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Research on Optimization of Concrete Structural Design and Analysis of Seismic Performance of High-rise Housing Buildings

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Abstract The concrete structural design effect of shear wall plays a supporting role in the safety of high-rise houses. In this paper, the shear wall assembly model of high-rise housing building is constructed, and the structural arrangement of the model is adjusted to optimize the design of shear wall force through trial calculation analysis. The time course analysis method is introduced to review the design results of the shear wall structure. Seismic tests are conducted on the house structure by selecting seismic waves. Evaluate the response performance of shear walls under earthquakes by means of seismic pattern decomposition reaction spectrum method and static elastic-plastic analysis, and backward optimize the design of concrete structure. The changes in structural performance of the reinforcement measures proposed in the model can be accurately calculated using the 2 methods, seismic pattern decomposition response spectrum method and static elasto-plastic analysis method. The optimization of structural reinforcement resulted in a 42.5% reduction in maximum horizontal displacement, a 42.0% reduction in maximum inter-story displacement, a 25.8% reduction in maximum deflection angle, a 13.1% increase in maximum nodal shear force, and a 29.5% increase in maximum bending moment.

Index Terms shear wall assembly model, seismic performance, concrete structure, time-course analysis, seismic decomposition reaction spectrum, static elasto-plasticity

I. Introduction

With the rapid development of the economy, the number of urban population steadily increasing, in the context of the continuous scarcity of urban resources, urban construction land is becoming less and less, the resulting land problems make the housing construction in the city shows the characteristics of high density and high volume, high-rise housing construction has become inevitable [1]-[3]. Excessive volume rate, away from the ground, insufficient security and so on have become the reality of high-rise buildings faced with problems, such as structural stability and seismic performance, but also become a barrier to the quality of life of the residents to improve the quality of several major difficulties [4]-[6].

Compared with ordinary buildings, high-rise buildings have some special challenges in terms of loads and environmental impacts in the design of their concrete structures. First, wind load is also one of the common and important loads in high-rise buildings, especially in cities with high regional wind speeds, which may become a key factor affecting the structural design [7], [8]. Secondly, seismic load is also an important factor that must be considered in the design of high-rise buildings, due to the differences in high-rise buildings with the degree of planar and vertical regularity, structural system, height and other differences in the complexity and intensity of the role of seismic forces, and the current finite element computational model of the plastic hinge of shear wall simulation error is too large, resulting in seismic design of seismic loads is unreasonable [9]-[12].

However, the concrete used in the actual project is more fragile (C60 or above), and the seismic design requirements are contrary to each other [13]. However, the current code categorizes high-rise buildings of different structural forms, and there are stricter code requirements for buildings of higher heights, but there is not much consideration of situations such as displacement in seismic design. In addition, in the design of concrete structure of high-rise buildings, due to the relatively large self-weight and inertia load of high-rise buildings, especially in the lateral deformation and vertical deformation of high-rise buildings, the deformation control of the structure has become one of the focuses and difficulties of the design, and there is a tendency for the stability of the reinforced concrete structure to attenuate under the motion load [14]-[17]. Therefore, in the design of concrete structures for high-rise buildings, the constraints of material properties, technology, and codes are waiting to be solved.

This paper focuses on the structural safety improvement of shear walls in high-rise housing buildings. An assembly model based on the standard floor plan of a high-rise house is established by computer, and the initial model structure is adjusted to meet the actual computational optimization requirements. The calculation results of reaction spectrum and inelastic phase are examined by using time course analysis. In order to improve the seismic performance of shear walls, specific seismic waves are selected to simulate seismic tests on the building structure. The seismic pattern decomposition reaction spectrum method is used to simplify the calculation of the bearing level of the structure in multiple-occurrence earthquakes, and combined with the static elastic-plastic analysis method to polarize the force of the structure in rare earthquakes, and to judge the optimization direction of the design of shear walls from the overall and component deformation level.

II. Analysis of optimization methods for concrete structures in high-rise buildings

II. A. Optimized Design Parameters for Shear Walls in High-Rise Housing Buildings

In the structural design of high-rise housing buildings, according to the height of the building structure, structural form and geological conditions to implement the corresponding design optimization processing mode, compared with the traditional shear wall monolithic design program, in the optimization process, we should comprehensively analyze the specific conditions of the site to determine the actual number of shear walls, to avoid blindly adding shear walls to aggravate the building's deadweight and cost, so as to better achieve the economic and safe design purposes. Design purpose. First, comprehensive analysis of the characteristics of the building structure, and the seismic force distribution law of the construction area to be systematic assessment, to ensure that the location and direction of the shear wall design is more reasonable, pay full attention to the use of high-rise housing buildings functional, spatial layout requirements and other factors, not only for the occupants to provide a livable space, but also to meet the high-rise building structural safety requirements, to improve the comprehensive use of the building's functionality.

