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Finite element analysis of seismic behavior of FRP reinforced concrete frame structure

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Abstract. A finite element model of FRP reinforced concrete frame structure is established to analyze the structural performance of FRP reinforced concrete frame. The load displacement hysteretic curve, skeleton curve and ductility of the AFRP reinforcement, CFRP bar and GFRP reinforced concrete frame model are analyzed. The results show that the bearing capacity of the CFRP reinforced concrete frame is the highest, and the AFRP coagulation is used for the concrete frame. The GFRP reinforced concrete frame is the smallest, and the reinforced concrete frame model with AFRP reinforcement is the best in the three types of FRP reinforced concrete frame models.

1. Introduction
Fukuyama and other researchers studied the stress conditions of the AFRP reinforced concrete frame structure under low cyclic loaded, and analyzed its structural performance. The test showed that it is feasible to apply the FRP bars to the frame structure design, and the frame can show a certain ductility. The research on FRP reinforced concrete members mainly concentrates on the study of the single concrete members, especially the mechanical properties of the FRP beams and columns, and the research on the overall performance of the FRP reinforced concrete frame structure is relatively small, so it is necessary to study the progressive system of the concrete frame structure of the FRP bars. Therefore, the finite element software ABAQUS software is used to analyze the seismic behaviour of the braced concrete frame considering the node model.

2. Structural design
FUKUYAMA et al. designed a 3 story pure frame structure (as shown in Figure 1), which had a height of 3.6m, a two span in the direction of the X axis, a span of 7m, a three span in the direction of the Y axis, and a span of 5.5m. The reinforced bars and stirrups of concrete members such as beams, plates, columns are all made of aramid bars (AFRP bars), and the strength of concrete design is C30. The specimen used in the test is designed according to the 1/2 proportional model of the designed building.

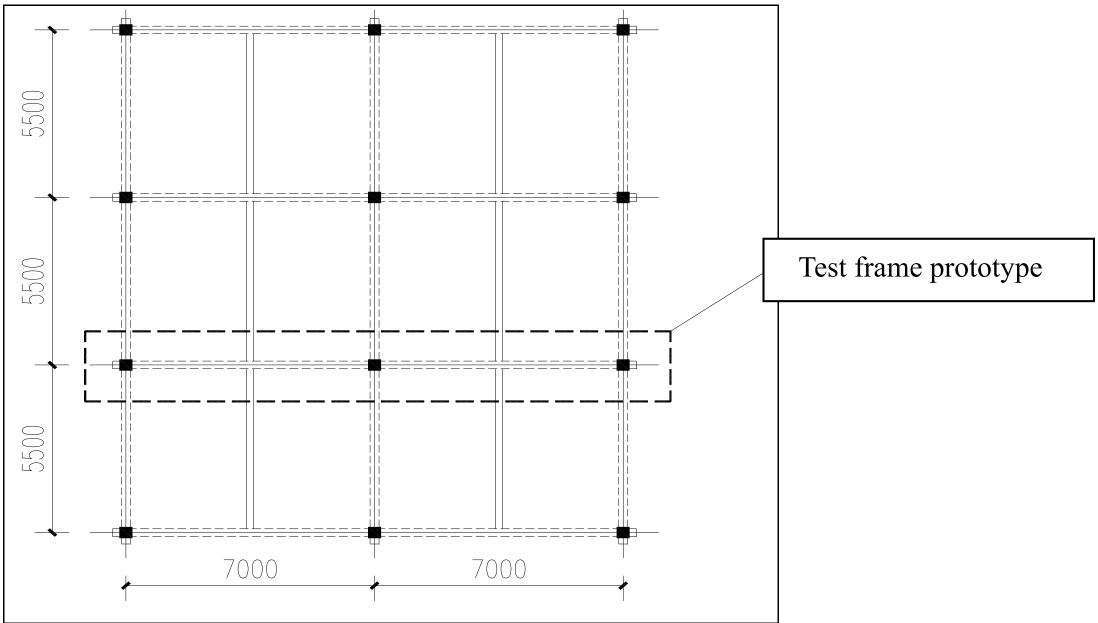

Figure.1 building plan

3. Model establishment

Finite element software ABAQUS is used to model the FRP bar frame as a whole. This simulation does not need to consider the bending effect of FRP bars, so the FRP bar selects the two node linear truss element in the Truss space unit, that is, the T3D2 unit. It is necessary to study the stress of the FRP reinforcement and the concrete material, so in view of the characteristics of the above three modelling methods, the model should be established by the separation modelling method. Referring to the size of the frame structure, the length of the concrete unit is 75mm, the length of the FRP bar is 50mm, and the mesh results of concrete and FRP bars are shown in Figure 2 and Figure 3.

