foundation construction under contour line tracking technology [20]. Considering the accuracy of the final test results, it is necessary to conduct analysis in the same testing environment, setting up a traditional symmetrical settlement deformation monitoring group, a traditional compression observation settlement deformation monitoring group, and the contour line tracking settlement deformation monitoring group designed by the author. The final test results need to be discussed in a comparative form to ensure their reliability. Before analyzing and studying the practical application effect of the settlement deformation monitoring method for green building pile foundation construction under contour line tracking technology, a testing environment needs to be established. Firstly, set the edge contour line and use the Sobel operator to calculate the dynamic ratio of edge monitoring at the calibrated position, as shown in equation 3.3.

$$C = \sqrt{k^3} + \sum_{q=1}(\theta \times \frac{q^3}{f_1 f_2}) - 1 \tag{3.3}$$

In formula 3.3: C represents the dynamic ratio of edge monitoring, k represents the number of operators, θ represents the measured monitoring range, q represents the number of monitoring cycles, f_1 represents the preset monitoring range, and f_2 represents the actual monitoring range. Through the above calculation, the actual dynamic ratio of edge monitoring can ultimately be obtained. Based on the relevant monitoring platforms and nodes, set specific dynamic monitoring programs and use models to determine their applicability and

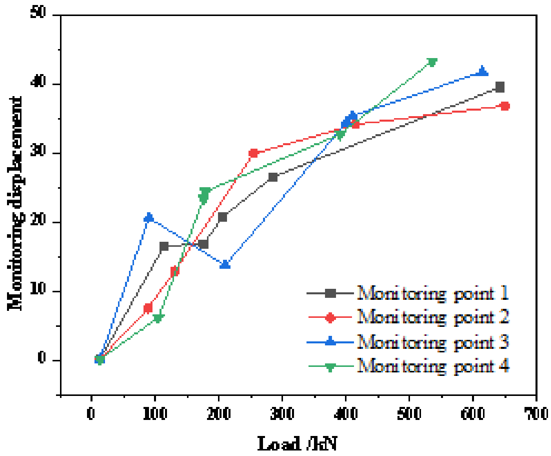

Fig. 3.4: Analysis of settlement and deformation at measurement points during construction

error probability. If within a reasonable range, it can ensure the final monitoring results. Subsequently, it is necessary to select D building as the main target object for testing, and obtain specific data and information for measurement to form a complete monitoring reference. By combining contour line tracking technology to obtain the original monitoring images, installing Gaussian space filters to help the equipment obtain monitoring signals more smoothly, setting zero crossing monitoring points, and combining with actual settlement deformation situations, calculating the specific unit monitoring distance, which generally needs to be controlled between 5.5m and 10.5m. After verifying whether the tested device is in a stable state, ensuring that there are no external factors interfering with it, and ensuring that it is in good condition, specific testing can begin.

Based on the testing environment built above, combined with contour tracking technology, conduct specific testing analysis. When the monitoring area is in the optimal smooth state, a second-order edge operator is used to construct a multi-dimensional construction settlement deformation monitoring matrix. By using cyclic detection, the monitored values and information are measured, and the binarization threshold is calculated, as shown in equation 3.4.

$$r = \frac{\int \zeta - \sqrt{t}}{0.2\eta^2 + \epsilon} - \chi^3 \tag{3.4}$$

In formula 3.4, r represents the binarization threshold, η represents the settlement depth, ζ represents the elevation distance, represents the offset length of the contour line, t represents the node difference, and χ represents the interference range.

3.7. Results and Discussion. Through the above calculation, the actual binarization threshold can be obtained. According to the changes in settlement deformation, the binarization threshold obtained will also change. Four main monitoring nodes are set, combined with the Roberts operator monitoring mode and changes in load force, to determine the actual monitoring situation, as shown in Figure 3.4.

According to Figure 3.4, the analysis and research on the settlement and deformation of the measurement points during construction can be completed. Based on professional equipment and monitoring nodes, obtain corresponding test values and information. At the same time, conduct the same test in different areas to determine the detection errors of four monitoring nodes. The test results are shown in Table 3.2.

According to Table 3.2, the analysis of the test results can be completed: compared with the traditional symmetrical settlement deformation monitoring group and the traditional compression observation settlement

Table 3.2: Comparison and Analysis of Test Results

Monitoring nodes	Monitoring error of traditional symmetrical settlement deformation monitoring group	Monitoring error of traditional compression observation settlement deformation monitoring group	Monitoring error of the settlement deformation monitoring group for tracking the contour line
Monitoring point 1	2.54	3.046	1.01
Monitoring point 2	3.03	3.16	1.04
Monitoring point 3	2.07	2.01	1.00
Monitoring point 4	3.41	2.45	1.08

deformation monitoring group, the monitoring error obtained by the contour line tracking settlement deformation monitoring group designed by the author is controlled below 1.1. Indicating that this monitoring method has better effect, high accuracy, small error, and practical application value.

4. Conclusion. The author proposes the monitoring and three-dimensional numerical analysis of rock and soil deformation under construction. Combining contour line tracking technology, the author constructs a settlement deformation monitoring method for green building engineering pile foundation construction, and analyzes and studies the practical application effect. For the construction of green buildings, the mode is relatively novel, so it is necessary to construct a monitoring mode with stronger characteristics, in complex environments, monitoring errors can be minimized as much as possible, and cyclic and multi-objective settlement and deformation monitoring methods can be constructed to achieve comprehensive monitoring and analysis. In addition, within a reasonable range, simplify the construction monitoring process as much as possible, save monitoring costs, and create a more stable monitoring environment to improve the construction speed and quality effect of the building.

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