Second, the shear wall parameters in the shear weight ratio, span to height ratio for centralized management, to ensure that the relevant parameters set normative, and better maintain the horizontal load environment of the shear wall structure of the bearing capacity, deformation capacity, the designers should be in accordance with the specific needs of high-rise housing building structural design, the use of standardized calculations and experimental verification of the processing mechanism, to better improve the level of application of the shear wall.

Third, the preferred material and strength, according to the actual needs of the project, and systematic analysis of the overall high-rise building structure cost budget information, select the appropriate wall materials, not only to optimize the level of material configuration, but also to provide protection for structural safety control and balanced economic development, and to achieve the goal of unified management.

Fourth, the process of optimization parameters can be properly implemented computer-aided design software, play the advantages of technology application, better design parameters to be refined processing, to ensure that the level of optimization and control to meet the design requirements, and with the finite element analysis and structural optimization algorithms processing link, better shear wall structure of the specific design of the content of the launch of the refinement of the processing, so as to accurately determine the shear wall geometric dimensions in the optimal material Configuration environment to improve the design efficiency and maintain the accuracy of the overall building structure shear wall.

Fifth, the seismic parameters of the shear wall should be optimized, based on a comprehensive analysis of the relevant elements and operating environment, to ensure that the design processing effect meets expectations. Take the design content of short limb shear wall as an example, in the structural design of high-rise housing buildings, it is not appropriate to take a wide range of short limb shear wall structure, if the number of walls is large, then the arrangement of the cylinder, so as to form the shear wall and cylinder parallel resistance to the horizontal force of the shear wall structural system, which is better suited to the actual environment. In order to ensure that the parameters of the number of shear walls meet the requirements, in the seismic design link, the first vibration mode of the cylinder and general shear wall is set as the bottom seismic overturning moment is higher than the total bottom seismic overturning moment of the structure by more than 55%, and the structure concentrates on the improvement of the ductility of the short-limbed shear wall.

II. B. Calculation of shear wall structural models

II. B. 1) Model Trial Analysis

According to the building conditions, the shear wall arrangement is carried out, trying to make the shear wall arrangement scientific and reasonable, uniform in plane and continuous in vertical direction. The initial structural model is assembled on the basis of the standard floor plan of the building, and the height and number of floors of the building are assembled through the calculation software, and the loads are input or imported accurately, and we try to find out the axial compression ratio of the wall limbs quickly, make adjustments, and try our best to make the value of axial compression ratio of the wall limbs close to the normative limit value, and estimate the thickness of the shear wall first, and adjust the length, thickness, and concrete grade of the shear wall through the output of the axial compression ratio and make adjustments to the initial structural model one by one and check and compare it with the conditions of each floor of the building. The initial model of the structure is adjusted and checked and compared with the plan conditions of each floor of the building one by one. Modify the connection methods of other components except the shear wall to make the structural model as close as possible to the actual stress conditions. After that, the model was subjected to detailed calculations, and the model was optimized according to the values of deformation, period, displacement, etc. in the output results.

II. B. 2) Model adjustments

Preliminary structural arrangement program model trial calculation, such as inter-story displacement does not meet the specification requirements, you can view the displacement file to find the specific structural nodes of the overrun, if the local stiffness is weak, through the increase in the length of shear walls or increase the thickness of the wall can be resolved. If the cycle ratio of torsion and code conflict, you can view the barrel center structure arrangement, additional holes, reduce the connecting beam to solve; or you can increase the number of peripheral shear walls to reduce the torsion effect; or you can compare the results of the calculation of the spatial vibration to find out unreasonable nodes, appropriate structural strengthening.

II. C. Time course analysis

Time-course analysis is a method for solving the vibration response of a structure based on the integration of the basic equations of motion along the time course. It is often used as a supplementary calculation method for calculating the structure of high-rise buildings. The code states that it is appropriate to use this method for review of complex, Class A buildings and buildings with heights exceeding a certain range.

1) Main function:

To check the calculation results of the code reaction spectrum and make up for its deficiencies; to calculate the seismic response of the inelastic phase of the structure; to calculate the structural seismic response (internal force and deformation) at each moment; to find the weak parts more accurately and to carry out seismic-resistant structural measures.