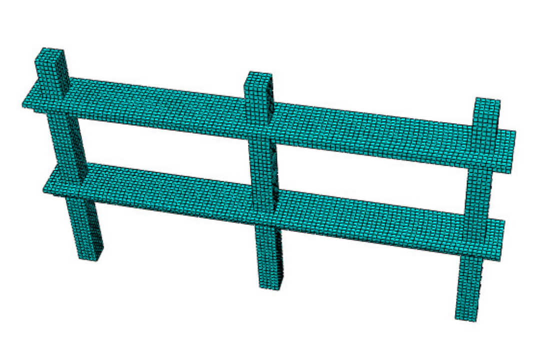

Figure 2. Partition of concrete mesh

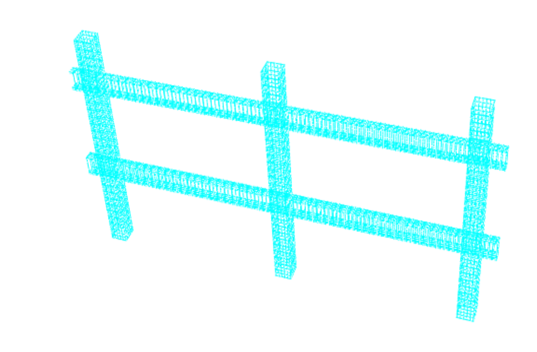

Figure 3.Partition of FRP bars mesh

The FRP reinforced concrete frame specimens are cast with the base as a whole, so the position of the bottom of the column can be considered as consolidation. Therefore, the fixed constraints should be imposed on the section of the column bottom to limit all the displacement of the column root section .A more complete hysteretic curve is obtained to simulate the stress situation of FRP reinforced concrete frame under repeated low cyclic loading, and the seismic performance analysis of the frame structure is convenient to follow. The three pillars are coupled to a reference point, and the horizontal displacement is applied to the reference points.

In the numerical simulation process, when the FRP bar reaches its ultimate tensile strength, the calculation terminates .The finite element models of AFRP, GFRP and CFRP reinforced concrete frames are established respectively. The constitutive relation of GFRP bars and CFRP bars is used to determine the constitutive relation of bonded sand GFRP bars and CFRP bars produced in Shanghai by the mechanical properties test of FRP reinforcement, and the constitutive relation of AFRP bars for the constitutive relation of the AFRP reinforcement materials used in the test of AFRP reinforced concrete frame structures.

4. Seismic performance analysis of FRP reinforced concrete frame structure

4.1. Analysis of skeleton curve

Through the numerical simulation of the concrete frame structure with different FRP bars, the load displacement hysteretic curves of the AFRP, CFRP and GFRP reinforced concrete frame models under the load are obtained respectively. Comparing the load displacement skeleton curves of the above three FRP reinforced concrete frame models and the test frames, we can draw the following conclusions:

(1) The load displacement skeleton curve is not the time standard antisymmetric shape, and the load value of the reverse loading point is greater than that of the forward loading point. The main cause of this phenomenon is the larger residual deformation of the model when the forward displacement load is applied to the model, while the reverse loading must first offset this part of the residual deformation to be loaded to the target displacement, so the load value of the reverse loading is slightly greater than that of the forward loading.

(2) Skeleton curves can be roughly divided into three segments: ascending section, oblique straight line segment and subsequent growth section. As the load continued to increase, the damage of concrete increased, and the load was mainly supported by FRP bars, and the bearing capacity of this stage increased further.

(3) Among the three types of frame models, the bearing capacity of the CFRP reinforced concrete frame model is the highest, the AFRP concrete frame model is the second, and the GFRP reinforced concrete frame model is the smallest. The main reason is that the elastic modulus and ultimate tensile strength of CFP bars are larger than those of AFRP bars and GFRP bars, and GFRP bars are the smallest.

(4) The load displacement skeleton curve of the GFRP reinforced concrete frame model is very close to the corresponding part of the skeleton curve of the AFRP reinforced concrete frame model. The reason is that the elastic modulus of the two kinds of FRP reinforcement materials used in the simulation is very close.

4.2. Finite Element Analysis of Composite Ring Damper Analysis of ductility

In this paper, the ductility coefficient of the displacement ductility factor is used to evaluate the ductility of the FRP reinforced concrete frame structure model. The yield displacement and load of three kinds of numerical models and three chapter AFRP reinforced concrete frame specimens are calculated respectively. The displacement ductility coefficient is calculated and compared. The limit displacement of the frame structure is calculated when the FRP reinforcement reaches the ultimate tensile stress. The calculation results are shown in table 1.

Table 1 . Calculation result of displacement ductility coefficient

Type of frame FRP bars	Yield displacement （mm）	Limit displacement （mm）	Displacement ductility coefficient
Test pieces of AFRP	44.6	195	4.37

bars			
AFRP bars	42.1	212	5.03
CFRP bars	32.8	150	4.57
GFRP bars	22.8	60	2.63

Table 1 data shows that comparing the results of three types of FRP reinforced concrete frame model, it is found that the displacement ductility of the AFRP reinforced concrete frame model is the largest, which indicates that the ductility of the AFRP reinforced concrete frame structure is the best. The displacement ductility factor of GFRP reinforced concrete frame model is less than that of CFRP concrete frame model, which indicates that the GFRP reinforced concrete frame model has poor ductility.

5. Conclusion

(1) The mechanical properties of the single fiber type FRP bars have some shortcomings, or the elastic modulus is low, or the ductility is poor. The hybrid fiber reinforcement with better mechanical properties can be applied to the concrete frame to study the seismic performance characteristics of the single fiber type.

(2) There are many factors affecting the ductility of concrete frame structure. The influence of some factors such as concrete strength, reinforcement ratio and axial compression ratio on the ductility of FRP reinforced concrete frame structure should be further studied, and more reasonable suggestions for structural design should be put forward.

(3) FRP bars have high tensile strength and can be used as prestressed bars in concrete structures to study their stress characteristics.

Acknowledgments

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