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Research Article

Planning Research on Application of Nanomaterial Technology in Disaster Prevention and Reconstruction

Jun Shao,[1] Huihui Yan ,[2] and Haosheng Xu[3]

[1]*School of Urban Construction, Wuhan University of Science and Technology, Wuhan, Hubei 430081, China*
[2]*Wuhan Planning and Design Institute, Wuhan,, Hubei 430074, China*
[3]*Electronic Circuit Division, GCI Science & Technology Co. Ltd., Guangzhou, Guangdong 510220, China*

Correspondence should be addressed to Huihui Yan; shaojun@wust.edu.cn

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An earthquake causes a huge loss of life and property. After an earthquake, many buildings are seriously damaged or collapsed. On the one hand, it is necessary to make full use of nanomaterials technology to improve seismic strength during reconstruction; on the other hand, scientific planning is needed to reduce pollution, carbon emissions, and energy consumption. This paper mainly studies the application of nanomaterial technology in disaster prevention and reconstruction. Through a series of planning safeguard measures, the overall seismic performance of the city is improved in order to provide theoretical guidance and technical support for disaster prevention and reconstruction. This paper mainly introduces the stress analysis of frame joints after earthquake and the planning of urban disaster prevention and reconstruction. In addition to the different types of concrete materials (ordinary concrete, nano silica fiber concrete, PVA fiber concrete), the fixed amount of water, superplasticizer, reinforcement, sand, and gravel, the concrete strength grade is C30. Then, three kinds of concrete frame joints are tested under low cycle cyclic loading to compare the seismic performance of the three kinds of concrete. The experimental results show that the fuzzy evaluation of urban disaster prevention and reconstruction planning has been carried out for 6 communities in this city. Among them, 4 communities are qualified and 2 communities are unqualified. Therefore, it is necessary to focus on seismic reinforcement or carry out urban planning research again. Compared with ordinary concrete, the bearing capacity and ductility coefficient of nano silica fiber concrete and PVA fiber concrete are increased by 37.8% and 15.6%, respectively. It is proved that the seismic performance of nano silica fiber reinforced concrete is far better than that of ordinary concrete.

1. Introduction

In recent years, Wenchuan earthquake, Yushu earthquake, and other frequent earthquake disasters have accelerated the seismic planning-related research [1–3]. Building is the main constituent element of city. It is an important way to minimize the collapse and damage of buildings during earthquakes [4]. Due to the serious damage of earthquake, especially the damage of high-rise buildings, the structure in earthquake area should have enough ductility to ensure that the frame structure has sufficient seismic capacity. Reinforced concrete frame structure has been widely used in multistorey buildings for its many advantages. However, due to the large number of stories, the phenomenon of "thick column with less reinforcement" often appears in the lower column, which not only takes up the indoor space, but also increases the weight of the building, which is particularly unfavorable to earthquake resistance. The beam column joints of frame structure bear the shear and bending moment of frame column and frame beam at the same time, which is prone to shear failure. As the transfer hinge of frame structure, beam column joint is the key part of the whole structure. In order to improve the energy dissipation capacity and seismic performance of frame structures, the seismic fortification requirements of "strong joints and weak members" are proposed in seismic codes at home and abroad. Generally, in the actual project, more stirrups are arranged in the core area of the joint to meet the requirements of "strong joint." However, more shear reinforcement will cause reinforcement crowding in the joint, which will increase the construction difficulty and project cost. At the same time, the reinforcement of beam column joint is crowded, which is easy to make the concrete pouring vibration not dense, and the joint is easy to crack, so that the water and oxygen in the air contact with the reinforcement in the component through the crack, which makes the reinforcement rust, reduces the strength of the reinforcement, and shortens the service life of the steel bar. In addition, the tensile performance of concrete is far lower than its compressive strength performance, and its damage is often characterized by brittleness. The brittleness failure and cracking performance of concrete cannot be brought into full play, which reduces the durability of the structure, shortens the service life of the concrete structure, increases the maintenance cost of the concrete structure, and limits the use of concrete in the structure. Therefore, improving the strength and ductility of columns, especially low-rise columns, has become one of the main measures to improve the seismic performance of multistorey buildings.