2) Selection of seismic wave

Select the seismic wave that meets the site characteristics for time-range analysis. The basic process includes: determining the basic parameters of the structure; determining the main parameters such as the seismic intensity, seismic grouping and site category of the project; determining the target response spectrum; determining the other parameters that need to be met by seismic waves according to the specification (number, seismic influence coefficient, base shear ratio, etc.); and selecting the qualified seismic waves.

The selected number of seismic waves, according to the specification requirements, the general elastic time course and large earthquake elastic-plastic time course analysis were selected 8 and 4 waves respectively, of which the number of natural waves should be more than 3/4 of the total number.

II. C. 1) Theory of reaction spectrum analysis

The basic method for calculating seismic forces is the mode decomposition reaction spectrum method, which is commonly used as a structural dynamic analysis method to evaluate the response of structures under seismic loading. The method is based on the theory of vibration mode analysis and response spectrum, and couples the vibration mode of the structure with the response spectrum of the earthquake in order to obtain the dynamic response of the structure under seismic action. For the equations of motion of a multi-mass system under horizontal seismic action, it can be expressed as:

$$M_u + C_u + K_u = P_0 \tag{1}$$

where M is the mass matrix, which describes the mass distribution of the system; C is the damping matrix, which takes into account the damping characteristics of the system; K is the stiffness matrix, which describes the stiffness characteristics of the system; u is the displacement vector, which denotes the displacement of each mass; u is the second-order time derivative of the displacement vector, which denotes the acceleration of each mass; and P is the external force vector under the action of earthquake. In order to utilize the principles of mode decomposition and mode quadrature, assuming that the mode and the intrinsic frequency of the system are known, the displacement vector can be expressed as a linear combination of the mode vectors:

$$u = \sum_{i=1}^{n} a_i \varphi_i \tag{2}$$

where a_i is the coefficient of the vibration mode vector, which represents the amplitude of the i th vibration mode, and φ_i is the vibration mode vector, which represents the i th vibration mode. Substituting the above expressions for the displacement vectors into the equations of motion and using the property of orthogonality of the vibrational modes, one obtains:

$$\sum_{i=1}^{n} (M\ddot{\varphi}_i + K\varphi_i)a_i = P - C_i \tag{3}$$

Since the vibration vectors are orthogonal, the above equation can be decomposed into multiple independent equations of motion for an equivalent single-degree-of-freedom system:

$$M_i\ddot{\varphi}_i + K_i\varphi_i = P_i - C_i\dot{a}_i \tag{4}$$

where M_i is the mass matrix corresponding to the vibration vector φ_i; K_i is the stiffness matrix corresponding to the vibration vector φ_i; P_i is the external force vector under seismic action corresponding to the vibration mode vector φ_i; C_i is the damping matrix corresponding to the vibration vector φ_i; φ_i is the first-order time derivative of the coefficients a_i of the vibration vector.

Solving the above equations of motion for independent equivalent single-degree-of-freedom systems, the action effects corresponding to each vibration mode, i.e., the maximum seismic response for each vibration mode, can be obtained. By combining the maximum seismic responses of all the vibration modes, the seismic response of the whole multi-mass system can be obtained. Through the vibration mode decomposition response spectrum method, the seismic response calculation of the multi-mass system can be effectively simplified by decomposing it into independent single-degree-of-freedom systems, thus simplifying the solution process. Meanwhile, since the vibration mode is solved based on the intrinsic properties of the structure, the response of the structure under seismic action can be evaluated more accurately.

II. C. 2) Static elasto-plastic analysis

The static elasto-plastic analysis method is mainly aimed at analyzing the response of the structure under rare earthquakes, which is also known as the pushover method, and analyzes the response of the member when it enters the elastic-plastic state and reaches the ultimate capacity. Static elastic-plastic analysis is used when the height of the structure is h⩾200m or 200m⩽h⩽250m and the structural characteristics allow it.

Figure 1 shows the specific form of the floor pushover method. A lateral force is applied in the direction along the height of the structure, followed by gradual loading until overturning or the performance point is reached. The performance point is found by using the load-displacement curve in combination with the reaction spectrum to find the intersection of the two lines (corresponding to the capacity spectrum curve and the demand spectrum curve).

