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Experimental study on seismic behaviour of shear wall with reinforcement of column form,concrete-filled steel tubular frames and diagonal bars

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Abstract: In order to reasearch and develop more efficient anti-seismic system of high-rise building structures, a new shear wall with reinforcement of column form,concrete-filled steel tubular frames and diagonal bars was put forward in this paper. Three shear wall specimens with different structural form were designed and made, and then tested by the low-cycle loading experiment. According to the test results, anti-seismic behaviour indexes such as failure characteristics, bearing capacity, ductility, and stiffness degradation of three specimens were analized. The ABAQUS model of new shear walls was established. The experimental results show that, compared with other specimens, the anti-seismic energy dissipation capacity and bearing capacity of the shear wall specimen with reinforcement of column form,concrete-filled steel tubular frames and diagonal bars is enhanced significantly, and the process of stiffness degradation is more slow. The column-form reinforcement can improve ductility, and the concrete-filled steel tubular frames can guarantee the lateral stiffness.

1. Introduction

The shear walls and tubular structures play an important role in aseismic of high-rise building structure. Because the traditional common reinforced-concrete shear wall is difficult to meet aseismic requirements on large and complex high-rise building, it makes sense to research and develop the shear walls with the superior ability of aseismic in the current[1].

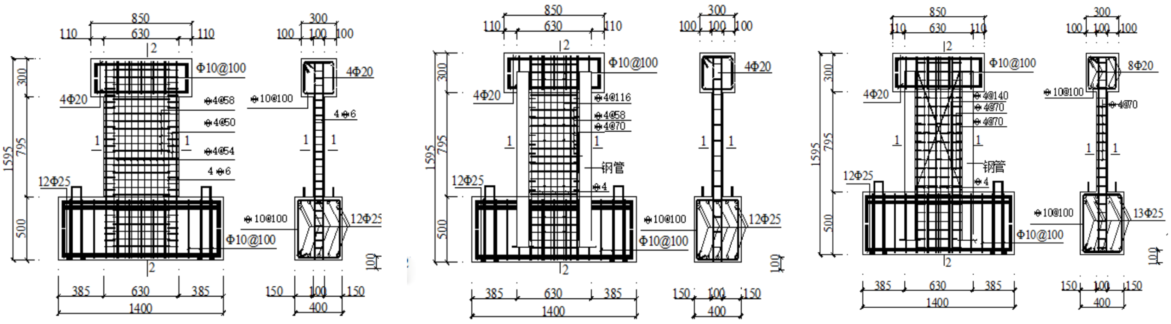
Experts and scholars at home and abroad made a lot of research about the new shear walls. Bailiang[2]made experiments about a new shear wall with high concrete constrained by steel tube. The experimental results show that the seismic performance of specimen is suprior. The bearing capacity of the specimen decreases slowly and the deformability of the specimen is obviously improved due to the restraining effect of the steel tubular frames. John Wallace[3] designed and made two pieces of common concrete shear wall specimens and four pieces of concrete-filled steel tubular shear wall specimens, and carried out low-cycle loading experiment on six pieces of shear wall specimens. The experimental reasults show that the shear wall set steel tube has great integrity. The bearing capacity, energy consumption and ductility of concrete-filled steel tubular shear walls specimens are stronger. Low-cycle loading experiment was carried out on four pieces of shear wall specimens with diagonal bars by Cao wanlin[4]. The research results show that the diagonal bars effectively limit the development of the oblique cracks and significantly improve the energy dissipation capacity of the specimens. Yin Yue[5] analyzed the hysteretic behavior of plasterboard wall reinforced with in-filled RC columns under low-cycle loading. The results indicate that walls have plump hysteretic curves. It has great energy dissipation capacity and better aseismic performance. The finite element software ABAQUS was used to simulate the bottom slotted shear wall in the low-cycle loading experiment by Dangxiangliang[6].The research results show ABAQUS software could simulate the whole process of the experiment realistically, and the results of simulation are consistent with the experimental results, which proves the correctness of the numerical analysis .

On the basis of current results of research, a new shear wall with reinforcement of column form,concrete-filled steel tubular frames and diagonal bars was presented in this paper.

2. Test condition

2.1 Design of shear wall specimens

Three shear wall specimens were designed and made in this experiment. [7]The number of three shear wall specimens was SW,GSW,ZSW respectively. The geometric size and reinforcement of the specimens were shown in Figure1.



(a)SW (b)GSW (c)ZSW

Figure 1. Wall size and reinforcement drawing

2.2 Loading device

The experimental device was servo control system, and the speicimens were tested under the reaction frame during the experiment. The experimental loading devices were shown in Figure 2.

