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Structural Safety and Seismic Evaluation of Steel Structure Design in Construction Engineering

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Abstract:

In this paper, according to the current national reliability evaluation standard of civil buildings, the safety detection and evaluation and seismic bearing capacity checking calculation of a pure steel frame structure building are carried out. Through calculation, the safety rating and seismic capacity level of the building are obtained. The results provide a certain reference for the detection, identification and seismic checking calculation of similar pure steel frame buildings. This paper also expounds the purpose and main contents of seismic performance evaluation of steel structures, and summarizes the failure characteristics of steel structures under earthquake. In this paper, it is proposed that the subsequent service life and seismic fortification category of existing steel structures should be determined in the seismic appraisal. This civilization determines the basic fortification intensity and seismic acceleration in this area, as well as the structural system and component layout. Finally, this paper constructs the identification technology related to the checking calculation of connection and seismic bearing capacity..

***Keywords**: Reliability, Pure Steel Frame Structure, Safety Inspection and Appraisal, Checking Calculation of Seismic Bearing Capacity.*

I. INTRODUCTION

In China, the development and application of steel structure housing system is still in the primary stage. Since the 1950s, China's steel structure has ushered in the preliminary development [1-2]. There is still a big gap between multi-storey and high-rise civil steel structure housing, and there is still a great room for progress compared with developed countries [3]. Since the end of the eighties and nineties of the 20th century, China's steel structure has rapidly entered the stage of development, and multi-storey civil steel structure housing has gradually begun to appear [4]. At the beginning of the 21st century, dozens of steel structure housing scientific research projects passed the review of the Ministry of construction, and the first steel structure housing industrialization in Beijing was finally determined, thus forming a science and technology demonstration project [5-6]. Since then, a large number of pilot projects of steel structure housing have been completed in an endless stream. In addition, some large state-owned enterprises and emerging private enterprises have begun to set foot in the research and development of steel structure industry. National construction departments and major colleges and universities, such as the Ministry of construction, Tongji University and Tianjin University, have laid a solid theoretical analysis and research

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foundation, making the steel structure residence better applied in practice [7]. Of course, it is also inseparable from the active promotion of the national construction and scientific and Technological Development Department. The China Steel Structure Housing Association, established for the development of domestic steel structure, came into being under the active promotion of the Ministry of construction. All parts of the country have also invested their best efforts to constantly explore their development ways, held various seminars, and put into practice to build some experimental houses.

II. THEORY AND METHOD OF SEISMIC DESIGN OF MULTISTORY STEEL STRUCTURES

2.1 Design principles and basic requirements

The probability limit design method is adopted in the structural design, and the partial coefficient design expression is used for calculation. Like other building structures, the limit design states of steel structures are divided into two categories: bearing capacity limit design state and normal use limit design state. The bearing capacity limit state refers to the maximum bearing capacity of the structure or member or the deformation that is not suitable for continuous bearing, including the strength failure, fatigue failure of the member and connection, the member of the structure loses stability, the structure becomes a mobile system and the structure overturns, etc. Serviceability limit state refers to a specified limit value for the normal use or durability of structures or components, including deformation affecting the normal use or appearance of structures, components and non structural components, vibration affecting normal use, local damage affecting normal use or durability, etc. [8-10].

The calculation model and basic assumptions of the structure shall be consistent with the actual performance of the member connection as far as possible. The internal force of multi-storey steel structure is generally analyzed by static method, and the member section is allowed to develop plastic deformation. Plastic analysis can be used for fixed end beams, continuous beams and single-layer and two-layer frames composed of solid web members that do not directly bear dynamic loads. In the frame structure, the rigid connection between beam and column shall comply with the assumption that the included angle of beam and column remains unchanged during the stress process, and the connection shall have sufficient strength to bear all the most unfavorable internal forces transmitted by the end of the converging member. When the beam and column are hinged, the connection shall have sufficient rotation capacity to effectively transfer shear and axial force. In semi-rigid connection, the moment rotation relationship of the connection must be determined in advance.

The internal force analysis of frame structure should also comply with the following provisions:

$$H_{ni} = \frac{\alpha_y Q_i}{250} \sqrt{0.2 + \frac{1}{n_s}} \tag{1}$$

For the pure frame structure without support, when the second-order elastic analysis is adopted, the bending moment M_{II} at the end of each member can be approximately calculated by the following formula:

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$$M_{II} = M_{Ib} + \alpha_{2i} M_{Is} \tag{2}$$

$$\alpha_{2i} = \frac{1}{1 - \frac{\sum N \cdot \Delta u}{\sum H \cdot h}} \tag{3}$$

A sudden natural disaster that endangers human life and property during an earthquake. China has a vast earthquake area with frequent and strong earthquakes. In the 20th century alone, there were nearly 70 earthquakes with magnitude greater than or equal to 7, including 9 strong earthquakes with magnitude greater than or equal to 8. In recent years, Wenchuan earthquake and Yushu earthquake in Qinghai have also caused heavy losses to the country. With the understanding of earthquake and structural dynamic performance, the seismic theory of engineering structures has developed rapidly. When an earthquake occurs, the ground motion is generated due to the action of seismic wave, and the superstructure vibrates through the foundation. The inertial force generated by house vibration is the earthquake action. There are two kinds of seismic action: horizontal action and vertical action. However, the damage of general houses is mainly caused by horizontal seismic action. If they are far from the epicenter, the vertical vibration is small, and the safety reserve of houses against vertical force is large. Therefore, horizontal seismic action is mainly considered in the design.