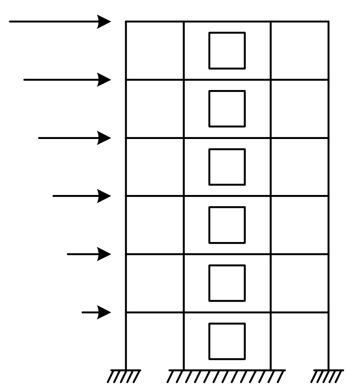

Figure 1: Forms of floor pushing force

Figure 2 shows the process of converting the reaction spectrum into a demand spectrum. Static elasto-plasticity is analyzed by equating the structure to a single-degree-of-freedom system, and two assumptions are made about the structure when performing the calculations: 1) The seismic response of the structure is related to the reflection of a certain equivalent single-degree-of-freedom system, and 2) The shape vectors along the height direction of the structure, which are assumed by the analysis, are kept constant throughout the seismic process.

During the analysis, the curves of the demand spectra are obtained by transforming the response spectra through Eqs. (5) and (6):

$$S_a = \alpha(T,\zeta)\cdot g \tag{5}$$

$$S_d = \frac{T^2}{4\pi^2}S_a \tag{6}$$

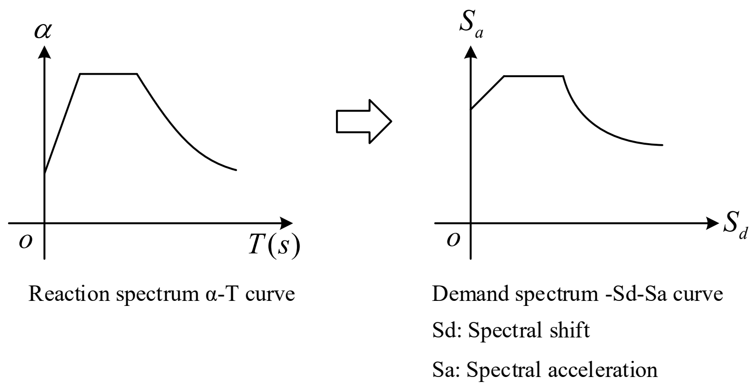

Figure 2: Reaction spectrum conversion requirement spectrum

Figure 3 illustrates the conversion of the shear-displacement curves into capacity spectra. The curves of the capacity spectrum are obtained by converting the reaction spectrum through Eqs. (7) and (8):

$$S_a = \frac{V_{base}}{M\alpha_K} \tag{7}$$

where, V : base shear force, α_K : mass participation factor for the "first" mode of vibration in the pushover direction.

$$S_d = \frac{u_{roof}}{\gamma_1\varphi_{roof,1}} \tag{8}$$

where, u : Displacement from overturning calculation, γ : Participation factor of vibration mode, Φ : vibration mode component at the corresponding u .

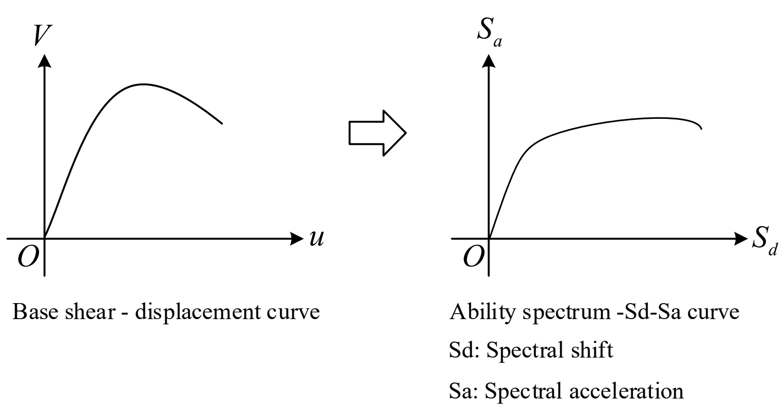

Figure 3: Shear - Displacement curve conversion capacity spectrum

The nonlinear energy dissipation form of the structure is demonstrated in Figure 4. As the structure enters the elastic-plastic phase, the structure generates nonlinear energy dissipation, and then the demand spectrum needs to be discounted. The discounting method is to equate the nonlinear energy dissipation into damping energy dissipation, and then utilize the equivalent damping for the discounting of the elastic response spectrum. The discounting of the demand spectrum is first calculated according to equation (9):

$$\xi_{add} = \frac{E_d}{4\pi E_s} \tag{9}$$

where, E_d : nonlinear hysteretic dissipation energy, E_s : maximum strain energy

