Analysis on the deformation monitoring theory of fabricated high-rise residential buildings

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Abstract. Under the influence of various factors, the assembled high-rise residential buildings will undergo different degrees of deformation in the horizontal and vertical directions. The amount of deformation is within the allowable range and the building can be used safely. However, if the amount of deformation exceeds the allowable range, it may have a greater impact on the integrity and stability of the fabricated high-rise apartment, and may even form a disaster. Therefore, the deformation law of the building during a certain period of time is studied, and the deformation prediction analysis of the assembled high-rise residential building is carried out according to the relevant data, thereby ensuring the safe operation of the assembled high-rise residential building. This paper first introduces the development status and development opportunities of fabricated buildings in China, discusses the main contents of the deformation monitoring of fabricated high-rise buildings, various methods, monitoring technical solutions, and analyzes the various existing forecasting methods and their respective advantages and disadvantages.

1. Prefabricated building development status and opportunities
On September 14, 2016, Premier Li Keqiang presided over the State Council executive meeting and decided to vigorously develop prefabricated buildings and promote industrial restructuring and upgrading. Subsequently, the General Office of the State Council issued the “Guiding Opinions on Vigorously Developing Prefabricated Buildings” (Guo Ban Fa [2016] No. 71). The opinion pointed out that it is necessary to promote the area with the three major urban agglomerations of Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta. Other cities with a permanent population of more than 3 million are actively promoting the area. The rest of the cities are encouraged to promote the area and develop the fabricated concrete structure according to local conditions. Prefabricated buildings such as steel structures and modern wood structures. Strive to use 30 years or so, the proportion of prefabricated buildings to the newly built building area reached 30%.

On November 19, 2016, the Ministry of Housing and Urban-Rural Development held a national assembly site meeting in Shanghai. The party secretary and minister of the Ministry of Housing and Urban-Rural Development Chen Zhenggao pointed out that prefabricated buildings are a major change in the way of construction, and it is necessary to fully understand the significance of the development of prefabricated buildings. First, the need to implement the concept of green development. The second is the need to achieve modernization of the building. The third is to ensure the quality of the project. The fourth is to shorten the construction cycle. Fifth, it can promote new industries and related service industries.
In August 2016, the Jiangxi Provincial Government issued the “Guiding Opinions on Promoting the Development of Prefabricated Buildings”. By 2018, the proportion of newly built buildings in the province using prefabricated construction reached 10%, of which government investment projects reached 30%. In 2020, the proportion of newly built buildings in the province using prefabricated construction reached 30%, of which government investment projects reached 50% of the proportion of new buildings in the same period. All eligible government investment projects were assembled. It is understood that the Jiangxi Provincial Party Committee and the provincial government attach great importance to the advancement of the prefabricated building, and listed it as an important indicator for the comprehensive evaluation and evaluation of the scientific development of the city and county in the provincial party committee and the provincial government in 2017. Jiangxi provincial finance will arrange a special fund for the construction of building construction of 12 million yuan. This year, 18 assembly-type production bases will start construction. Among them, Nanchang Zhaohui Building, Municipal Yuanda, Zhangzhou Construction Industrialization Co., Ltd. and Zhangzhou Huaqiang Hangxiao Construction Co., Ltd. have been officially put into operation. Three assembly-type construction bases, such as Zhaohui Urban Construction Group Co., Ltd., Jiangxi Xiongyu (Group) Co., Ltd. and Jiangxi China Coal Construction Group Co., Ltd., were listed as the first assembly-type construction industry base by the Ministry of Housing and Urban-Rural Development.

Sum up: China's fabricated building market is still in its infancy, and the whole country is basically concentrated in the field of residential industrialization, especially in the narrow area of affordable housing. The initial investment is large, the production scale is small, and within a short period of time. Unable to compete with the traditional cast-in-place structure market. However, as the country and the industry successively issued relevant development goals and guidelines and policies, in the face of the urgent need for the transformation and upgrading of the modernization of the construction industry across the country, more than 20 provinces and cities across China have successively issued policies to support the development of related construction industries and promote the industry. Chemical base and pilot demonstration project construction. It is believed that with the improvement of technology and the improvement of management level, the prefabricated building will have a broad market and space. After more than 30 years of silence, it has re-emerged in China. The prefabricated building still in its infancy. The national, industry and local major standard specifications have been basically completed and promulgated. Meet the transformation and upgrading needs of the modernization of the construction industry.