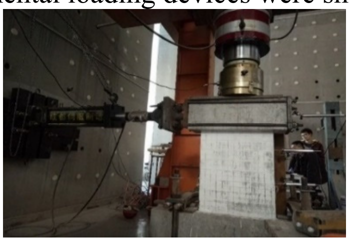


Figure 2. Loading device

3. Failure mode

The Specimen SW was damaged after 8 cycles of loading. The cracks were mainly concentrated on the middle and low parts of the wall. The bearing capacity was low, and the ductility was poor. The Specimen GSW was damaged after 12 cycles of loading. The cracks were crossed, and the concrete was crushed down. The steel tube buckled. The specimen ZSW was damaged after 10 cycles of loading. The wall had good ductility and high bearing capacity.The cracks extanded on the whole wall. Steel tube buckled and concrete was crushed down.

(a) SW (b)GSW (c)ZSW

Figure 3. Failure mode

4. Analysis of experiment

4.1 Bearing capacity and ductility performance

The F_{cr} ,F_y ,F_m is cracking loading, yielding loading,max loading respectively. The U_{cr} ,U_y ,U_d is cracking displacement, yielding displacement,destroying displacement respectively.μis ductility coefficient. θ_u is angle of max displacement.

Table 1 The value of loading and dispalcement

Wall	F_{cr} (KN)	F_y (KN)	F_m (KN)	U_{cr} (mm)	U_y (mm)	U_d (mm)	μ	θ_u
SW	39.7	94.29	113.1	0.89	6.88	18.57	2.70	0.0197
GSW	48.6	221.4	267.0	0.92	12.35	37.32	3.02	0.0395
ZSW	50.2	245.6	318.0	1.23	16.00	49.10	3.06	0.0520

According to the table1, compared with other shear walls, specimen ZSW characteristic value is obviously high.The speciemem ZSW have superior aseismatic performance.

4.2 Energy consumption

The energy dissipation coefficient E is usually used to indicate energy dissipation capability of the shear wall specimens[8]. The curve of displacement-energy dissipation coefficient is shown in figure5.

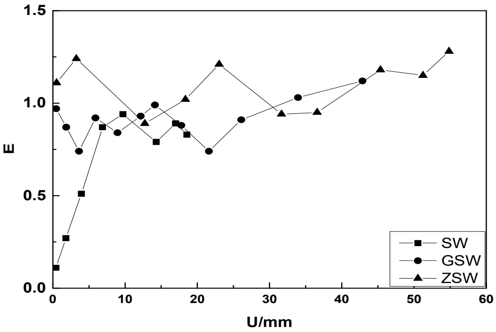


Figure 4. The curve of displacement-energy dissipation coefficient

According to figure5, E of the specimen ZSW is significantly larger and substantially greater than 1 compared with other specimens. The specimen ZSW has a superior ability of enengy consumption.

4.3 Stiffness degradation

The equivalent stiffness degradation coefficient is used to describe the degree of stiffness degradation[9], and that is equal to stiffness K of that cycle divided by the initial stiffness K_0 . The relation between stiffness degradation coefficient and the angle of displacement is shown in Figure5.

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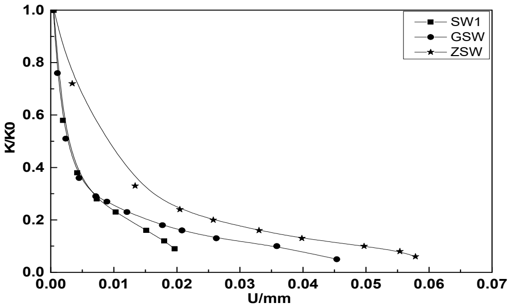

Figure 5. The curve of equivalent stiffness degradation cofffcient

According to Fig5,the stiffness degradation process of the specimen ZSW is slow, and the specimen ZSW has certain stiffness when it is destroyed.

5. Finite element model

5.1The constitutive relation of concrete and steel

Concrete: the constitutive model of Liu wei is used. That model corrects the peak strain and the descending section of the curve, and can truly reflect the stress of concrete.

Steel: In order to simplify the calculation and take into account the harden effection of steel after yield, the stress and strain of steel is selected as a model of double-fold line

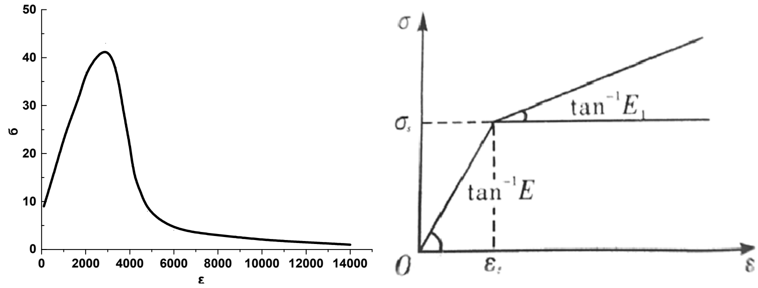

Figure 6. The constitutive relation of concrete and steel

5.2 The section of units and mesh generation

The units of C3D8R is adopted by the concrete and steel tube. It is corresponding to the actual situation and it is easy to converge in caculation. The units of T3D2 is used by reinforcement, and that only withstand axial loading of tension and compression[10]. Mesh generation is shown in figure7.