Field investigation and related scientific research show that beam column joints without lateral limit and poor details cannot resist medium and large earthquake events. In order to improve the seismic performance of existing RC beam column joints, Vecchio et al. proposed a new strength bearing capacity model to explain the strength increase provided by FRP system in seismic reinforcement of low-detail angle joints. Through the analysis of a large number of experimental data, the accuracy of the model is verified [5]. Del Vecchio et al. discuss the numerical seismic evaluation of reinforced concrete structural systems designed without appropriate seismic details of gusset plates and the benefits of local FRP reinforcement. Del Vecchio et al. proposed a new finite element analysis method to consider the nonlinear behavior of joints and fiber reinforced polymer (FRP) reinforcement. Several case studies are selected to verify the model. On the component level, the model predictions were compared with recent test results on full-scale beam to column joints with or without FRP reinforcement [6]. The Del Vecchio study evaluates the effectiveness of a new seismic strengthening method for reinforced concrete beam column joints and establishes a shear strength model of the strengthened joints. Under the action of reversed cyclic load, the four joints without transverse reinforcement were poured and tested. The first joint is used as the control specimen, and the other three joints are bonded around the column with concrete cover in the joint area, which is changed from square section to circular section, and then wrapped with different proportions of CFRP. Based on the concept of average plane stress, the shear strength model of joints was established and evaluated by the collected database. Among them, 32 joints were strengthened with conventional FRP and 3 nodes were strengthened with new methods [7]. Verderame et al. carried out an experimental study on the full-scale external unreinforced reinforced concrete beam column joints of four typical unqualified reinforced concrete frame structures. Verderame et al. observed different failure modes, i.e., the failure of joints with or without beam yielding, analyzed the local response of gusset plates, and evaluated different joint deformation mechanisms and their contributions to deformation capacity and energy dissipation capacity [8]. In this paper, the mechanical behavior of beam column joints strengthened under cyclic loading is studied experimentally. The test scheme includes eight external beam column joint components, which are tested in two stages: one is the failure stage, the second stage is the repair stage. Beam column joints are designed for gravity loads only. There is no transverse reinforcement of beam column joint, and there is no special stirrup in the critical zone of beam column. These nonseismic design (NS) joints were damaged to varying degrees in the first stage of the test. In the second stage, damaged joints were strengthened with carbon fiber reinforced polymer (c-frp) sheets [9].

In addition to the different types of concrete materials (ordinary concrete, nano silica fiber concrete, and PVA fiber concrete), the fixed amount of water, superplasticizer, reinforcement, sand and gravel, and the concrete strength grade is C30. Then, the low cycle repeated load test is carried out on the sample frame joints. In this paper, the bearing capacity, ductility, energy dissipation capacity, and stiffness degradation of ordinary concrete, PVA fiber concrete, and nano silica fiber concrete frame joints are compared and analyzed. It is proved that the seismic performance of nano silica fiber reinforced concrete is far better than that of ordinary concrete.

The application of nanomaterials technology is essential in postdisaster reconstruction. On the one hand, the application of nanomaterials can effectively improve the seismic level of buildings and ensure the safety of people's lives and property. On the other hand, the application of nanomaterials technology can improve the level of building science and technology and reduce pollutant emissions and energy consumption, which is one of the important contents of scientific reconstruction.

2. Seismic Resistance of Nanomaterials and Reinforced Concrete Nodes

2.1. Planning Research on Urban Disaster Prevention and Reconstruction. The idea of urban planning first appeared in the West and then spread to China, which provided a strong support for China's urban planning. From the background of the formation of the theory, we can see that before World War II, Western developed countries had relatively concentrated capital, urban industrial development was abnormal, population density was large, land use was very tight, and people's living space was facing more and more problems. After World War II, these problems became more prominent. Environmental pollution, deterioration of living conditions, and shortage of urban land make these countries aware of the crisis and put forward urban planning theory to solve these problems. Urban planning is the rational allocation of urban land and space, which aims to coordinate the urban environment, allocate land reasonably, and promote social prosperity and development.

In many urban planning theories, urban planning considers the impact of various disasters on the city, which is the best performance. Obviously, there will be a reasonable green space layout in various plannings. The distribution form of urban green space is closely related to urban planning, which determines the layout of the city. Urban green space should meet the requirements of disaster prevention and mitigation according to the distribution of the city. Urban planning theory will inevitably affect the disaster prevention and mitigation function of urban green space.

