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A study of structural performance improvement methods in the reinforcement and renovation of old urban housing buildings

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Abstract The rapid development of the construction industry and the acceleration of urban integration have resulted in the emergence of a large number of old buildings, and their remodeling to make them have the potential for sustainable development is an essential part of future urban development. In this study, we construct a finite element analysis model of urban old housing buildings, realize the simulation analysis of the overall structure and performance of urban old housing buildings before and after reinforcement and renovation through the model, and propose the bottom shear method to analyze the structural performance of urban old housing buildings. The retrofitting and strengthening of the case building object is carried out by means of seismic strengthening and damper installation, and the results show that under the action of seismic wave RSN6546, the Y-direction damping rate of the floor of the retrofitted and strengthened old urban housing building is -11.76%, and the structural seismic performance of the building has been improved. It was also found that the floor displacement of the residential building under the influence of wind load was significantly reduced and the wind resistance performance was also improved. This study can promote the increase of the life span of the old housing buildings and make them have sustainable development potential, which provides useful reference for the further research and application of the structural strengthening technology of the old residential buildings.

Index Terms finite element modeling, bottom shear method, retrofit strengthening, structural performance, residential buildings

I. Introduction

The importance of reinforcement and remodeling of old buildings occupies a crucial position in urban construction and development. Reinforcement and remodeling of old buildings can prolong the service life of the buildings, improve the safety and seismic resistance of the buildings, and reduce the occurrence of accidents due to the structural problems of old buildings [1]-[4]. Reinforcement and remodeling of old buildings can improve the overall image and cultural heritage of the city, preserve the historical and cultural heritage, and enhance the sense of history and cultural atmosphere of the city. Reinforcement and remodeling of old buildings can also stimulate urban economic development, drive the development of related industries, increase jobs and promote the development process of the city [5]-[8]. In the reinforcement and remodeling of old buildings, the enhancement of the structural performance of the building becomes an important link, because the structural performance determines the safety and stability of the building itself [9], [10].

The improvement of the structural performance of the building cannot be separated from the structural reinforcement and remodeling technology, which is of great significance for urban construction and protection. Structural reinforcement and remodeling technology can be reformed from several aspects. In terms of reinforcing the foundation, the method of increasing the foundation area can be used to reinforce the foundation of the building and improve the carrying capacity and stability of the building [11]-[14]. In terms of structural reinforcement, methods such as reinforced columns, reinforced concrete beams and wall reinforcement can be used to strengthen the overall structure of the building and improve the seismic performance. In terms of reinforced columns, the load-bearing capacity of columns can be increased by adding reinforced concrete and steel plates to the outside of the original columns. In terms of reinforcing beams and walls, the methods of adding reinforced concrete shells to the beams and walls can be used to increase the load carrying capacity and seismic performance of the beams and walls [15]-[18].

Literature [19] aims to apply BIM to the design of structural remodeling of old buildings and simulation analysis of its performance. The results of simulation experiments point out that BIM can be applied to the retrofit of old buildings, which makes up for the shortcomings of traditional design methods and makes the design more intuitive. Literature [20] proposed solutions including integrated exoskeletons for the aging building stock problem. The impact of their effectiveness and intrusiveness is also analyzed. The need for validation of these technologies through applications on large buildings, as well as the support of appropriate design methodologies, regulations is emphasized. Literature [21] emphasizes the application of seismic restoration and enhancement techniques, especially in enhancing the seismic capacity of building structures, and reviews the development and achievements of seismic restoration and enhancement techniques, their application in typical projects, and identifies future research directions to lay the foundation for their wide application in engineering practice. Literature [22] studied a retrofit project in South Korea, aiming to provide insights for it and other similar projects. The results of the study showed that green retrofits are beneficial in terms of improving building envelope components and reducing heat transfer coefficients. It also suggests a shift towards retrofitting individual buildings for sustainable community development. Literature [23] evaluated different green roof solutions and compared their performance with previous findings. Examples were analyzed to draw conclusions about the suitability of the solutions for retrofitting existing buildings, energy efficiency, and many other aspects. Literature [24] introduced a calculation model based on the TNM decree and initiated the calculation and analysis of energy consumption for heating and hot water supply before and after retrofitting old buildings. The results show that the important factor affecting the energy consumption of old urban buildings is the thermal insulation performance of the building envelope. Literature [25] aims to examine the methods and strategies of old building renovation to meet the needs of urban renewal and cultural preservation. Typical case studies were used to analyze the techniques and methods for retrofitting old buildings. The results reveal that cultural heritage preservation and renovation of old buildings at the same time can enhance urban image and promote sustainable development. It is believed that policy support and technological innovation are important factors affecting the transformation of old buildings. Literature [26] introduces strategies that combine building simulation tools and optimization methods in order to raise awareness of the role of BIM in improving energy efficiency and comfort conditions. It is shown that the combination of these strategies with BIM not only improves the construction process but also explores alternative methods.