With the rapid development of society and the continuous accumulation of people in cities, urban land is becoming more and more tense, and a large number of fabricated high-rise residential buildings have also emerged. For example, the total investment of Vanke Real Estate Development Co., Ltd. as the construction unit, Beijing Residents Third Development and Construction Co., Ltd. as the construction unit of the Jinyu Huafu industrial high-rise residential building, it is 27 stories, the total height is about 80 meters, is currently the highest in China Fully-assembled residence; Vanke's new prefabricated industrial high-rise residential building at 2878 Gaoqing Road, Pudong New Area, Shanghai. As the number of floors increases, the load on the high-rise buildings increases. To ensure the safety of building construction and operation, it is necessary to periodically observe the observation points placed on the high-rise buildings to obtain observation points. The position change amount, so as to study the causes and laws of deformation, avoid the damage of the main structure of the building caused by uneven settlement or the cracks that affect the function of the structure, and provide reliable information for future survey and design.

2. Prefabricated high-rise residential deformation monitoring

2.1. Prefabricated high-rise residential monitoring content
The deformation monitoring of fabricated high-rise buildings, in addition to static deformation observations, static observations include settlement, tilt and crack observations, as well as dynamic observations[1].

2.1.1. Settlement monitoring
Establish a high-precision elevation control network, repeat observations on the observation points, and record the displacement of the points in the vertical direction. Analyze the law of settlement to ensure the safety of fabricated high-rise residential buildings.

2.1.2. Horizontal displacement monitoring
Plane displacement monitoring can be divided into absolute displacement and relative displacement. The purpose of relative displacement monitoring is to monitor the safety of buildings; the purpose of absolute displacement monitoring is to monitor the safety of fabricated high-rise buildings and to study the causes of the overall deformation of buildings to ensure the safety of fabricated high-rise buildings.

2.1.3. Tilt monitoring
The tilting observation of the main body of the fabricated high-rise residential building shall determine the inclination, inclination direction and inclination rate of the observation point at the top of the building relative to the bottom fixed point or the upper layer relative to the lower observation point. The overall tilt of a rigid building can be determined indirectly by measuring differential settlement of the top surface or foundation.

2.1.4. Crack monitoring
The width, depth, and staggering of the cracks generated in the fabricated high-rise residential buildings are monitored.

2.1.5. Internal monitoring
Stress monitoring, temperature monitoring and groundwater level monitoring of the foundation of a prefabricated high-rise apartment.

2.2. Monitoring method and technical design
According to the environment around the deformation body and the ground conditions, select the appropriate deformation monitoring method.

2.2.1. Conventional geodetic method
The elevation, angle and side length of the monitoring points are observed by conventional instruments such as level, theodolite and total station to determine the absolute deformation information of the whole body.

2.2.2. GPS monitoring method
Using its spatial positioning technology, a high-precision deformation monitoring network is established. Moreover, the method is not limited by climatic conditions and is highly automated.

2.2.3. 3D laser scanning measurement technology
The deformed body is scanned by a three-dimensional laser scanner to obtain a large number of three-dimensional point cloud data on the surface of the deformed body, and then the deformation information is extracted.

2.2.4. Close-range photogrammetry
The deformation camera with an object distance of less than 300 m is photographed and measured by a measuring camera, and then the captured image is processed to extract deformation information.
2.2.5. *Synthetic aperture radar technology*

The electromagnetic pulse is used for ranging and two-dimensional imaging to obtain deformation information. According to the nature of the project, the allowable deformation value, the size and the observation period, the deformation monitoring accuracy of the assembled high-rise residential building is determined. Measurements must be made in strict accordance with the standards of the Precision Engineering Measurement Specification\[2\].