(1) Fortification intensity. Seismic intensity refers to the intensity of earthquake vibration at a certain place, which can also be understood as the intensity of seismic field. Due to the great randomness of earthquakes, they can be divided into basic intensity (10%), frequent intensity (63%) and rare intensity (2%) according to the occurrence probability within the 50 year design reference period. (2) Building seismic fortification objectives and design methods. The seismic code GB50011 adopts the "three levels" seismic fortification target of buildings: the first level: when suffering from frequent earthquake intensity lower than the seismic fortification intensity in the region, it can still be used without damage or repair; The second level: when it suffers from a certain degree of damage equivalent to the seismic fortification intensity (basic seismic intensity) of the region, it can still be used without repair or after general repair; The third level: when suffering from the pre estimated rare earthquake intensity higher than the seismic fortification intensity in the region, it should not collapse or cause serious damage to personal safety.

In principle, the seismic design should meet the three-level seismic fortification target. In the specific practice, for the sake of simplification, the seismic code adopts the "two-stage" design method. Design in the first stage: check the bearing capacity of structural members and the elastic deformation of the structure under the action of small earthquake according to the basic combination of small (frequent) earthquake action effect and other load effects, so as to meet the seismic fortification target requirements of the first level. The second stage design: check and calculate the elastic-plastic deformation of the structure under the action of large (rare) earthquake, so as to avoid the third level seismic fortification target requirements. As for the seismic fortification target requirements of the second level, the seismic

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code is guaranteed by seismic structural measures.

2.2 Analysis method of structural seismic design

The response spectrum method is based on the response of single mass point elastic system in the actual earthquake process to analyze the structural response. According to this theory, the response of buildings can be calculated according to the actual ground motion by using the seismic spectrum curve. The so-called response spectrum curve is the functional relationship between the maximum response of the elastic system of a single mass point to the actual ground motion and the natural vibration period of the system.

In general, to describe the movement of the structure in a certain direction, only the corresponding vibration modes of the inherent n natural vibration cycles of the structure need to be understood in advance. The seismic response of any point of the structure is the linear combination of the seismic response of n equivalent single degree of freedom systems and the corresponding vibration modes, which is the concept of mode decomposition. The natural vibration period and vibration mode of the structure are the natural characteristics of the structure when it is not subjected to any external force (called free vibration). Concentrate the representative value of gravity load on the floor or particle, and the frequency equation corresponding to free vibration can be written as:

$$-\omega^2\left[m\right]+\left[k\right]=0 \tag{4}$$

The calculation formula of seismic action standard value of each order of vibration mode is as follows:

$$F_{ji}=\alpha_j\gamma_j X_{ji}G \tag{5}$$

$$\gamma_j=\sum X_{ji}G_i/\sum X_{ji}^2G_i \tag{6}$$

After determining the standard value of horizontal seismic action of each vibration mode, the seismic action effect Sj (bending moment, shear force, axial force, displacement, deformation, etc.) corresponding to each vibration mode can be obtained by elastic mechanics method, and then combined according to the square sum square root method (SRSS) to obtain the calculated value s of seismic action effect:

$$S=\sqrt{\sum_{j=1}^{m}S_j^2} \tag{7}$$

In addition, corrosion is also one of the main factors affecting the structural strength. Chloride ion corrosion is the main reason for the reliability reduction of steel structure anti-corrosion coating. The chloride in the deicing salt used in winter will penetrate the concrete slab, reach the top layer of the

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reinforcement and accumulate to the critical concentration, that is, the "chloride threshold level" at which the reinforcement begins to corrode. In the pore water solution of high alkaline concrete, the surface of reinforcement is protected by a passive iron oxide film. Chloride will cause the dissolution of iron oxide layer, which will lead to the dissolution of steel. Therefore, once the passivated iron oxide film is destroyed by chloride ion, the chloride ion concentration on the surface of reinforcement under natural conditions will activate the electrochemical reaction producing corrosion products. Corrosion products absorb water, greatly increase the volume, and produce stress on the surrounding steel members, resulting in cracking, delamination and spalling of steel members and loss of bond between reinforcement and concrete. Finally, it may lead to the failure of concrete structure due to the reduction of bonding force and strength, which seriously threatens the safety of construction.

III. ESTABLISHMENT OF STRUCTURAL FINITE ELEMENT MODEL AND ANALYSIS OF DYNAMIC CHARACTERISTICS

3.1 Structural finite element modeling

SAP2000 finite element program is developed from sap (structure analysis program) series programs founded by Edwards Wilson, and many versions have been published so far. It is a general structural analysis and design software, which is widely used all over the world. SAP2000 program is different from other general structural finite element programs in that its powerful analysis function. Many different types of analysis are used in SAP2000, which basically integrates the methods often encountered in the existing structural analysis, such as time history analysis, ground motion input, dynamic analysis, push over analysis and so on. In addition, it also includes static analysis, modal analysis of vibration mode with eigenvector or Ritz vector, response spectrum analysis of seismic response and so on. These different types of analysis can be carried out in the same run of the program, and the results are synthesized and output.