This paper utilizes an innovative program of seismic damping and installation of damper reinforcement to improve the structural performance of the old urban housing building after reinforcement and renovation, laying the foundation for the renewal and development of urban buildings. The old urban housing building structure is divided into a finite number of units to realize the discretization of the building structure. The unit characteristics of the housing building structure are analyzed by displacement method and equivalent nodal force, and then the ANSYS finite element model of the old urban housing building is constructed according to the defined boundary conditions of the housing building structure, which is used for the simulation and analysis of the structural renovation and reinforcement of the residential building. Subsequently, the structural performance of the urban old housing building is analyzed according to the finite element dynamic analysis method and the bottom shear method, such as wind resistance and seismic resistance. In this study, an old urban housing building is selected as a case study, which is simulated to be retrofitted and strengthened by means of seismic strengthening and damper installation, and the structural performance of the residential building is analyzed before and after the retrofitting and strengthening in the finite element model to explore the effectiveness of the retrofitting and strengthening of the building structure.

II. Finite element analysis modeling of old urban housing buildings

II. A. Structural discretization

Structural discretization [27] is the first step of finite element method analysis, that is, the structure to be analyzed is divided into a finite number of units, and after discretization, the units are connected to each other using nodes. The setting of the nodes, the nature of the units and the number of units should depend on the nature of the problem, the accuracy of the calculation and the deformation pattern to be described. Generally speaking, the more detailed the unit division is, the more accurate the description of deformation is, i.e., the closer it is to the actual deformation, but the larger the calculation volume is. The structure analyzed in the finite element method is no longer the original object or structure, but a collection of materials with the same properties connected in a certain way.

II. B. Unit characterization

(1) Displacement mode

In the finite element method, the selection of nodal displacement as the basic unknown quantity is called the displacement method, the selection of nodal force as the basic unknown quantity is called the force method, and the selection of part of the nodal displacement and part of the nodal force as the basic unknown quantity is called the hybrid method. Since the displacement method is easier to automate the calculation, the displacement method is most widely used in finite elements. When the displacement method is used, after the structure is discretized, the physical quantities such as displacements, strains and stresses in the cell can be represented by nodal displacements. The distribution of displacements in the cell can then be described by some approximate functions.

(2) Unit properties

According to the material properties of the unit, shape, size, number of nodes, location, find out the relationship between the unit node force and node displacement. The geometric and physical equations in elastic mechanics are applied to establish the equations between the unit node stresses and strains, so as to derive the unit stiffness matrix.

(3) Equivalent Nodal Force

After the object is discretized, it is assumed that the force is transferred from one unit to another through the nodes, however, for the actual continuum, the force is transferred from the common boundary of the unit to another unit. Surface, volumetric, or concentrated forces acting on the surface of a cell are transferred equivalently to the nodes, i.e., equivalent nodal forces [28] are used to replace all the forces acting on the cell.

II. C.Finite element modeling of housing buildings

II. C. 1) Principles of modeling

The structural bearing system of the old urban housing building is composed of concrete members and formwork support system, whose material properties, geometric model and the loads borne change with time, so the structure at this time is a time-varying structure. The mechanical analysis problem of the time-varying structure belongs to the category of slow time-varying structural mechanics, which can be dealt with by discrete time-freezing approximation, i.e., the time-varying structure is regarded as consisting of a series of time-invariant structures, and static analysis is carried out for each of the time-invariant structures, and then iterated, i.e., a number of the most unfavorable states of the time-varying structure are investigated.

Considering that the commonly used shell and rod units cannot contain the reinforcement of the members, coupled with the coupling problem between different types of units, in order to accurately examine the structural performance of the old urban housing building, solid units are used for all the members, and the reinforcement is wrapped in a solid unit with a diametrical rod unit. This is a very large amount of work for modeling and the machine time consumed for analysis is quite long, but the details of the structural forces can be obtained more accurately. Since the supporting steel tubes are not in contact with the upper and lower floor surfaces in a way that constrains the rotation of the tubes, the use of a dirac bar unit is sufficient to model the tubes, which are predominantly subjected to compressive forces. The material properties of the steel bars and steel tube supports are subject to very little external influence and can be selected according to the code if measured values are not available.