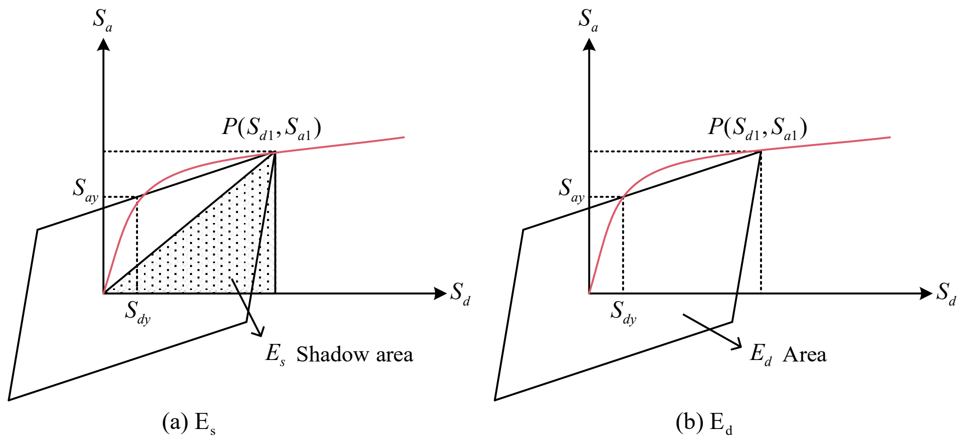

Figure 4: Nonlinear energy consumption of the structure

The additional damping ratio obtained through the above equation should be in the range of 25% to 50%, corrected by Eq. (10) to reflect the effect of the newness of the structure and the long distance from the epicenter.

$$\xi_{eff} = k\xi_{add} + 6\% \tag{10}$$

where, ξ_{eff} : full equivalent damping of the structure, k : energy dissipation correction factor for hysteretic damping, 6%: inherent damping and additional damping.

The result of the above equation is brought into the following equation to obtain the response spectrum discount factor:

$$S_{Ra} = \frac{4 - 20 - 0.69\ln\xi_{eff}}{2.14} \tag{11}$$

$$S_{Rv} = \frac{2.30 - 0.45\ln\xi_{eff}}{1-66} \tag{12}$$

where, S_{Ra} : constant acceleration region discount factor, S_{Rv} : constant velocity region discount factor.

Finally, a performance point is assumed, and the intersection of the demand spectrum and the capability spectrum is taken, and then the intersection point and the assumed point are detected according to certain conditions, and if the conditions are satisfied, the point is taken as the performance to meet the requirements, and if they are not satisfied, the calculation is recalculated.

After the calculation is completed, the results of the static elastic-plastic analysis are evaluated in two aspects: 1) the overall deformation; 2) the damage sequence of the members and the development state of the plastic hinges.

III. Practice of optimization of shear wall structure and seismic resistance of high-rise housing buildings

In order to verify the optimization effect of the method in this paper, a provincial landmark building is selected as the research object to construct a high-rise house building model. The landmark building in this province is as high as 45 floors and has high requirements for shear wall structure. The specific seismic wave types in the province are selected to simulate the vibration patterns that may be encountered, and the model is tested in relation to multiple and rare earthquakes.

III. A. Calculation and Analysis of Multi-Event Seismic Response Spectrum Method

The reaction spectrum method not only considers the dynamic response of the structure under seismic action during the multi-occurrence earthquake calculation, but also assumes a rigid floor slab for the whole building during the calculation and analysis process, which further improves the accuracy of the analysis. Under seismic action, the stiffness discount factor of the connecting beam is set to 0.65, and the stiffness amplification factor of the center beam is determined by the calculation software. The wind load was calculated using the specified basic wind pressure, which was multiplied by a factor of 1.0 in the load carrying capacity design to ensure the accuracy and reliability of the analysis results. The main calculation results include such indicators as the period and stiffness of the structure. These indicators can be used to assess the stability and durability of the structure, and also provide a reference basis for the optimal design and reinforcement of the structure. The following are the main calculation results:

III. A. 1) Periodicity

Table 1 shows the calculation results of the first 8 orders of vibration characteristics of the shear wall structure. According to the calculation results, the total participating mass coefficients of the advective vibration in the X and Y directions are more than 95%. The first two vibration modes mainly correspond to the translational vibration mode, the 1st vibration mode is mainly in the X direction and the 2nd vibration mode is mainly in the Y direction. The 3rd vibration mode is a torsional vibration mode. In addition, the ratio of the 1st torsional period to the 1st translational period is 0.93. It can be seen that the first 8 order vibration modes calculated by the building structure modeling software YJK and the vibration decomposition reaction spectrum method MDRSM are very close to each other, and at the same time, they satisfy the requirements of the code for seismic design of high-rise housing buildings.

