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Ecological Efficiency of Life Cycle of Concrete Fabricated Composite Slab in Earthquake Area

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Abstract:

With the development of prefabricated buildings, the construction mode of buildings has changed greatly. Infilled wall is an important part of architecture. The traditional manual masonry method is not suitable for the construction of prefabricated buildings. Precast concrete infilled wall, as a form of infilled wall suitable for the construction of prefabricated buildings, came into being. Infilled wall has a great influence on the performance of frame structure. Compared with the traditional masonry infilled wall, the concrete infilled wall has greater stiffness, better integrity and stronger bearing capacity. Based on the existing research, this paper analyzes the influence of the height width ratio of the concrete infilled wall, the wall thickness, and the tie mode with the frame on the structural performance through the finite element software Atena. Combined with the results of practical engineering modal analysis, this paper evaluates the value method of natural vibration period of concrete frame infilled wall structure, and puts forward some suggestions for Chinese codes.

***Keywords**: Earthquake Area, Concrete, Fabricated Composite Slab, Life Cycle*

I. INTRODUCTION

Prefabricated concrete structures can be divided into fully fabricated structures and partially fabricated structures according to the degree of assembly. Fully assembled structure means that all structural components are mechanized into batch production in the factory, and then assembled and connected on site [1-2]. Dry connection method is mainly adopted. The fully assembled structure has the advantages of fast construction speed, high mechanized productivity and little influence by climate. Prefabricated infilled wall can solve a series of problems existing in traditional masonry infilled wall because of its high degree of industrialization, high on-site construction efficiency and reliable quality. Precast concrete

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wallboard has the advantages of good heat and sound insulation performance, high bearing capacity and low transportation damage rate [3].

In addition, the precast concrete wall is generally produced and transported by the precast component factory together with the main precast components, which is guaranteed in quality and easier to manage by reducing subcontractors in management. Compared with other forms of infilled wall, precast concrete wall makes full use of the on-site construction machinery of prefabricated building, and has become the most convenient and fast form of infilled wall in prefabricated building [4-5]. Compared with masonry infilled wall, precast concrete infilled wall has greater strength, higher stiffness and better wall integrity, and its impact on the frame structure will be more significant [6]. Therefore, it is of great significance to study the impact of precast concrete infilled wall on the performance of frame structure.

II. FINITE ELEMENT ANALYSIS OF CONCRETE FRAME INFILLED WALL STRUCTURE

The structure adopted in this chapter is hoisting after the concrete infilled wall reaches the curing age, and then pouring the frame column with the concrete infilled wall as the side formwork, which is not essentially different from the method of secondary pouring of concrete infilled wall in Moretti's test [7-8]. Atena can check the load, deformation and crack corresponding to each loading step through the operation in the post-processing stage, and take four characteristic points of the structure, namely, cracking point, yield point, peak load point and limit load point, and their corresponding characteristic displacements to analyze the performance of the structure [9].

The research shows that when the load borne by the structure reaches the peak load, the structure still has a certain deformation capacity. Usually, the corresponding displacement when the load borne by the structure decreases from the peak load to the nominal limit load is taken as the limit displacement [10]. According to the code for seismic test methods of buildings, when carrying out the bearing capacity and failure characteristics test, it shall be loaded to the falling section of the ultimate load of the test body, and the falling value shall be controlled to 85% of the maximum load. Therefore, the limit displacement shall be the displacement corresponding to 0.85pmax within the falling range of the curve.

When many scholars study the influence of infilled wall on the performance of frame structure, the height width ratio h_w / l_w of infilled wall is taken as the research object. Because the stiffness of frame infilled wall structure is composed of infilled wall stiffness and frame stiffness, the height width ratio of infilled wall can significantly change the stiffness of infilled wall. The performance of concrete frame infilled wall structure with height width ratio of 0.47, 0.55 and 0.67 will be analyzed below.

TABLE I. Characteristic load and ductility

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NUMBER	ASPECT RATIO	YIELD LOAD	YIELD DISPLACEMENT	PEAK LOAD	PEAK DISPLACEMENT	ULTIMATE LOAD	LIMIT DISPLACEMENT	DUCTILITY COEFFICIENT
K1	0.55	935	4.9	1028	8.3	861.7	10.1	2.06
K2	0.47	978	4.8	1058	7.5	876.4	9.9	1.85
K3	0.67	891	5.7	962	8.8	806.7	11	1.93

It can be seen from table 1 that with the decrease of the height width ratio of the infilled wall, the stiffness of the concrete infilled wall frame structure increases accordingly, and the peak load and ultimate load of the structure also increase, but the yield displacement and peak displacement of the corresponding structure decrease. When the height width ratio of the wall increases from 0.47 to 0.67, the peak displacement that the structure can bear decreases by about 9.0%, and the displacement corresponding to the peak load increases by 17.3%. When the height width ratio of the wall is about 0.55, the ductility of the structure is the best.