II. C. 2) Model realization

(1) Simplified model

In order to facilitate the establishment of numerical analysis models and calculations, it is necessary to make some simplifications in the process of establishing the finite element analysis model [29]. The simplification of the model scope can be based on the purpose of the analysis, it is possible to model a part of the structure, narrowing the scope to a local part of the floor connected with the support, without having to establish the model of the entire structure. A steel pipe support is a load-bearing frame consisting of uprights, crossbars, diagonal bars and scissor braces, which is used to carry and transfer the structural deadweight. Referring to the information in this aspect, it can be seen that the setting of transverse, diagonal and scissor braces is mainly to improve the overall stiffness of the bracing system, which is conducive to the overall stability of the bracing. However, it has little effect on the generation of vertical axial force and the change of internal force of the floor slab of the whole brace system. Therefore, the numerical analysis model established in this paper is appropriately simplified without considering the favorable effects of cross bars, diagonal bars and scissor braces. In addition, no formwork is considered in the model. This is due to the fact that concrete in old urban housing buildings has a certain modulus of elasticity and the formwork has very little effect.

(2) Define boundary conditions

In order to more accurately reflect the structural performance of urban old housing buildings before and after strengthening and remodeling, the model volume should be as large as possible, in addition to the plane range should be larger, the direction of the floor height should be extended up and down, in order to eliminate the influence of boundary conditions. Therefore, the model defines the bottom of the complete constraints, the plane truncated part of the constraint rotation.

The modeling starts with the construction of geometric entities. The intersection of column sections with beams of rectangular cross-section complicates the construction of geometric entities, especially when there are beams of several directions intersecting the same column. In addition, in order to connect the supporting steel tubes between the upper and lower floors, it was necessary to divide the floor slabs into a number of separate entities according to the plane spacing of the tubes. In order to place reinforcing steel in beams and columns, it is also necessary to divide the beams and columns into several geometric entities. After each geometric entity is formed, the entire model is constructed and divided into units according to their geometric relationships. The actual configuration of the columns, beams, upper and lower longitudinal steel bars simulated with two-rod units, beams, columns, slabs and shear wall concrete simulated with solid units. At this point, the ANSYS finite element model of the urban old housing building is formally established, and this study will use the model to simulate the building structure of the urban old housing building before and after reinforcement and transformation, and to realize the analysis of the effect of reinforcement and transformation on the improvement of structural performance.

III. Methods for analyzing the structural performance of housing buildings

III. A. Finite element dynamic analysis method

For the finite element model dynamics problem, where both displacements and external forces are functions of time and there are mass-induced inertial forces acting on the structure, the potential energy of the whole structural system is, if the effect of damping forces is taken into account:

$$\Pi = U + V = \iiint_{\Omega}\left(\frac{1}{2}\{\varepsilon\}^T[D]\{\varepsilon\} - \{\overline{p}\}^T\{u\}\right)d\Omega - \iint_S \{\overline{q}\}^T\{u\}dS \tag{1}$$

where $\{\overline{p}\} = \{p\} - c\frac{\partial}{\partial t}\{u\} - \rho\frac{\partial^2}{\partial^2 t}\{u\}$, then the above equation can also be expressed as:

$$\begin{aligned}\Pi = &\iiint_{\Omega}\frac{1}{2}\{\varepsilon\}^T[D]\{\varepsilon\} - \left(\{p\} - c\frac{\partial}{\partial t}\{u\} - \rho\frac{\partial^2}{\partial^2 t}\{u\}\right)^T\{u\}d\Omega \\ &-\iint_S \{\overline{q}\}^T\{u\}dS\end{aligned} \tag{2}$$

where c is the viscous damping coefficient, ρ is the density of the material, $\{p\}$ is the body force matrix, $\{\overline{p}\}$ is the combined body force matrix, $[D]$ is the elasticity matrix, $\{\overline{q}\}$ is the surface force matrix, $\{u\}$ is the displacement matrix, and $\{\varepsilon\}$ is the strain matrix.

As with the static analysis, the shape function $N_{\mathrm{i}}(x,y,z)$ is introduced, and for a given cell of the discrete body, there is:

$$\{u\} = \sum_i\left[N_i(x,y,z)\right]\{a_i(t)\} = [N]\{a_e(t)\} \tag{3}$$

$$\{\varepsilon\} = [L]\{u\} = [L][N]\{a_e\} = [B]\{a_e\} \tag{4}$$

where $[N]$ is the shape function matrix, $[L]$ is the differential operator matrix, $[B]$ is the strain matrix, and $\{a_e\}$ is the unit node displacement column matrix.