2.1.1. Urban Disaster Prevention and Reconstruction Planning. Disaster prevention and reconstruction should conform to and coordinate with the requirements of urban master plan and comprehensive disaster prevention plan [10]. In addition, the supporting facilities for disaster prevention and reconstruction of Greenland station are relatively complete, which is a very important shelter for nearby residents, and can be used as the command center for disaster prevention and reconstruction in case of disaster. Therefore, the urban green space disaster prevention and reconstruction planning should become the content that cannot be ignored in the overall urban planning and disaster prevention planning.

Urban green space system is the basis of urban disaster prevention and reconstruction planning, which is a special planning under the green space system. Disaster prevention and risk avoidance planning should be combined with urban green space system planning to form a reasonable disaster prevention and risk avoidance system. Due to the limited area of urban green space, stadiums, parking lots, and schools in the city can be used as disaster relief and disaster prevention and reconstruction green space. Therefore, when making urban disaster prevention and reconstruction planning, other open space and public facilities in the city should be comprehensively considered for unified planning. Moreover, the diversity of disasters should also be considered comprehensively. People oriented means putting people's life and needs in the first place. In terms of urban disaster prevention and reconstruction, the capacity of green space for disaster prevention and reconstruction must meet the number of asylum seekers, and each person has a reasonable disaster avoidance area. Green space should be evenly distributed around people's lives, so that people can escape quickly and effectively when disasters occur.

2.1.2. Disaster Prevention of Collapse. Slope reinforcement is an effective way to prevent the development of slope weathering. The retaining wall is constructed on the high and steep slope with poor stability, which is used to cover with cement mortar. This method can effectively reduce the weathering of the slope and improve the stability of the slope. Leakage plugging, water blocking, and roof support pointed out that joints are also an effective method to control landslides and are mainly used for highway slope treatment where there is a danger of collapse. Occlusion and interception are used to deal with large-scale collapse and control small-scale collapse, respectively [11].

2.1.3. Disaster Prevention of Ground Collapse. According to the inducing factors and formation mechanism of surface subsidence, active prevention and control measures should be taken for the areas that have not yet collapsed, and the areas that have collapsed should be renovated to slow down or prevent the further development of surface subsidence. The specific disaster prevention measures are as follows:

(1) We should pay attention to patrol and real-time monitoring. Engineers and relevant personnel shall conduct inspection and real-time monitoring, record the occurrence of collapse truthfully, and report to relevant departments in time.

(2) The collapse area and goaf should be sealed and tamped in combination with the actual collapse area. At the same time, the backfill volume shall be measured, and the safety management department and geodetic survey center shall strictly check the backfill volume. In case of repeated landslides, the backfill shall be repeated.

(3) When karst collapse occurs on the ground, it is necessary to prevent pedestrians, vehicles, livestock, and other animals from entering the collapse area according to the size of the collapse, so as to prevent further casualties and property losses. It is necessary to strengthen targeted safety publicity and education and enhance people's awareness of disaster prevention, and on this basis, the collapse pit should be treated.

2.1.4. Evaluation of Seismic Performance of Buildings. Evaluation of seismic performance of buildings is an important part of seismic disaster prevention planning. At present, many scholars have put forward many methods to evaluate the seismic capacity of individual buildings and group buildings [12–15]. The evaluation results are basically expressed by vulnerability matrix or earthquake damage index.

2.2. Stress Analysis of Joints. In the seismic design of strong earthquakes, frame joints are important components that affect the nonlinear response of frame structures. In the reinforced concrete frame structure, the beam reinforcement and the column reinforcement converge at the joint, and the joint composition is relatively complex. Because the frame joint is an internal force transfer center, including pressure, shear force, and bending moment, the stress state of the joint is also complex. The joint is the joint of beam and column, and it is the key part of frame structure. It bears bending moment, shear force, and axial force from beam end and column end. Under the repeated action of earthquake, the node often becomes one of the vulnerable parts of earthquake. Through the stress analysis of the joint, the following conclusions are drawn.

Under the action of horizontal load, the deformation of the joints around the beam column is the bending moment of the tie beam in the same direction. The pressure of the bending moment on the concrete at the beam end is related to the tensile strength of the reinforcement. Therefore, for the longitudinal reinforcement of the same beam, under the action of pressure and tension, they are on both sides of the node, respectively. Therefore, under the action of horizontal load, the horizontal shear force is greater than that of the joint under vertical load shear force. Therefore, under the synergistic action of vertical pressure and horizontal shear stress, the core area of frame joints will bear large diagonal tension. At the same time, due to the weak tensile strength of concrete, the concrete at the joint will produce inclined cracks, which leads to shear failure of concrete in the core area.