The thickness of the wall is an important parameter of the concrete infilled wall, which can significantly change the stiffness of the wall. Therefore, the influence of the concrete infilled wall on the performance of the concrete infilled wall frame is analyzed through the model of different wall thickness.

TABLE II. Characteristic load and ductility

NUMBER	WALL THICKNESS(MM)	YIELD LOAD	YIELD DISPLACEMENT	PEAK LOAD	PEAK DISPLACEMENT	ULTIMATE LOAD	LIMIT DISPLACEMENT	DUCTILITY COEFFICIENT
K1	100	935	4.9	1028	8.3	861.7	10.1	2.06
K2	150	1028	4.5	1107	6.3	922.5	7.7	1.71
K3	200	1253	5.1	1366	5.8	1152	8.2	1.62

It can be seen from table 2 that with the increase of wall thickness, the stiffness of the structure increases significantly, the yield point of the structure is delayed, and the bearing capacity of the structure is also improved. When the wall thickness increases to 150mm, the

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peak load of the structure increases by 8%, and when the wall thickness increases to 200mm, the peak load of the structure increases by 32%. When K5 displacement increases to 2.6mm, cracks appear at the bottom of the left frame column, resulting in the decline of bearing capacity. In addition, with the increase of wall thickness, the ductility of the structure decreases.

III. PUSHOVER ANALYSIS PRINCIPLE AND EQUIVALENT COMPRESSION BAR MODEL

Pushover (static elastoplastic) analysis method is an important part of structural performance-based seismic design theory and an analysis tool of performance-based seismic design. Pushover analysis method has good engineering practicability. It can reflect the elastic-plastic performance of the structure, obtain the deformation of the structure and understand the failure mechanism of the structure. This method is a structural analysis method widely used at home and abroad in recent years. This new method of seismic design and analysis based on structural performance considers not only the simplicity of calculation, but also the elastic-plastic properties of members.

"Performance" is sometimes called "behavior", which is the general term for the reaction of structures, components or systems under external action. Performance level refers to. The maximum damage degree or allowable failure limit of the designed building under the possible earthquake. Pushover analysis method (Pushover analysis method) is a method to apply monotonically increasing horizontal load to the structure according to a certain horizontal lateral force distribution mode, and gradually push the structural monitoring point to the target displacement to study the nonlinear performance of the structure, so as to judge whether the structure meets the requirements. In the process of lateral displacement caused by lateral force, the internal force and deformation of structural members can be calculated. By observing the change of structure, the failure state of structure and members can be obtained. Under strong earthquake, the current bearing capacity design method can not effectively evaluate the working performance of the structure in the elastic-plastic working state. Through pushover analysis, the elastic-plastic deformation of the structure and components can be estimated. Compared with the bearing capacity design results, the results are closer to the actual requirements. Compared with the time history analysis method, pushover analysis consumes less workload and time, and the analysis results are more stable, which can better reduce the contingency of the analysis results.

After the capacity curve and demand curve of the structure are established, it can be used to evaluate the seismic performance of the structure under the possible earthquake. Drawing the capacity spectrum curve and the demand spectrum curve corresponding to a performance level in the same coordinate system may occur in the following two cases.

(1) If there is no intersection between the demand spectrum curve and the capacity curve,

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that is, the capacity curve of the structure is located below the structural demand spectrum. It shows that the displacement response capacity of the structure during the earthquake is less than the displacement demand of the structure under the seismic fortification level. The structure can not bear the given seismic action, and the structural performance can not meet the requirements of the corresponding fortification level. The existing structure needs to be strengthened, the design scheme needs to be modified, and then re evaluated. (2) If there is an intersection between the demand spectrum curve and the capacity spectrum curve, this intersection is the performance point of the structure, which indicates that the deformation capacity of the structure is greater than the displacement demand of the structure under the seismic fortification level. When the structure bears the earthquake, the structure is in a safe state. Therefore, the structural performance meets the corresponding requirements.

In addition to judging whether the structure meets the corresponding requirements, we can also qualitatively evaluate the structural response characteristics and damage according to the position of the performance point on the capacity spectrum curve; In addition, by converting the value of spectral displacement into the displacement of the original structural monitoring point and viewing the state of the structure under the displacement of the monitoring point, the structural inter story displacement, plastic hinge distribution, floor displacement, curvature of rod end section and other information of the structure under the earthquake can be determined, and the seismic capacity of the structure can be comprehensively tested.

IV. PUSHOVER ANALYSIS OF CONCRETE FRAME INFILLED WALL STRUCTURE

In SAP2000, beam and column components are usually simplified into members represented by axes by frame elements, and the mass of beam and column is concentrated at the nodes at both ends, or the mass element matrix with uniform mass distribution is adopted. Floor and other components are often simulated by shell element in software. In this paper, frame element and shell element are used to establish the model.