Then Eq. (2) can be written as:

$$\begin{aligned}\Pi_e = &\frac{1}{2}\{a_e\}^T\iiint_V([B]^T[D][B]dV\{a_e\} \\ &-\{a_e\}^T\left(\iiint_V [N]^T\{p\} - [N]^T c[N]\frac{\partial}{\partial t}\{a_e\}\right. \\ &\left.-[N]^T\rho[N]\frac{\partial^2}{\partial^2 t}\{a_e\}\right)dV - \{a_e\}^T\iint_S [N]^T\{\overline{q}\}dS\end{aligned} \tag{5}$$

Order:

$$\begin{aligned}
[K_e] &= \iiint_V [B]^T [D][B] dV \\
[M_e] &= \iiint_V [N]^T \rho [N] dV \\
[C_e] &= \iiint_V [N]^T c [N] dV \\
\{F_e\} &= \iiint_V [N]^T \{p\} dV + \iint_S [N]^T \{\overline{q}\} dS
\end{aligned} \tag{6}$$

Then equation (5) can be simplified as:

$$\begin{aligned}
\Pi_e = \frac{1}{2}\{a_e\}^T [K_e]\{a_e\} + \{a_e\}^T [C_e]\{\dot{a}_e\} \\
+ \{a_e\}^T [M_e]\{\ddot{a}_e\} - \{a_e\}^T \{F_e\}
\end{aligned} \tag{7}$$

where $[K_e]$ is the unit stiffness matrix, $[M_e]$ is the unit mass matrix, $[C_e]$ is the unit damping matrix, and $\{F_e\}$ is the unit nodal force vector.

It is obtained from the variational principle:

$$\delta\Pi_e = \delta\{a_e\}^T \frac{\partial \Pi_e}{\partial\{a_e\}} + \delta\{\dot{a}_e\}^T \frac{\partial \Pi_e}{\partial\{\dot{a}_e\}} + \delta\{\ddot{a}_e\}^T \frac{\partial \Pi_e}{\partial\{\ddot{a}_e\}} \tag{8}$$

Notice that for instantaneous variable scores, there are:

$$\delta\Pi_e = 0, \delta\{\dot{a}_e\} = 0, \delta\{\ddot{a}_e\} = 0 \tag{9}$$

Thus from equation (8):

$$\frac{\partial \Pi_e}{\partial\{a_e\}} = [K_e]\{a_e\} + [C_e]\{\dot{a}_e\} + [M_e]\{\ddot{a}_e\} - \{F_e\} = \{0\} \tag{10}$$

To wit:

$$[M_e]\{\ddot{a}_e\} + [C_e]\{\dot{a}_e\} + [K_e]\{a_e\} = \{F_e\} \tag{11}$$

This is the equation of motion of the unit. The equations of motion of the units are superimposed and combined to obtain the overall equations of motion of the building structure of the old housing in the urban area:

$$[M]\{\ddot{a}\} + [C]\{\dot{a}\} + [K]\{a\} = \{F\} \tag{12}$$

where $[K]$, $[M]$ and $[C]$ are the overall stiffness, mass and damping matrices of the structure, respectively. Plus the initial conditions:

$$t = t_0, \{a\} = \{a_0\}, \{\dot{a}\} = \{\dot{a}_0\} \tag{13}$$

A system of differential equations of motion with finite degrees of freedom in terms of finite cell node degrees of freedom as variables is then obtained.

III. B. Structural Performance Calculation Methods

The bottom shear method [30] can be used for simplified calculations for housing building structures with a relatively uniform distribution of mass and stiffness along the height, where shear deformation is dominant, and for structures approximating a single-mass point system.

Therefore, the ultimate bearing capacity in the cross-section structural performance of old urban housing buildings can be calculated according to the following formula:

$$V_b \le \gamma_{bE} \xi_N f_{v,m} A \tag{14}$$

Eq. for transmasonry:

$$f_{v,m} = 2.38 f_v \tag{15}$$

For rough masonry:

$$f_{v,m} = 2.70 f_v \tag{16}$$

For raw earth walls:

$$f_{v,m} = 0.125\sqrt{f_2} \tag{17}$$

where ζ_N is the positive stress influence coefficient of seismic shear strength of old urban housing buildings, $f_{v,m}$ is the average value of shear strength of housing buildings of non-seismic design, f_v is the design value of shear strength of housing buildings of non-seismic design $\left(N/mm^2\right)$, f_2 is the average value of compressive strength of housing buildings.

The standard value of horizontal seismic action in the structural performance of old urban housing buildings can be determined according to the following formula:

$$F_{Ehb} = \alpha_{\max b} G_{eq} \tag{18}$$

$$F_{11} = F_{Ehb} \tag{19}$$

where F_{Ekb} is the standard value of the total horizontal seismic effect of housing structures under the basic intensity of seismicity (kN), $\alpha_{\max b}$ is the maximum value of the horizontal seismic impact coefficient under the basic intensity of seismicity. F_{11} is the standard value of horizontal seismic effect of old urban housing buildings (kN).