When the load of the joint is vertical, the shear force of the beam to column joint is smaller than that of the beam end column joint. Under the action of the bending moment in the opposite direction of the beam column joint beam, the bending moment of the left and right sides of the beam is relatively small after the offset of the two ends. At the same time, due to the vertical load acting on the ends of the beams at both ends, the column is under the dominant action of the vertical internal force, resulting in the beam column eccentric compression in the center of small or compression state. Because the upper reinforcement of the beam end on both sides of the column is long and the stress direction is different, the transverse shear force in the core area of the joint and the shear force at the end of the column are relatively small. As only one side of the beam end column is connected to the beam end, the negative bending moment of the beam end is transmitted to the column end through the node, which makes the column end bear a large bending moment. Therefore, in order to transfer the moment at the column end, the core area of the joint needs to bear a large shear force [16].

In recent decades, the emergence of high-rise reinforced concrete frame structure makes the seismic work of high-rise buildings more and more important. When the earthquake disaster occurs, the collapse of the whole frame structure is often due to the first failure of the joints, which makes the maintenance work more difficult. Therefore, the safety and reliability of the node is the guarantee of the normal operation of the whole structure. In seismic design, the strength and ductility of beam column members should be guaranteed, and the strength and ductility of joint area should be improved. The theory of load transfer mechanism and joint failure characteristics needs to be improved, and the corresponding reasonable joint design method should also be put on the agenda [17].

2.3. Nanotube Model Solution. In order to evaluate the elastic modulus of the nanocomposites obtained by solving the model of doped ZrO_2 nanotubes, the H-T theory was used for the first time to calculate the elastic modulus of the doped ZrO_2 nanotube model. The model is based on the self-consistent method of classical theoretical methods and takes into account the influence of the length diameter ratio and filling ratio of ZrO_2 nanotubes on the mechanical properties of random reinforced phase reinforced composites [18]:

$$\frac{E_C}{E_m} = \frac{3}{8}E_1 + E_2. \quad (1)$$

In the formula, E_C/E_m is the ratio of elastic modulus of composite material to elastic modulus of matrix material:

$$E_1 = \frac{1 + 2\eta_1 V_Z (l/d)}{1 - \eta_1 V_Z},$$
$$E_2 = \frac{1 + 2\eta_T V_Z}{1 - \eta_T V_Z}. \quad (2)$$

V_Z is the filling ratio of ZrO_2 nanotubes in the matrix material, and l/d is the length diameter ratio of ZrO_2 nanotubes, which is the filling ratio in the whole RVE model:

$$\eta_L = \frac{E_Z/E_m - 1}{E_Z/E_m + 2(l/d)},$$
$$\eta_T = \frac{E_Z/E_m - 1}{E_Z/E_m + 2}. \quad (3)$$

It can be seen from the above formula that the method can only calculate the elastic modulus of the composite, but cannot observe the stress distribution between the ZrO_2 nanotube and the matrix material. Therefore, many researchers have improved the method from the aspect of aspect ratio, material geometric parameters, and loading direction.

2.4. Nanoparticles

2.4.1. Nano Ultrafine Calcium Carbonate. The particle size of ultrafine calcium carbonate is in the range of 1~100 nm. It is mainly used in rubber, plastics, coatings, and other industries, and the most mature industry is the plastic industry. It is mainly used for PVC plastic sol and high-grade plastic products for automobile inner sealing. It can improve the rheological property of plastic masterbatch and improve its formability. At the same time, as a plastic filler, it has the function of strengthening and toughening; it can improve the bending modulus and bending strength of the plastic, improve the thermal deformation temperature and dimensional stability of the plastic, and make the plastic have thermal hysteresis. In addition, in the coating industry, it can greatly improve the thixotropy of the system, significantly improve the washability, adhesion, stain resistance, surface finish, and strength of the coating, and has good anti-settlement effect [19].