Table 1: Calculation results of the first 8 vibration mode characteristics

Vibration mode	Cycle		Vibration mode quality participation coefficient						Cycle ratio	
			X-direction torsion		Y-direction torsion		Z-direction torsion			
	YJK	MDRSM	YJK	MDRSM	YJK	MDRSM	YJK	MDRSM	YJK	MDRSM
1	4.13	4.11	0.98	0.97	0.04	0.05	0.02	0.05	0.91	0.93
2	3.84	4.05	0.03	0.07	0.98	0.97	0.06	0.08		
3	3.52	3.84	0.03	0.08	0.07	0.09	0.99	0.98		
4	1.25	1.37	0.95	0.51	0.04	0.08	0.11	0.52		
5	1.18	1.32	0.13	0.73	0.06	0.05	0.94	0.35		
6	1.11	1.25	0.03	0.07	0.99	0.97	0.04	0.06		
7	0.74	0.82	0.07	0.11	0.04	0.07	0.93	0.96		
8	0.65	0.71	0.94	0.96	0.04	0.05	0.06	0.04		

III. A. 2) Stiffness ratio

The technical requirements for concrete structures in high-rise buildings require that the ratio of lateral stiffness between a floor and its adjacent upper storey should not be less than 0.950, but when the height of the first storey is greater than 1.100 times the height of the adjacent upper storey, the value of this ratio should not be less than 1.200. In addition, the ratio of the bottom embedded layer should be not less than 1.450. Figure 5 shows the lateral stiffness ratio of adjacent layers in the X direction. YJK calculates the X-direction stiffness ratio as 1.311 and MDRSM calculates the X-direction stiffness ratio as 1.923, both of which are greater than the requirement of 1.200. Figure 6 shows the lateral stiffness ratios of adjacent layers in the Y-direction. the Y-direction stiffness ratio calculated by YJK is 1.742 and the Y-direction stiffness ratio calculated by MDRSM is 1.154, which is also greater than 1.200. Meanwhile, the bottom embedded layer ratio in both directions is 1.650, which is higher than 1.450. According to the analysis results, the lateral stiffness ratio between the floor and its adjacent upper floor in the optimized design works of this model satisfies the relevant code requirements.

III. A. 3) Elastic time-course analysis of multiple-occurrence earthquakes

In multiple-occurrence seismic elasticity analysis, multiple analyses are usually required, with different seismic waves selected for each analysis and the interaction of seismic waves considered. The purpose of this analysis method is to determine the response of the concrete structure of the shear wall of a high-rise housing building under the action of different seismic waves, so that it can be optimally designed and improved to ensure its stability and integrity during an earthquake. It is an important part of the structural design of a building that helps the designer to determine the strength and stiffness of the structure and to improve the seismic performance of the building.

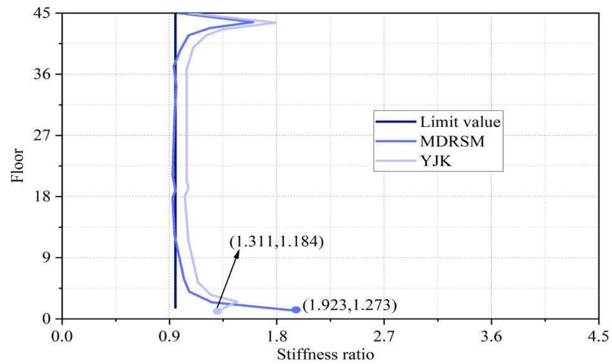

Figure 5: Lateral stiffness ratio of adjacent layers in the X direction

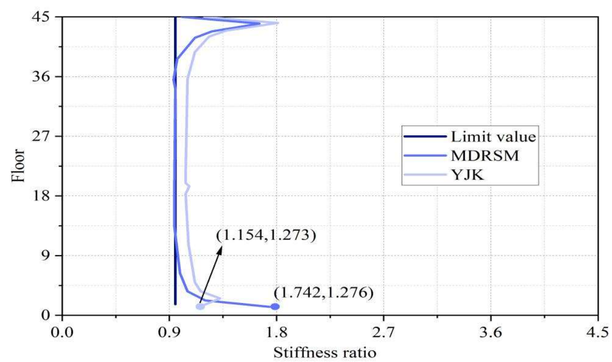

Figure 6: Lateral stiffness ratio of adjacent layers in the Y direction

In this paper, 2 waves are selected based on the field and soil conditions of the building: natural and artificial waves. Figure 7 shows the comparison between the normative spectrum and the response spectrum of seismic waves. The maximum acceleration of the normative wave is 0.107m/s², while the acceleration of the natural wave and the artificial wave is 0.212m/s² and 0.110m/s², respectively.The acceleration difference of the selected two waves is large, which can understand the response of the concrete structure of the shear wall of the high-rise housing building under the action of different seismic waves through the experiment.