The seismic shear ultimate bearing capacity of the section of the wall of the old urban housing building can be determined according to the following formula:

$$V_b \le \gamma_{bE} f_v A \tag{20}$$

$$V_b = \frac{A_1^f}{A^f} V_{EK} \tag{21}$$

$$f_v = \alpha\left(c + \sigma_0 \tan\phi\right) \tag{22}$$

where V_b is the standard value of the wall under the action of the basic intensity earthquake (kN), for the housing building (roof) cover, the horizontal seismic shear can be allocated according to the lateral force-resisting member (i.e., seismic wall) on the subordinate area of the gravity load representative value of the proportion of the subordinate area can be calculated according to the left and right sides of the spacing of neighboring seismic walls. A_1^f is the subordinate area of a single wall, A^f is the horizontal projected area of the entire roof, and V_{EK} is the standard value of horizontal seismic shear. γ_{bE} for the ultimate load-bearing force seismic adjustment factor, load-bearing can take 0.85, non-load-bearing wall (enclosure wall) can take 0.95, f_v for the average value of the wall composite force shear strength $\left(N/mm^2\right)$. A for the wall cross-sectional area $\left(mm^2\right)$, σ_0 for the corresponding to the representative value of the gravity load of the rammed earth cross-section of the average compressive stress, α for the wall shear strength fitting correction coefficient, take 0.45, c, ϕ for the wall of the straight shear test cohesion (MPa), and angle of internal friction.

IV. Analysis of the effects of strengthening and upgrading old urban housing buildings

IV. A. Housing construction works

The urban old housing building reinforcement and renovation project selected in this paper is located in Y city, S province, which is a civil 8-story residential building. This residential building was constructed in 2007, which is a typical urban old housing building and is suitable as a simulation case for this study. The seismic intensity of this old urban housing building is 6 degrees, and the design basic seismic acceleration value is 0.05 g. The building is square, with a side length of 12.36 m, a floor area of 485 m², and a height of 20 m. The thickness of the internal and external load-bearing walls of the building is 245 mm, and ring beams are installed on each floor, and structural columns are provided in the corners, the junctions of the internal and external walls, and the stairwells, etc., where the bricks are MU10, and the cement mortar is MU10, and the cement mortar is MU10, and the cementitious mortar is MU10. MU10, cement mortar is M10, concrete strength grade is C20, floor and roof slabs are precast concrete slabs, the building has simple modeling and simple force transmission path. Due to the local soil quality is good, there is no uneven phenomenon, the upper structure of the building is simple, the foundation is concrete bar foundation. In the course of its use, it has not suffered any significant man-made damage other than natural weathering and natural aging. The city's older housing buildings need to be reinforced and upgraded to improve their structural performance, as the structural performance of the housing building walls was not considered comprehensively and permanently during the initial planning and design.

IV. B. Structural inspection prior to upgrading

IV. B. 1) Foundation testing

First of all, the old urban housing buildings before reinforcement and reconstruction are meticulously inspected and surveyed, especially the upper structure of the house is comprehensively inspected. The main contents of the inspection of the foundation structure are the status of the foundation's bearing capacity, whether the expansion joints are aging, cracking and broken, whether the foundation concrete is broken and other diseases, and whether the foundation is settled and deformed. The specific inspection of housing structure mainly includes crack width and distribution inspection, concrete strength test, concrete carbonation depth test, concrete exposed reinforcement condition inspection and protective layer thickness.

The project has been suspended since its completion for 18 years, as the foundation of the building adopts pile foundation with rock as the holding layer, the foundation is deeper, and the soil quality around the foundation is better, the foundation has not changed a lot, and the deformation of foundation is basically stable, according to the inspection of this testing site on the part of the components of the main building of the old urban housing building, the crack and deformation caused by the foundation foundation settlement have not yet been found, with reference to the Reliability Appraisal Standard for Civil Buildings", it can be seen that the foundation of the project has stabilized in the current deformation and the bearing capacity also meets the requirements, so the foundation part can meet the requirements of structural safety, and there is no need to test the foundation.