The main production methods of calcium carbonate are physical method and chemical method. The physical method is that the raw ore is directly crushed into calcium carbonate powder by mechanical processing. The products prepared by this method usually have large particle size and wide distribution and are generally used as fillers for medium- and low-end products. Chemical method is a method to obtain calcium carbonate by controlling reaction conditions and chemical reactions between substances. Calcium carbonate produced by chemical method has small particle size, narrow distribution, and controllable crystal shape. Its performance is obviously better than that of calcium carbonate prepared by physical method [20].

At present, most enterprises use carbonization method to produce nano calcium carbonate. According to the different carbonization methods, it can be divided into continuous spray carbonization and intermittent bubbling carbonization.

Continuous spray carbonization is the principle of putting the lime milk pressure atomizer on the top of the carbonization tower and atomizing it uniformly into small droplets. Carbon dioxide gas is ejected from the bottom of the tower. The contact between them is carbonized. This method usually uses two or three carbonization towers in series with multiple process stages. The solution obtained from the first carbonization tower enters into the second carbonization tower for carbonization reaction, and the solution obtained from the second carbonization tower continues to enter the third carbonization tower for carbonization reaction until the finished nano calcium carbonate is obtained [21]. This method is a continuous carbonization process with high production capacity and easy control of product quality. However, the equipment investment is large and the practical application is less.

Intermittent bubbling carbonization is the most commonly used carbonization method with mature technology, moderate equipment investment, and simple operation. A certain concentration of lime milk is pumped into the carbonization tower, and a certain concentration of kiln gas is introduced from the bottom of the tower for bubbling and carbonization. In order to make the reaction fast, the gas distributor is usually installed in the carbonization tower at the bottom, and the agitator and baffle plate are installed in the carbonization tower, which can improve the quality and heat transfer effect of the system, make the kiln gas more evenly enter the lime milk, and improve the reaction speed.

2.4.2. Nano Silica. Nano silica is a kind of fine powder, nontoxic, white, and amorphous. The particle size is small, and the surface contains hydroxyl group, which is easy to aggregate. Nano silica has large internal surface area, good chemical stability, light weight, good dispersion, and no combustion. Nano silica has good compatibility with other materials and can be used as other nano materials. Due to its small proportion, it is easy to fly in the air, which brings great inconvenience to transportation and storage. Nano silica has a large number of highly active silicon hydroxyl groups, which can react with most of the modifiers. It can improve the physical and chemical properties of silica surface, improve the processing performance, and optimize the performance of nano silica.

At present, the common preparation methods of nano silica are physical method and chemical method. As the name implies, the physical method is to crush the silicon aggregate into silica particles through physical methods [22]. Chemistry is the preparation of nano silica by chemical reaction, mainly including microemulsion method, sol-gel method, and high gravity method.

(1) Preparation of Nano Silica by the High Gravity Method. The overweight method is to put the filtered sodium silicate solution into a high gravity reactor according to a certain concentration, heat it to the specified temperature, add flocculant and surfactant, turn on the liquid material circulation pump, rotate the packed bed, and let carbon dioxide pass through after the temperature is stable. When the pH value is stable, stop carbon dioxide emission. Add acid to adjust pH value, keep temperature aging; finally through washing, filtering, drying, grinding, and screening, produce silica particles.

(2) Preparation of Nano Silica by the Microemulsion Method. Among these processes, controlling the synthesis of uniform nanoparticles has great attraction. The microemulsion was prepared by using octanol/TritonX-100/water/cyclohexane as raw material and nanoparticles were hydrolyzed by tetraethyl orthosilicate.

(3) Sol-Gel Method. The size of SiO_2 nanoparticles prepared by sol-gel method is different from the influence of ammonia concentration of the reactants, the type of silicates, the type of alcohols, the catalyst, and the temperature. By controlling these conditions, nano silica with different particle size and structure can be obtained [23].

3. Seismic Behavior Test of Concrete Frame Joints

3.1. Experimental Materials. Materials needed in the experiment are ordinary portland cement, sand, first-class sand ash, high-efficiency polycarboxylate water reducer, steel bar, PVA fiber, and nano silica.

When pouring concrete, it should start from the node core area and adopt the method of mechanical vibration. After pouring, it is placed on the vibration table for vibration.

The experimental samples are divided into three $200 \times 200 \times 400$ mm concrete prisms and three 200 mm × 200 mm × 300 mm concrete cubes.