SAP2000 establishes the model in a completely empty way, which is flexible, fast and intuitive. The integrated operation interface greatly simplifies the specific operation steps of the modeling process. For the operation of objects, the model is completely graphical and spatial, and the modeling process is simplified into an intuitive graphic drawing process. Using SAP2000 finite element analysis modeling is mainly divided into three steps: model establishment, model analysis and model design.

The finite element modeling assumes that: (1) the connection of structural beam and column joints is considered as rigid connection, and the column and foundation are fixed; (2) Ignoring the torsion and axial deformation of the member itself; (3) The mass is approximately concentrated to the plane of each floor in the structural dynamic calculation. (4) Based on the assumption of infinite stiffness in the floor plane, the floor is calculated as a rigid floor, and each frame column has the same horizontal displacement at the same floor height.

Because the primary stiffness is the sum of the primary stiffness of lead rubber bearing and the horizontal stiffness of natural rubber bearing. The primary stiffness of lead rubber bearing is much larger than that of natural rubber bearing with the same diameter. Taking RB500 and LRB500 as examples, the horizontal stiffness of RB500 is 0.760 kN/mm, while the horizontal stiffness of LRB500 before yield is

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10.075 kN / mm, which is as much as 12 times. The secondary stiffness of the isolation layer is the sum of the secondary stiffness of the lead rubber bearing and the horizontal stiffness of the natural rubber bearing. After the lead core yields, it does not provide horizontal stiffness, which is equivalent to that only the natural rubber bearing provides horizontal stiffness. The horizontal stiffness of rubber bearings with the same diameter is basically the same, so the secondary stiffness is basically the same

Although normalized seismic waves are used, the seismic response of structures is still closely related to the type and intensity of seismic waves. In order to accurately explain the seismic response characteristics of the structure and avoid too large dispersion of the time history analysis results, the data processing adopts the method of calculating the mean value of six waves, and the seismic wave intensity adopts 8.5 degree frequent and rare. The evaluation principle of the parameters of the isolation layer: the displacement of the isolation layer in case of double control large earthquake and the shear force of the isolation layer in case of small earthquake.

3.2 Dynamic characteristic analysis of structure

Natural frequency and vibration mode are the dynamic characteristics of the structure itself. In fact, important parameters in structural design reflect the dynamic response of the structure under dynamic load. At the same time, if we want to solve other dynamic problems, we must first analyze the structural dynamic characteristics. Therefore, in this paper, the modal analysis of the structure is carried out by using SAP2000 finite element software, so as to obtain the natural vibration period, natural vibration frequency and vibration mode of pure steel frame structure and steel frame structure with infilled wall (see Table 1 and table 2).

TABLE I. Natural vibration period of structure (s)

Structural system	**First cycle**	**Second cycle**	**Third cycle**	**Fourth cycle**	**Fifth cycle**
Pure frame structure	1.48	1.09	0.92	0.49	0.35
Frame structure with infilled wall	0.92	0.64	0.48	0.29	0.16
Structural system	Sixth cycle	Seventh cycle	Eighth cycle	Ninth cycle	Tenth cycle
Pure frame structure	0.3	0.29	0.22	0.2	0.18
Frame structure with infilled wall	0.13	0.1	0.1	0.1	0.1

TABLE II. Natural frequency of structure (Hz)

Structural system	**First frequency**	**Second frequency**	**Third frequency**	**Fourth frequency**	**Fifth frequency**
Pure frame structure	0.67	0.92	1.09	2.02	2.82

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Frame structure with infilled wall	1.09	1.57	2.1	3.44	6.28
Structural system	Sixth frequency	Seventh frequency	Eighth frequency	Ninth frequency	Tenth frequency
Pure frame structure	3.35	3.44	4.59	4.9	5.65
Frame structure with infilled wall	7.43	9.61	9.76	9.87	10.09

Through the comparative analysis of the natural vibration period of the structure obtained from the analysis, it can be seen that the natural vibration period of pure steel frame structure is larger and that of steel frame structure with infilled wall is smaller. It fully shows that the infilled wall makes a great contribution to the stiffness of the whole structure and improves the stiffness of the whole steel pivot frame structure.

IV. CONCLUSION

This paper briefly introduces the development of steel frame structure with infilled wall, the application of steel frame structure with infilled wall, the research status and development trend of steel frame structure with infilled wall at home and abroad. This paper analyzes the influence of infilled wall on infilled wall frame structure, expounds the synergistic mechanism of infilled wall and frame structure, and some seismic advantages and disadvantages of infilled wall under earthquake. The infilled wall and the frame restrict each other. At the same time, the infilled wall also supports the frame structure. In this paper, the finite element models of multi-storey pure frame structure and steel frame with infilled wall are established by using SAP2000 finite element software, and the structural dynamic characteristics and dynamic response are analyzed respectively.

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