Table 1: Analysis of crack cracking in concrete

Member	Range	Position	Root number	Mean depth (mm)	Mean length (mm)	Maximum fracture width (mm)	Categories
Frame post	Peripheral	1-5 floor	58	6.5	86.6	5.5	Cu
		6-8 floor	113	4.8	11.1	4.2	Bu
	Center part	1-5 floor	42	5.6	84.6	3.2	Bu
		6-8 floor	89	1.6	53.2	1.5	Au
Shear wall	Peripheral	1-5 floor	28	5.9	50.9	3.9	Cu
		6-8 floor	0.0	0.0	0.0	0.0	Bu
	Center part	1-5 floor	21	4.2	13.4	3.5	Bu
		6-8 floor	79	2.5	62.9	2.6	Au
Frame beam	Peripheral	1-5 floor	45	5.9	87.4	5.9	Cu
		6-8 floor	112	4.6	45.9	4.5	Bu
	Center part	1-5 floor	36	5.2	105.7	3.6	Bu
		6-8 floor	89	1.4	52.4	2.4	Au
Floor slab	Peripheral	1-5 floor	26	2.6	80.3	2.3	Cu
		6-8 floor	75	2.6	31.7	2.1	Bu
	Center part	1-5 floor	18	2.4	101.5	1.5	Bu
		6-8 floor	65	1.6	56.4	1.8	Au

IV. B. 2) Detection of structural defects

(1) Concrete crack width detection

The detection of cracks in the structure or components of the old housing buildings in this city should be carried out in accordance with the relevant provisions of the Building Deformation Measurement Regulations, and the specific test results are shown in Table 1. The cracks in the peripheral parts of the main structural layer of the housing building are the most serious, and the maximum crack widths in the peripheral parts of the frame columns and frame beams on the 1st-5th floors have reached 5.5mm and 5.9mm, respectively, and the relevant measures should be taken immediately to carry out crack repair and renovation and reinforcement. The crack development of the center part of the main structural floor is relatively not very serious and does not need to carry out crack repair measures, and the crack development of the other parts of the main structure is in line with the basic requirements for structural reinforcement and renovation.

(2) Concrete carbonation depth and strength testing

The results of concrete carbonation and strength testing in the structure of the old housing buildings in the city are shown in Table 2. 1-5 floors of concrete frame columns (14.5mm, 12.4mm), shear walls (14.6mm, 13.5mm), frame beams (13.4mm, 10.9mm) and floor slabs (11.7mm, 10.9mm) have deeper carbonation depths and higher degrees of concrete deterioration. 6-8 floors of concrete frame columns, shear walls, frame beams and floor slabs have shallower depths compared to the floors, and the degree of concrete deterioration is lower. The carbonation depth of concrete frame columns, shear walls, frame beams and floor slabs in floors 6-8 is lighter compared to the floors, and the degree of concrete deterioration is lower.

Table 2: Analysis of concrete carbonization

Member	Range	Position	Carbonization depth (mm)			Categories
			Average	Minimum	Maximum	
Frame post	Peripheral	1-5 floor	14.5	12.3	15.6	Cu
		6-8 floor	8.9	7.6	10.3	Bu
	Center part	1-5 floor	12.4	9.6	13.5	Bu
		6-8 floor	6.5	5.9	8.4	Au
Shear wall	Peripheral	1-5 floor	14.6	11.3	16.9	Cu
		6-8 floor	0.0	0.0	0.0	Bu
	Center part	1-5 floor	13.5	11.8	15.9	Bu
		6-8 floor	8.6	7.4	10.2	Au
Frame beam	Peripheral	1-5 floor	13.4	10.4	15.6	Cu
		6-8 floor	8.5	7.4	10.3	Bu
	Center part	1-5 floor	10.9	8.6	12.4	Bu
		6-8 floor	5.6	4.2	8.2	Au
Floor slab	Peripheral	1-5 floor	11.7	8.9	13.4	Cu
		6-8 floor	8.6	7.2	11.4	Bu
	Center part	1-5 floor	10.9	8.6	12.4	Bu
		6-8 floor	6.4	5.4	8.9	Au

(3) Concrete strength test results

In accordance with the provisions in the Technical Procedure for Testing Compressive Strength of Concrete by the Rebound Method, the converted concrete strength values of specific components can be derived. According to the building standard specification and random sampling scheme, this study carried out concrete strength testing on the construction site of the main structure of the old urban housing building, and the concrete strength testing results of the old urban housing building before strengthening and renovation are shown in Table 3.The measured values of the concrete strength of the periphery of the framed columns and the center structure in the floors of 1-5 were decreased by 18.75% and 13.60% compared with the original design values. . This indicates that the concrete strength does not meet the design requirements, and it is necessary to reinforce the concrete in this part of the building. The strength of concrete in other parts of the housing structure meets the design requirements of the structure.