3.2. Experimental Design. According to the seismic code, the frame joints should be designed as "strong column and weak beam." In order to ensure that the plastic hinge appears at the beam end first, the bearing capacity of the column end must be greater than that of the beam end. With the development of modern seismic theory, deformation capacity, stiffness degradation, ductility, and energy dissipation capacity have replaced the traditional strength indicators and become the indexes to measure the seismic performance.

Because the stress state near the bending point is the same as the actual stress state, the beam column joints in the middle story of plane frame are selected as the research object. Except for the different types of concrete materials, the other sample sizes and reinforcement are the same, and the concrete strength grade is C30.

Some scholars have shown that concrete with PVA fiber will show obvious strain hardening characteristics, and its tensile strength, toughness, and shear strength will be greatly improved. In order to study the influence of concrete on the seismic performance of joints, low cycle cyclic loading tests were carried out on frame joints of ordinary concrete, nano silica fiber reinforced concrete, and PVA fiber reinforced concrete. For simple identification, ordinary concrete, PVA fiber concrete, and nano silica fiber concrete are marked as N1, N2, and N3, respectively.

4. Analysis of Seismic Performance of Concrete Frame Joints

4.1. Fuzzy Evaluation of Urban Disaster Prevention and Reconstruction Planning. The values of urban building density, population density, ratio, earthquake suitability, earthquake resistance capacity of land and buildings, and temporary evacuation conditions are calculated, and the corresponding membership functions are generated [24]. The membership degrees are normalized. The membership degrees of qualified, basically qualified, and unqualified are 0.3598, 0.4896, and 0.0589.

The fuzzy evaluation of disaster prevention and reconstruction planning is calculated in six communities in the city.

It can be seen from Figure 1 that the building density and seismic capacity of the six communities selected in this paper are 0.658, 1.123, 0.913, 0.895, 0.935, 0.785, and 0.165, 0.569, 0.459, 0.789, 0.685, and 0.158, respectively. The six index values of the six communities selected in this paper are substituted into the corresponding membership function, and the corresponding membership degrees of the six communities can be calculated as 0.0369, 0.5123, 0.5638, 0.5469, 0.5879, and 0.0468. Other communities 1 and 6 are not qualified, so they need to be included in the key seismic reinforcement or carry out urban planning research again. In the remaining four communities, although qualified, we still need to pay attention to the building density and population density and other issues. We need to reduce the building density and population density. Otherwise, there will be an earthquake, which is not conducive to the earthquake evacuation and disaster relief.

4.2. Bearing Capacity and Deformation Capacity of Frame Joints. The bearing capacity of a member is one of the important bases to measure its seismic performance. The load reflected includes the cracking load when the core area of the frame joint is cracked and the yield load of the longitudinal reinforcement when it is in tension. When the beam end reaches the maximum bearing capacity, the ultimate load and ultimate load of the member are reduced by 15%. The bearing capacity, deformation capacity, and ductility coefficient of frame joints of ordinary concrete, PVA fiber concrete, and nano silica fiber concrete are shown in Tables 1 and 2.

Usually, in the process of reciprocating loading, due to the Bauschinger effect, the value obtained by each loading is different. In order to eliminate this error, the positive and negative data of the left end beam and the right end beam are averaged. It can be seen from Figure 2 that the values of nano silica fiber concrete in cracking, yield, limit, and failure under load pressure are much higher than those of ordinary concrete. The value of PVA fiber concrete is slightly worse than that of nano silica fiber concrete, but it is also higher than that of ordinary concrete. It can also be seen from Figure 3 that the displacement and ductility coefficient of nano silica fiber concrete are much higher than those of ordinary concrete.

It can be seen from Figures 2 and 3 that fiber reinforced concrete can significantly improve the bearing capacity, deformation capacity and ductility of samples. In particular, nano silica fiber reinforced concrete can significantly improve the deformation capacity and ductility of joints.

4.3. Stiffness Degradation of Frame Joints. In the low cycle reciprocating test, the stiffness decreases with the cyclic loading of load and displacement. The slope of the straight line between the peak point and the origin of each cycle is defined as the equivalent stiffness, which is used to characterize the stiffness of the member. In order to eliminate the influence of different batches of materials and the asymmetry of equivalent stiffness calculation caused by pre- and postloading, stiffness residual rate is used to represent the stiffness degradation of components. The stiffness residual rate formula is as follows:

$$\omega = \frac{X_y}{X_0}. \quad (4)$$

In the formula, ω is the residual stiffness, X_y is the equivalent stiffness under operating conditions, and X_0 is the equivalent stiffness of the first cycle.