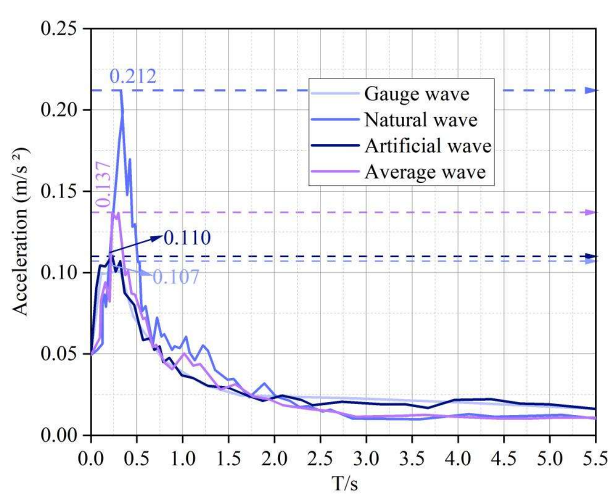

Figure 7: Comparison of gauge spectrum and response spectrum of seismic waves

III. B. Static elastic computational analysis for rare earthquakes

The building structure analysis software YJK and the static elastic-plastic analysis method PSHA are used to calculate the elastic effects of rare earthquakes on the structure, respectively. The calculations include the maximum inter-story displacement angle and the floor shear capacity ratio under seismic loading. The structural displacement of this model optimization project is controlled by the X-direction seismic load. The following are the results of the calculations:

III. B. 1) Angle of maximum interstorey displacement of floors under seismic loading

Fig. 8 shows the maximum displacement angle of the floors under X-direction seismic action. Fig. 9 shows the maximum displacement angle of the floor under seismic action in Y direction. In X-direction, the maximum displacement angle of static elastic-plastic analysis method PSHA is calculated as 0.00171°, while the software YJK is calculated as 0.00177°. In the Y direction, the maximum displacement angle calculated by the static elastoplastic analysis method PSHA is 0.00157°, while the software YJK is 0.00158°. In 2 directions, the difference between the interlayer displacement angle calculated by the static elastic-plastic analysis method PSHA and the software YJK is not more than 0.001°, which proves the computational validity of the method. And the maximum interstorey displacement angle of the floors under seismic loading of the optimized project of the model in this paper is very small, which indicates that the optimization in this paper is effective.

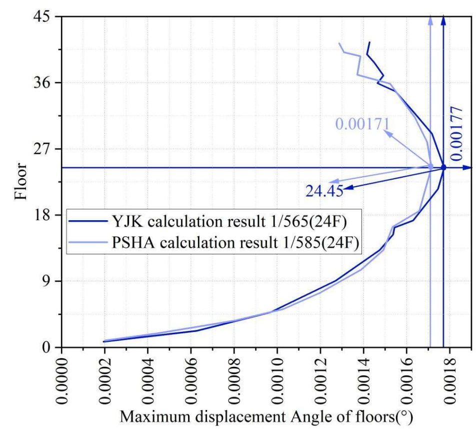

Figure 8: The maximum floor displacement Angle in the X direction

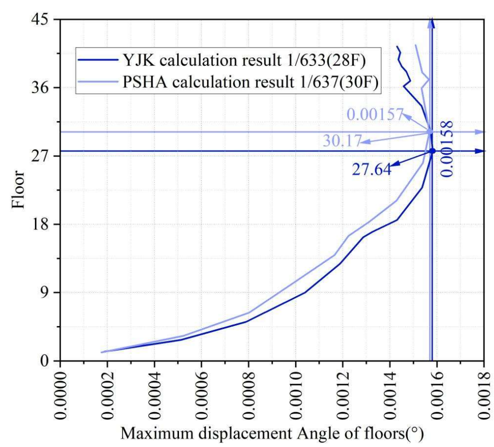

Figure 9: The maximum floor displacement Angle in the Y direction

III. B. 2) Floor shear capacity ratio

Further the static elasto-plastic analysis method PSHA is utilized to calculate the ratio of shear capacity of the floors. Figure 10 shows the ratio of the shear capacity of the floor to that of the neighboring upper floors in the X and Y directions.In the X direction, the ratio of the shear capacity of the floor to that of the neighboring upper floors ranges from 1.03634 to 1.72958; in the Y direction, the ratio of the shear capacity of the floor to that of the neighboring upper floors ranges from 1.03426 to 1.76037. The calculation meets the requirement of the technical requirements of concrete structure of high-rise buildings that the shear capacity of the interstory lateral force-resisting structure of the middle floor should not be less than 95% of the shear capacity of its upper floor. Through the size comparison, it can be judged that the floor shear bearing capacity ratio of the model structure optimization project in this paper meets the requirements.