Table 3: Concrete strength test results

Member	Range	Position	Determination of concrete strength (MPa)	Original design value (MPa)	Intensity difference (MPa)	Intensity reduction (%)
Frame post	Peripheral	1-5 floor	22.1	27.2	5.1	18.75%
		6-8 floor	19.6	22.3	2.7	12.11%
	Center part	1-5 floor	23.5	27.2	3.7	13.60%
		6-8 floor	24.6	27.2	2.6	9.56%
Shear wall	Peripheral	1-5 floor	25.4	27.2	1.8	6.62%
		6-8 floor	0.0	0.0	0.0	0.00%
	Center part	1-5 floor	26.9	27.2	0.3	1.10%
		6-8 floor	18.9	22.3	3.4	15.25%

Frame beam	Peripheral	1-5 floor	25.3	27.2	1.9	6.99%
		6-8 floor	19.7	22.3	2.6	11.66%
	Center part	1-5 floor	24.6	27.2	2.6	9.56%
		6-8 floor	20.3	22.3	2.0	8.97%
Floor slab	Peripheral	1-5 floor	26.4	27.2	0.8	2.94%
		6-8 floor	21.9	22.3	0.4	1.79%
	Center part	1-5 floor	24.6	27.2	2.6	9.56%
		6-8 floor	20.6	22.3	1.7	7.62%

IV. C. Analysis of the structural performance of housing buildings after strengthening and renovation

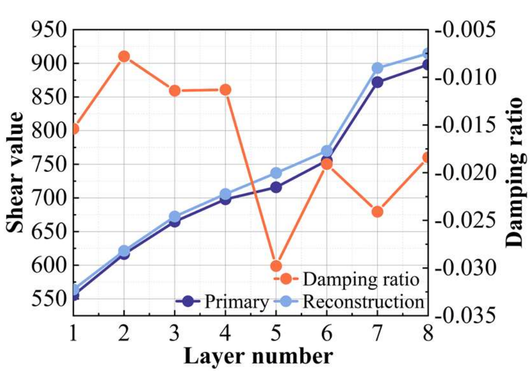
IV. C. 1) Reinforcement measures

Using conventional methods to directly reinforce the old urban housing buildings selected in this study, it is difficult to solve the new requirements on a large number of construction measures, and new ideas for reinforcement and renovation must be considered. If the reinforcement is done only by expanding the cross-section, posting steel plates, etc., it is difficult to solve the problems of insufficient length anchorage and insufficient spacing, which may easily lead to the increase of construction volume and the increase of reinforcement and renovation cost, which will affect the normal work of the old urban housing buildings. Specific project strengthening and renovation program should be in accordance with the requirements of the housing construction code, the selection of appropriate strengthening and renovation methods and the amount of deformation to ensure that the structural performance of urban old housing buildings after strengthening and renovation to meet the relevant requirements.

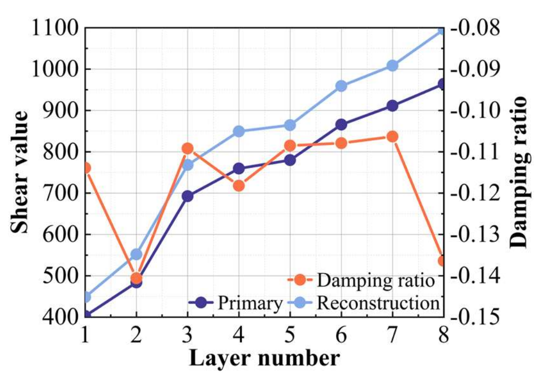
Therefore, this project adopts the seismic strengthening program and arranges dampers at suitable locations to improve the structural damping ratio, reduce the seismic response of the main structure from the energy principle and control the expected deformation of the structure, which significantly improves the structural performance of the old urban housing building. Through the finite element model for the simulation of strengthening and retrofitting, the simulation analyzes the changes in the shear force values in the X and Y directions of each floor of the housing building under the influence of different seismic waves to reflect the seismic performance of the building structure, and analyzes the displacement ratios of the housing building under the action of the wind to reflect the changes in the wind-resistant performance of the building structure, so as to explore the effect of the improvement of the structural performance of the urban old housing building after strengthening and retrofitting.

IV. C. 2) Comparative analysis of seismic performance of buildings before and after retrofitting

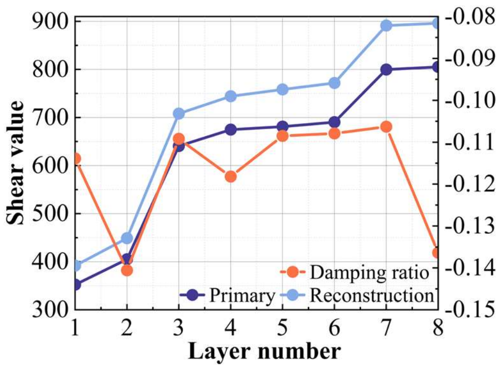
The simulation results of the original structure and the reinforced and retrofitted floor shear under seismic wave excitation are shown in Fig. 1, and (a)-(d) represent the results of the analysis of the X- and Y-direction floor shear values of the residential building structure under the influence of the natural and artificial seismic waves RSN6546 and RG1, respectively. The average reduction rates of X- and Y-direction floor shear under the effect of natural seismic wave RSN6546 are -1.72% and -11.76%, respectively, for the retrofitted and strengthened old urban housing buildings. The average damping rates of X- and Y-direction under artificial wave RG1 are -11.76% and -12.55%, respectively. Compared with the old urban housing structure before reinforcement, the shear force of all floors of the residential building structure after reinforcement increases to different degrees, indicating that reinforcement increases the overall stiffness of the residential building structure and also increases the seismic force on the structure, and it is more obvious in the Y-direction floors.