The equivalent stiffness residual rates of samples N1, N2, and N3 are shown in Figure 4.

One part of the energy is dissipated by the elastic deformation of the structure, and the other part is dissipated by the inelastic deformation of the structure. It can be seen from Figure 4 that the equivalent viscous damping coefficient of the member increases with the increase of displacement after the drop $(n - 2)$ and slow growth in the loading stage and after n $(n1 - 3)$, and the growth rate of the member after reaching the yield stage is obviously accelerated and then presents the trend of slow decrease or slow increase. The main reason is that in the stage of elastic energy dissipation, the internal damage factors such as fracture development speed and internal friction of materials develop continuously, but the development speed is slow, and the equivalent viscous damping coefficient increases slowly. After the member reaches the yield stage, the concrete cracks develop rapidly, the deformation of reinforcement and internal friction of materials increase, and the formation of plastic hinge increases the rotational energy dissipation capacity of the member. When the member reaches the limit state, the crack continues to develop into concrete falling off, and the residual deformation of the component increases significantly, resulting in the slow change of equivalent viscous damping coefficient at this stage.

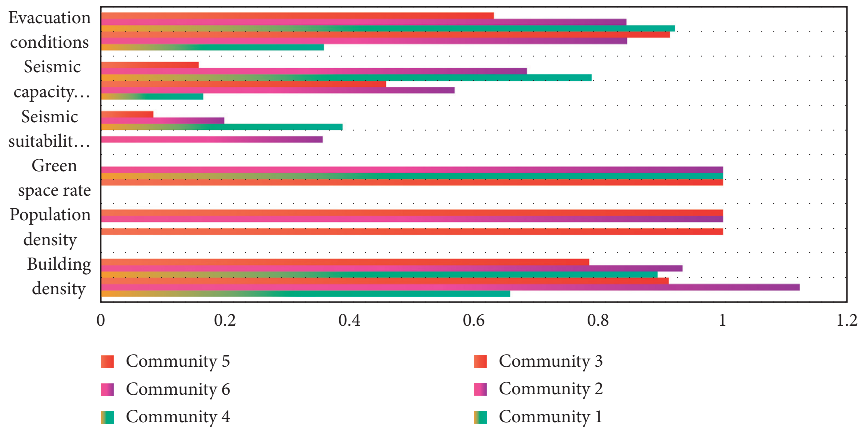

Figure 1: The value of six evaluation indexes in six communities.

Table 1: Bearing capacity of frame joints.

Experiment number		Load (kN)			
		Crack	Yield	Limit	Destruction
N1	Average value	48.69	85.65	108.35	75.65
N2	Average value	55.49	94.56	131.65	77.89
N3	Average value	76.89	95.67	145.37	79.56

Table 2: Displacement and ductility coefficient of frame joints.

Experiment number		Displacement (mm)				u
		Crack	Yield	Limit	Destruction	
N1	Average value	12.15	32.56	84.65	103.35	3.34
N2	Average value	17.35	31.65	73.56	152.42	3.65
N3	Average value	16.35	32.56	58.56	152.89	4.56

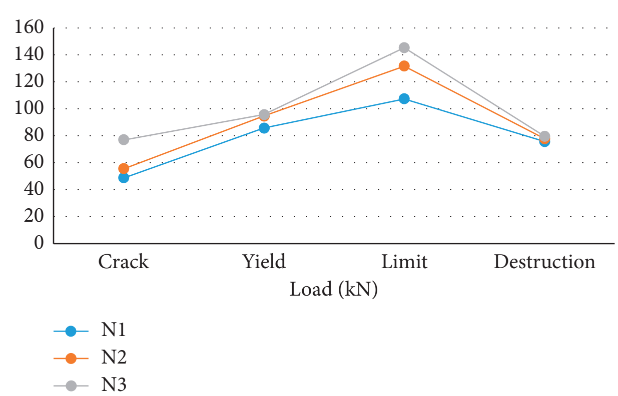

Figure 2: Bearing capacity of frame joints.

