Study on Seismic Performance of Prefabricated Concrete Structure building

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Abstract: The application scope of prefabricated concrete buildings in China's high-rise building projects is expanding, which has far-reaching application value for promoting energy conservation and emission reduction in the construction industry and promoting the development of green construction concept. This paper selects a prefabricated concrete high-rise building as the research object, analyzes its seismic performance with the help of model establishment, and compares and studies the seismic performance of prefabricated concrete buildings from three aspects, that is the bearing capacity of prefabricated members, the way of reinforcement and the way of joint connection, in order to provide reference for the improvement of seismic performance of concrete prefabricated buildings.

1. Introduction

Prefabricated concrete structure is one of the structural forms of building industrialization, which is manufactured by all or part of the components of the structure, and then assembled on site through reliable connection. It conforms to the development trend of the construction industry. The fabricated integral structure is a partially fabricated structure. Some of its components are prefabricated in the factory and the other is cast on site to form a whole. Post-cast monolithic and prestressed splicing are mostly used, as shown in Figure 1. Compared with cast-in-place concrete structure, it has the following advantages, namely, the quality of industrialized production components is easy to guarantee, the impact of climatic conditions is small, the construction speed is fast, the construction period is short, the construction waste is small, and environmental protection and energy conservation. These advantages conform to the concept of contemporary social development, can promote the transformation and upgrading of the construction industry, and can be used for commercial buildings and civil residences. They are the main development and application forms in China. As a new structural system, the seismic performance of prefabricated concrete structures has also been widely concerned.

Figure 1 Prefabricated concrete structure.

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2. Project Case Analysis

2.1. The General Situation of the Project

In this paper, a prefabricated building project is selected as a specific example. The building mainly uses the integral frame, namely the shear wall structure. The building has 15 floors with a total height of 42.8m, of which the ground floor is 3.6m high and the other 14 floors are 2.8m high.

2.2. Model Building

In this study, the horizontal part of the building is selected to complete the modeling, and the concrete material with Poisson's ratio of 0.2 is used to construct the model. The load value of the building is comprehensively investigated, and the material density of reinforced concrete is uniformly set as 3000kg/m^3. In view of the relatively low reinforcement content in the model, the elastic modulus value of the model is also lower than that of ordinary reinforced concrete. When setting the parameters of the structural model, it is proposed to set the element type of the frame column, shear wall and floor as SHELL63, and the element type of the frame beam as BEAM4. The concrete strength grade of each member is C50, and the value of the elastic modulus is 3.25 × 1010E/pa. During the construction of the model, the vertical load is usually set as the self weight of the building structure, and the horizontal load only takes the seismic action as the consideration index. The actual seismic wave is directly applied after processing, and the seismic load has an effect on the building structure in the form of acceleration. Since the selected model belongs to a high-rise building structure, its pile foundation is usually buried deep, resulting in a small range of movement and rotation of the building structure on the ground. Therefore, the bottom foundation of the building structure should also be set according to the fixed support.

2.3. Frequency Analyses

Through modal analysis on the selected building model, the frequencies of the building under different modes can be basically obtained, which are 0.50Hz, 0.52Hz, 0.56Hz, 1.31Hz, 1.53Hz and 1.63Hz respectively.

2.4. Seismic Performance Analysis

2.4.1. Seismic Performance Analysis of Building Structures

In view of the strong differences in the properties of seismic waves in the past elastoplastic dynamic analysis, scientific and reasonable analysis should also be carried out according to the properties of different seismic waves. In this paper, three seismic waves such as Kobe wave, Tianjin wave and Elcentro wave are mainly used as the analysis objects. The duration of each seismic wave is 20min, and the interval between each seismic wave is 0.05s. Three seismic accelerations in different directions are selected, of which the maximum acceleration is 7 degrees and the maximum peak acceleration is 220gal. Their peaks are adjusted and input into the model. Firstly, the displacement of the building structure in the horizontal direction is analyzed. Taking the 7 degree rare earthquake as an example, the maximum displacement of the building under the three seismic waves is 0.4m, 0.26M and 0.43m respectively. It can be seen that the displacement of the building under the rare earthquake is large, and the whiplash effect occurs on the top floor of the building. Then, by analyzing the inter story displacement angle of the building, it can be found that the maximum displacement angle of the building under the action of three kinds of seismic waves is 1/46, 1/72 and 1/43. It can be seen that the building can generate the maximum inter story displacement angle under the two kinds of seismic waves of Kobe wave and Elcentro wave, and the maximum inter story displacement angle appears on the top floor. However, in the process of constructing the model, only the self weight of the building and the influence of earthquake action were investigated, and the stressed reinforcement was not really investigated, and there was a certain gap between the value of elastic modulus and the specified value of reinforced concrete. Combined with multiple factors, it can be basically determined that the building can better meet the seismic design requirements of China.