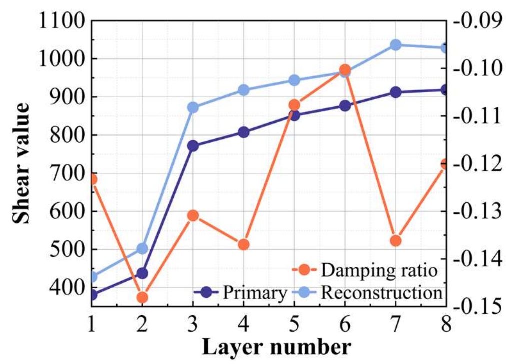
(a) Natural wave RSN6546(X)



(b) Natural wave RSN6546(Y)



(c) Artificial wave RG1(X)



(d) Artificial wave RG1(Y)

Figure 1: Analysis of shear value of construction under seismic wave

IV. C. 3) Simulation and Analysis of Wind Resistance of Building Structures

The results of simulation analysis of the structural performance of this urban old housing building under wind load before and after reinforcement are shown in Table 4. The maximum displacements of the building structure in the X direction and Y direction before retrofitting were 14.57 mm and 23.50 mm, respectively, and the displacement of the building structure in the Y direction was larger than that in the X direction under the wind load of one in 50 years for the old urban housing building, because the stiffness of the residential building structure in the Y direction was larger than that in the X direction, and the bearing area in the Y direction was larger than the bearing area in the Y direction. After retrofitting and strengthening, the simulation analysis results show that the displacements of the 8-story floor in X direction and Y direction under wind load of this old residential building are 13.62mm and 19.39mm respectively, which is a significant reduction of the displacement compared with that before retrofitting and strengthening, indicating that the wind resistance of the residential building structure has been improved.

In summary, it can be found that under the simulation of seismic and wind loads, the displacements in X and Y directions of the retrofitted and strengthened old urban housing structures supported by the seismic strengthening scheme and damper retrofitting are significantly reduced, and the retrofitted and strengthened structures provide additional stiffness while increasing the seismic forces on the structures, resulting in an increase in the shear force on the floors.

Table 4: Analysis of floor displacement under wind load

Layer number	Before retrofitting		After retrofitting	
	X (mm)	Y (mm)	X (mm)	Y (mm)
1	2.17	0.87	0.54	0.62
2	3.04	3.09	1.17	1.26
3	3.19	10.55	1.55	1.84
4	9.91	10.8	5.68	7.65
5	10.59	16.35	5.99	9.46
6	12.41	21.15	6.36	12.85
7	12.72	22.57	10.72	17.96
8	14.57	23.5	13.62	19.39

V. Conclusion

In this study, the ANSYS finite element model of an urban old housing building is constructed to realize the simulation and analysis of reinforcement and structural performance, and the structural performance of the residential building is calculated by using the bottom shear force and other methods. An urban old housing building belongs to a typical urban old housing building, and the cracks in the peripheral parts of the main structural floor of the housing building are the most serious, and the maximum width of the cracks in the peripheral parts of the frame beams on the 1-5 floors reaches 5.9 mm, and it is found that the measured value of the strength of the concrete in the peripheral structure of the frame columns on the 1-5 floors of the building has decreased by 18.75% in comparison with the original design value, so it is necessary to carry out crack repair and retrofitting reinforcement for the housing building urgently. Crack repair and retrofit reinforcement are urgently needed for this residential building. The structural performance of the building was analyzed before and after the seismic strengthening retrofit, and it was found that the average damping rate of the X- and Y-floor of the housing building under the influence of the natural seismic wave RSN6546 was -1.72% and -11.76%, respectively, and the shear values of all floors increased significantly. In addition, the displacements of each floor of the retrofitted and strengthened building under wind loads were significantly reduced compared to those before retrofitting and strengthening, indicating that the wind resistance of the residential building structure was also improved.

This paper studies the overall structural performance analysis of urban old housing buildings, which is of great practical significance, and will provide some theoretical references for the future structural reinforcement and renovation of similar buildings.

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