It can be seen from Figure 4 that the initial stiffness degradation values of the three groups of samples are the same. Compared with N1 sample, the displacement span of N2 and N3 samples is larger and the curve is more gentle, which indicates that the stiffness degradation of fiber reinforced concrete structure is gentle when it enters into the ductility stage, which is conducive to the structural seismic resistance. The curvature of sample N3 is small at the later stage of loading, and the stiffness degradation is slow, which indicates that nano silica fiber reinforced concrete can improve the stiffness degradation performance of joints.

5. Discussion

With the development of materials science, nanoparticles have large specific surface area, small particle size, high

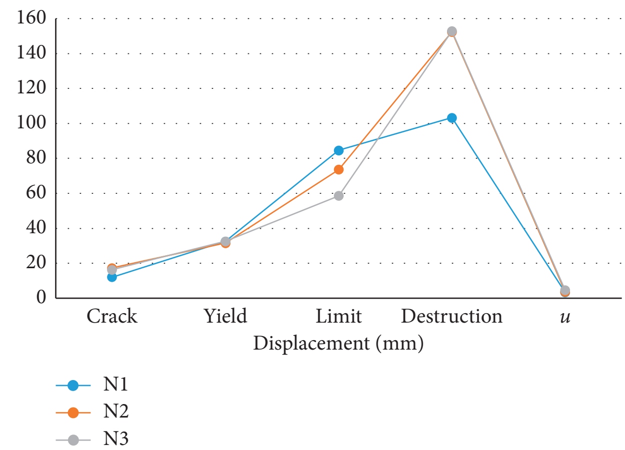

Figure 3: Displacement and ductility coefficient of frame joints.

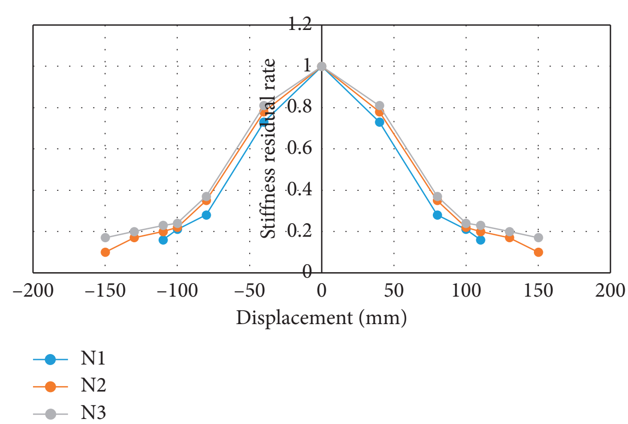

Figure 4: Node stiffness residual rate degradation curve.

surface energy, and unique nano effect. Adding nanoparticles to concrete can effectively improve the tensile strength of concrete and inhibit the early plastic cracking and crack propagation, so as to improve the crack resistance and durability of concrete.

In this paper, the bearing capacity, ductility capacity, energy dissipation capacity, and stiffness degradation of frame joints of ordinary concrete, PVA fiber concrete, and nano silica fiber concrete are compared and analyzed. The experimental results show that the frame joints with nano silica fiber concrete have good bearing capacity and ductility index. Compared with ordinary concrete, the bearing capacity and ductility coefficient of nano silica fiber concrete and PVA fiber concrete are increased by 37.8% and 15.6%, respectively. Compared with ordinary concrete frame joints, the energy dissipation capacity of nano silica fiber reinforced concrete and PVA fiber reinforced concrete frame joints is much higher. In particular, nano silica fiber reinforced concrete joints have excellent equivalent viscosity coefficient and energy dissipation capacity. Therefore, the seismic performance of nano silica fiber reinforced concrete frame joints is far superior to that of ordinary concrete frame joints.

Due to the error of the experimental method, the complex stress of the frame joints, and the limitations of the cast concrete samples, the experimental results may be affected. In this paper, only two kinds of materials, nano silica fiber concrete and PVA fiber concrete, are considered. The next step should be to consider whether there is better fiber concrete to improve the seismic performance of frame joints.

The application of nanomaterials technology requires a series of planning safeguards. The next step should be to scientifically formulate the seismic performance standards of buildings in seismic disaster prevention planning, encourage the adoption of new materials and new technologies, and improve the overall seismic level of cities. At the same time, the application standards of supervision and control of seismic technology in postdisaster reconstruction should be studied according to the design code, seismic fortification standard, project schedule, and quality requirements.

Data Availability

The data in this article are available from the corresponding author upon request.

Disclosure

The authors confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

All the authors have read and approved to submit the manuscript.

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