2.4.2.Seismic Analysis of Key Joints in Buildings

Firstly, by comparing the shear strength of precast column and cast-in-place column joints, it can be concluded that the shear capacity of the two joints is 572.4KN and 597.7KN respectively, which shows that the strength of cast-in-place column joints is greater than the strength of precast column itself, and can basically meet the requirements of cast-in-place. Then, by comparing the shear strength at the joints of precast wall and cast-in-place wall, it can be concluded that the shear forces of the two are 1620.5KN and 1920.2KN respectively, and the strength of precast wall joints is higher than that of precast wall itself, which is basically the same as that of cast-in-place wall. With the help of the above shear strength calculation, it can be basically determined that the building structure can meet the seismic performance requirements, and the model construction is established.

3. Comparison of Seismic Performance of Prefabricated Concrete Buildings

The comparative study on the seismic performance of prefabricated concrete buildings is mainly carried out from three aspects, that is the bearing capacity of prefabricated members, the way of reinforcement and the way of joint connection.

3.1. The Bearing Capacity of Prefabricated Members

On the one hand, starting with the added materials of precast concrete components, water reducing agent and slag were mainly used as additives in the past. Now, the new environmental water reducing agent represented by polycarboxylic acid has been widely used. Polycarboxylic acid has good compatibility with cement, which can effectively reduce the segregation and bleeding of concrete, and improve the stability and strength of concrete. Another example is air entertaining agent, which is mainly used to improve the collapse degree of concrete mixture, and strive to improve the fluidity and plasticity of concrete. By mixing small bubbles evenly in concrete, the work ability and application properties of concrete can be well improved, so as to further strengthen the stability of prefabricated components. The last is slag. The application of slag is mainly to improve the plasticity and water retention of concrete. The slag is ground into ultra-fine powder with the help of grinding technology, so that the activity of slag can be well stimulated, the influence of hydration heat on concrete can be further reduced, the wear resistance and durability of components can be improved, and the economic cost can be saved.

On the other hand, starting from the mixing mode, the vibration mixing method can be mainly selected, which not only helps to improve the mixing quality, but also has strong economy. Vibration while mixing the concrete can fully disperse and hydrate the cement and water, make the concrete reach a uniform state in the shortest time, improve the air content and fluidity in the concrete, and further improve the bearing capacity of precast concrete components.

3.2. The Way of Reinforcement

On the one hand, the strength of longitudinal reinforcement and stirrup is selected for comparative analysis. Compared with the seismic performance, the strength has a deeper impact on the reinforcement. Compared with ordinary reinforcement, adding longitudinal reinforcement can improve the seismic performance and stability of members by virtue of its strength performance advantages. At the same time, if the stirrup is properly added to the concrete reinforcement, it can effectively improve the binding force on the concrete, effectively avoid the bending of the longitudinal reinforcement under the external force, and better improve the strength and durability of the members, which plays an important role in improving the seismic performance of the precast concrete columns.

On the other hand, the non prestressed reinforcement and the combined reinforcement can be compared and analyzed. From the point of view of load, the change of load and reinforcement strength is in direct proportion during the configuration of non prestressed reinforcement members. Therefore, in order to effectively improve the load effect of buildings, the previous method of interval reinforcement should be changed and the form of combined reinforcement should be

selected for reinforcement. In prestressed concrete members, the main reinforcement and reinforcement usually bear the stress together, while in non prestressed concrete members, the non prestressed reinforcement mainly bears the buffer effect when the prestressed reinforcement has brittle failure. The selection of non prestressed reinforcement can effectively increase the limit displacement of precast units, improve the deformation resistance of members under earthquake, and further promote the steady improvement of the seismic performance of the overall building. According to the analysis and comparison of a large number of test data, it can be observed that when the strength ratio of non prestressed reinforcement reaches 53%, the seismic performance of precast concrete members can be significantly improved, which also helps to save construction costs. Therefore, the mixed reinforcement form can achieve the best effect.

3.3. The Way of Joint Connection

Through the investigation results of rare earthquakes at home and abroad, it is found that the concrete frame joints are the main parts of prefabricated buildings that are seriously damaged. The main reason for this problem is that the construction unit did not use stirrups to encrypt each node of the concrete frame structure in strict accordance with the design requirements of the construction drawings during the construction process, and lacked a clear understanding of setting two groups of stirrups at the concrete frame nodes, which led to serious potential safety hazards in the engineering structure itself. Once an earthquake occurs, it will be seriously damaged, and it is difficult to get good repair, or even serious enough to make the whole frame collapse. Therefore, it is necessary to strengthen the control of this key node, ensure the reasonable control of the node according to the overall layout, strengthen the binding force on the core concrete of the node, and strictly set up two groups of stirrups to strengthen the node, so as to maximize the structural strength and ductility of the node and improve the stability and firmness of the overall stressed reinforcement.

4. Conclusion

In short, compared with ordinary concrete buildings, the construction cost of concrete prefabricated buildings is relatively low, and the use performance is also more prominent. The promotion of concrete prefabricated buildings can create higher economic benefits to a great extent. In the face of the continuous development of China’s urbanization construction and construction industry, it is also necessary to take effective measures to optimize the seismic performance of concrete prefabricated buildings, so as to significantly improve the service life and quality of buildings, and promote the rapid development of China’s construction industry.

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