When establishing the boundary conditions of the model, according to the current practice of structural calculation, the interaction between foundation and superstructure is not considered, and the column bottom of the first floor is regarded as consolidated with the ground. Therefore, the bottom support selected in the model is a fixed support. As the frame column adopts the cast-in-situ form, the overlapped beam and frame column are overlapped by reinforcement, the joint is cast-in-situ, the overlapped plate and overlapped beam are overlapped with the reinforcement at the upper part of the beam through overlapping reinforcement, and the cast-in-situ layer is cast completely, so the common joint of overlapped beam, overlapped plate and frame column is set as rigid connection. The boundary condition of middle laminated plate is fixed support on both sides and simple support on both sides. The boundary condition of edge laminated plate is fixed support on three sides and simple support on one side.

The constitutive relationship of masonry adopts the compression constitutive model of

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ordinary brick masonry proposed by LV Weirong and Shi Chuxian:

$$\frac{\sigma}{f_m} = 2.3\frac{\varepsilon}{\varepsilon_0} - 1.555\left(\frac{\varepsilon}{\varepsilon_0}\right)^2 + 0.195\left(\frac{\varepsilon}{\varepsilon_0}\right)^3 + 0.075\left(\frac{\varepsilon}{\varepsilon_0}\right)^4 - 0.015\left(\frac{\varepsilon}{\varepsilon_0}\right)^5 \quad (1)$$

Where, f_m - average value of axial compressive strength of masonry;

ε_0 - peak strain;

σ- Compressive stress of masonry;

ε- Compressive strain of masonry.

Through pushover analysis, the performance point results of the structure are shown in Table 3:

TABLE III. Pushover analysis performance points

FRAME TYPE	LOAD DISTRIBUTION	DEMAND SPECTRUM	DISPLACEMENT (MM)	BASE SHEAR (KN)
FRAME A	Evenly distributed load	Rare earthquake	81.275	5911.74
		Frequent Earthquake	15.66	1460
FRAME B		Rare earthquake	27.87	14279.31
		Frequent Earthquake	3.9	2938.94
FRAME C		Rare earthquake	52.35	9794.68
		Frequent Earthquake	9.26	2061.45
FRAME A	Inverted triangular distributed load	Rare earthquake	90.2	5526.57
		Frequent Earthquake	17.6	1329.74
FRAME B		Rare earthquake	31.96	13112.6
		Frequent Earthquake	4.98	2830.6
FRAME C		Rare earthquake	58.44	8872.3
		Frequent Earthquake	10.46	1870.33

It can be seen from the above results that different load distribution modes have an impact on the results of performance points. Compared with the inverted triangular load distribution, the displacement of the obtained performance point is smaller and the base shear is larger, that is, the stiffness of the structure is larger. Because the structural deformation caused by the inverted triangular load distribution mode is greater, the performance index adopts the inter story displacement angle. The following will be analyzed according to the results under the

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inverted triangular load distribution mode.

In addition, under rare earthquake, compared with pure frame (frame a), the displacement at the performance point of concrete infilled wall frame (frame B) decreases by 64.6%, the base shear increases by 137.3%, the displacement at the performance point of masonry infilled wall frame (frame C) decreases by 35.2%, and the base shear increases by 60.6%. It can be seen from the above that the masonry infilled wall can affect the stiffness of the frame structure and improve the overall bearing capacity of the structure, while the concrete infilled wall has a significantly higher impact on the frame structure than the masonry infilled wall.

Referring to the previous research data, the seismic performance level of frame infilled wall structure is divided into five levels:

(1) basically intact: the structure has basically no damage, the structure is in the fully elastic stage, and the structure can continue to be put into use without repair. (2) Minor damage: minor damage occurs to the main components of the structure and the surface of the infilled wall, and the structure can be put into normal use with only a small amount of repair. (3) Medium damage: the main components of the structure and the filled wall have been obviously damaged. The functional continuity and integrity of the structure can only be guaranteed after repair. The repair at this stage is acceptable economically and manually. (4) Serious damage: the structure has been greatly damaged, and the main components and filling walls of the structure have been seriously damaged. In order to make the structure continue to be put into use, the repair has exceeded the acceptable range in economy and manpower, so the building can only be demolished. (5) Structural collapse: when this level is reached, the structure has been destructively damaged, the use function of the structure has been completely lost, and the main structure has lost its bearing capacity.

V. CONCLUSION

With the development of prefabricated buildings, many changes have taken place in the construction mode of buildings. Concrete infilled wall is an internal wall form that can greatly improve the construction efficiency. At the component level of concrete infilled wall, the effects of different wall height width ratio, wall thickness and tie bar arrangement on the structure are considered in this paper. Based on the conclusion of finite element analysis, the equivalent compression bar model is modified, which lays a certain foundation for the calculation of concrete frame infilled wall structure. Then, based on the engineering example and the modified equivalent compression bar model, the pushover analysis of the concrete frame infilled wall structure is carried out, and the calculation method of the natural vibration period of the structure is proposed.

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