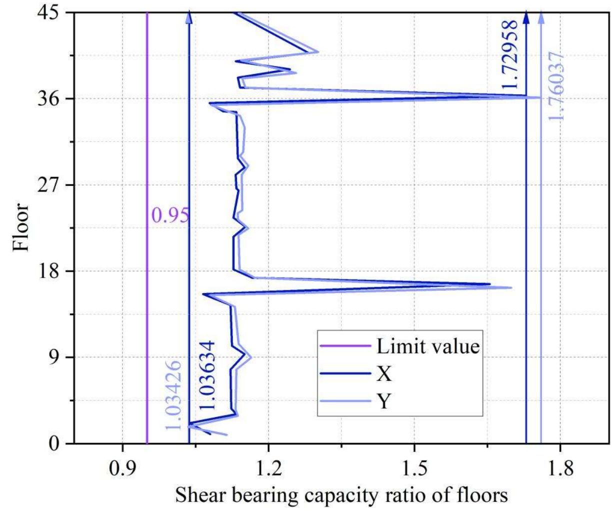

Figure 10: The shear bearing capacity ratio of floors

III. C. Analysis of reinforcement effects

Table 2 shows the results of the comparison of seismic performance before and after reinforcement. After reinforcement, the seismic performance of the building is significantly improved. By comparing the data before and after reinforcement, the analysis results are as follows: maximum horizontal displacement: 70.1 mm before reinforcement and 40.3 mm after reinforcement, which is a reduction of 42.5%. The outer reinforced concrete layer and the steel reinforcement support system increased the structural stiffness and reduced the displacement. Maximum inter-story displacement: 30.2mm before reinforcement and 17.5mm after reinforcement, a reduction of 42.0%. The diagonal bracing support and node reinforcement effectively increased the inter-story stiffness and optimized the seismic deformation resistance. Maximum deformation angle: 1/421 before reinforcement, 1/565 after reinforcement, which meets the specification requirements, and deformation control is improved. Shear wall node bearing capacity: the maximum shear force of the node was 3157kN and the maximum bending moment was 183kN·m before reinforcement; after reinforcement, it was increased to 3569kN and 237kN·m, respectively, which was about 13.1% and 29.5%. The model-optimized reinforcement measures in this paper significantly improve the seismic stability of the shear wall concrete structure of high-rise housing buildings, optimize the deformation and node bearing capacity, and enhance the seismic performance of the structure in strong earthquakes.

Table 2: Comparison of seismic performance before and after reinforcement

Performance index	Calculation results before reinforcement	Calculation result after reinforcement	Improvement rate /%
Maximum horizontal displacement/mm	70.1	40.3	42.5%
Maximum interlayer displacement/mm	30.2	17.5	42.0%
Maximum deformation Angle	1/421	1/565	25.8%
Maximum shear bearing capacity/kN	3157	3569	13.1%
Maximum bending moment response/(kN·m)	183	237	29.5%

IV. Conclusion

In this paper, a concrete structural model of a high-rise housing building is constructed to verify the effect of the structural optimization design through model reinforcement and performance calculation tests. The model reinforcement effect is calculated under two scenarios of multiple earthquakes and rare earthquakes by two methods of vibration mode decomposition reaction spectrum method and static elastic-plastic analysis, respectively, to verify that the proposed optimized design is effective. The optimization of the reinforcement of the concrete structure of high-rise housing buildings improves the seismic capacity of the building. After strengthening, the maximum horizontal displacement is reduced to 40.3 mm, the maximum interstory displacement is reduced to 17.5 mm, the maximum deformation angle is reduced to 1/565, the maximum shear force of the nodes is improved to 3569 kN, and the maximum bending moment is improved to 237 kN·m. The five indexes have been optimized by

42.5%, 42.0%, 25.8%, and 13.1%, respectively, 29.5%. In the future, we can try to construct the building model of higher floors to verify the effect of model reinforcement and calculation methods.

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