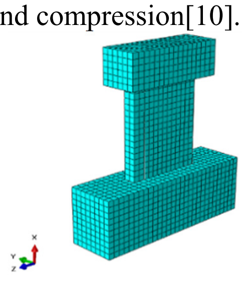
Figure 7. Mesh generation of model

5.3 Contact setting

The normal contact surface of steel tube and in-filled concrete is defined as hard contacting, and tangential contact surface is defined as the model of coulomb friction to transfer shear stress. The concrete-filled steel tubular, loading beam, foundation beam and wall contact are all tied together to make the model become a whole. Embedded region is used as the contact between reinforcement and concrete of the wall.The reinforcement is distributed to the concrete of the wall.

5.4 Boundary conditions and loading mode

The condition of the foundation beam is set as fixed boundary. That is, the foundation beam does not have any displacement and rotation. Then apply a vertical loading on the top of loading beam and apply a horizontal displacement on the side of the loading beam.

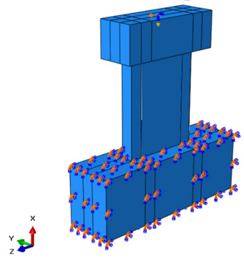

Figure 8. Boundary conditions and loading mode of model

6. Finite element analysis

6.1 Stress nephogram

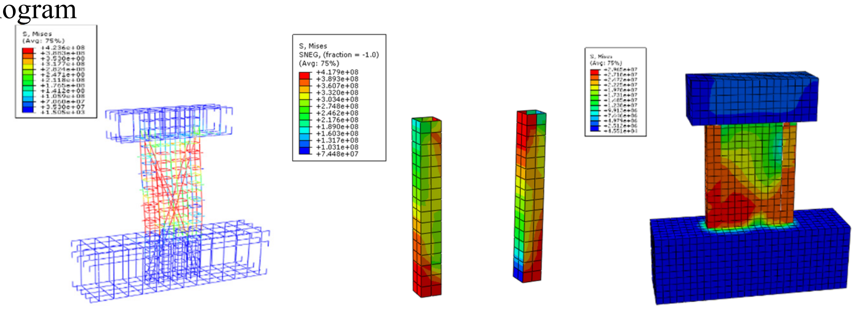

Figure 9. Stress nephogram

When the specimen ZSW is destroyed, the concrete of the wall fall down. On one side, the foot of steel tube has large buckling area under compression and a certain degree of upswelling and tearing. The wall has a certain deformation, and the stress concentration is obvious. On the other side, the foot of steel tube is pulled to yield. The results of simulation are basically consistent with the experimental failure modes, and it can reflect the destruction of the wall.

6.2 Simulation of skeleton curve

The skeleton curve can reflect the relationship of loading- displacement. The skeleton curves obtained from the simulation are compared with the skeleton curves obtained from experiment.

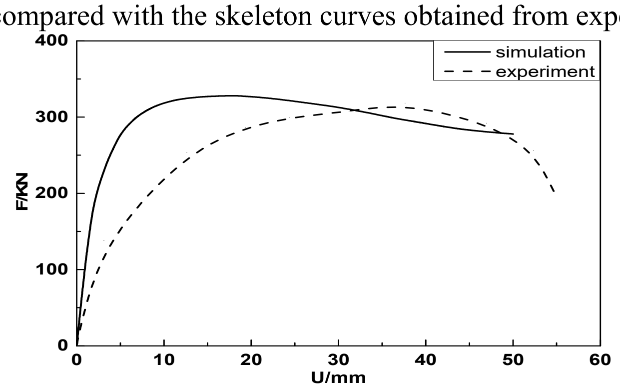

Figure 10. Skeleton curve of simulation and experiment

The experimental skeleton curve is similar to the simulated skeleton curve, which shows that the ABAQUS simulation could simulate the actual situation of the wall. Simulation of ZSW has certain value of reference.

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7. Conclusion

1.Compared with other specimens, the bearing capacity, ductility and energy consumption capacity of the new shear wall specimen ZSW are significantly improved, and stiffness degradation of specimen ZSW is more slower. That wall shows good seismic performance.

2. According to the results of ABAQUS simulation, the model of specimen ZSW can better reflect the actual stress and failure mode of shear wall. Simulation of ZSW has certain value of reference.

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