2.3. *Settlement monitoring point layout*

2.3.1. *Reference point layout*

The reference point is the basis of deformation monitoring. Whether the reference point layout is reasonable or not directly affects the results of deformation monitoring. The reference point must be set outside the deformation zone. In general, the number of reference points for a project should be no less than three, which is beneficial to the protection, recovery and stability analysis of the reference point\[3\].

2.3.2. *Work base point layout*

Under normal circumstances, the reference point is placed far away from the engineering survey area, which is not conducive to periodic observation. In order to reduce the observation work, some working basis points are arranged in the vicinity of the survey area. However, the working base point must be periodically checked to ensure the reliability of the deformation monitoring results.

2.3.3. *Monitoring point layout*

The location of the settlement monitoring point is selected by the measurement unit, the design unit and the supervision of Party A, and then deposited in the construction unit. The deformation point should be placed on a prefabricated high-rise apartment that reflects the location of the building settlement.

3. *Common prediction models and their advantages and disadvantages*

3.1. *Grey prediction model*

The grey theory is a theory put forward by Professor Deng Julong of Huazhong University of Science and Technology in China. The principle of the theory is to establish a grey prediction model through a small amount of missing data information, and to predict and analyze the deformation law of the deformed body. The settlement deformation of prefabricated high-rise residential buildings is long-term, and the grey prediction model generally performs short-term predictions. The results are ideal, but as the number of predictions increases, the accuracy of the results may not be sufficient\[4\].

3.2. *Regression analysis model*

The statistical analysis of the deformation relationship between the deformed body and various related factors is carried out, and the law in the data is obtained, and then applied to the deformation prediction analysis of the deformed body.

Due to the many influencing factors of the deformation of the high-rise residential buildings, there are many independent variables involved, so the independent variables are very difficult to select, resulting in the accuracy of the regression analysis model not meeting the requirements of production. The existing results show that the regression analysis method is still feasible under special circumstances, but the application in the prediction of settlement deformation of high-rise buildings is not accurate enough.
3.3. **Time series analysis model**

Time series analysis is a statistical method of dynamic data processing, which mainly studies the interdependence of data sequences. The data is processed by mathematical methods, and relevant mathematical models are established to analyze the deformation trend of the deformed body.

In the observation of settlement deformation of high-rise residential buildings, there are many influencing factors, and it is difficult to meet the conditions for the prediction of impact factors. Applying the time series prediction model, the accuracy is related to the size of the prediction period. When the prediction period increases, the error increases. The model adaptability and timing spacing of the model need further research[5].

3.4. **Artificial neural network model**

Artificial neural network is a research hotspot in the field of artificial intelligence in the 1980s. It abstracts the human brain neuron network from the perspective of information processing, establishes a simple model, and forms different networks according to different connection methods. A neural network consists of a large number of nodes connected to each other. Each node represents a specific output function, called an excitation function; the connection between every two nodes represents a weighting value for the signal passing through the connection, which is equivalent to the memory of an artificial neural network. The neural network can be divided into three layers: the input layer, the hidden layer, and the output layer. The external environment or stimulus is the input layer; the output layer implements the output of the system results; between the input and output units is the hidden layer[6]. Artificial neural network is a non-programming, adaptive, brain-style information processing. Its essence is to obtain a parallel distributed information processing function through network transformation and dynamic behavior, which can solve complex nonlinear problems.

The artificial neural network continuously adjusts the weights to approximate the fitting target output value through the training of the learning function. In the process of application, it has certain adaptability and expresses the ability of self-learning, and can also realize this process of self-organization. However, the number of hidden nodes of the network and the center of hidden nodes are difficult to obtain, which affects the accuracy of the entire network, which greatly restricts the wide application of the network[7].

4. **Conclusion**

China needs strong assembly buildings, and it also ushers in development opportunities. With the emergence of high-rise buildings in China, there will be more and more high-rise building buildings. This paper analyzes the relevant principles and methods for high-rise assembly building deformation monitoring. The advantages and disadvantages of various methods are compared, which improves the theoretical basis for the deformation monitoring of high-rise assembly buildings, and can be applied to high-rise assembly buildings in China to ensure the safety of high-rise assembly buildings.

**Acknowledgment**

Fund Project: Jiangxi Provincial Department of Education Science and Technology Project (GJJ161660)

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