Comparative analysis of concrete frame structure models with CFRP bars and GFRP Bars

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Abstract. In this paper, the finite element model of FRP reinforced concrete frame structure is established, and the seismic performance characteristics of CFRP bars and GFRP Bars concrete frame models are analyzed, such as stiffness degradation, strength attenuation, energy dissipation capacity, etc. The stiffness of CFRP reinforced concrete frame model is obviously greater than that of CFRP reinforced concrete frame model. The stiffness degradation curves of the two FRP reinforced concrete frame models are consistent, and the strength attenuation and energy dissipation capacity of GFRP reinforced concrete frame structure are better than that of CFRP reinforced concrete frame structure.

1. Introduction

Structural stiffness refers to the ability of a structure to resist deformation. Stiffness degradation refers to the phenomenon that the stiffness of the structure will gradually decrease with the influence of concrete cracking, crack development and other factors under repeated load. Stiffness degradation is also a main factor of structural seismic performance degradation, so it is necessary to study the stiffness degradation and analyze the stiffness degradation law.

2. Stiffness degradation analysis

Structural stiffness refers to the ability of a structure to resist deformation. Stiffness degradation refers to the phenomenon that the stiffness of the structure will gradually decrease with the influence of concrete cracking, crack development and other factors under repeated load. Stiffness degradation is also a main factor of structural seismic performance degradation, so it is necessary to study the stiffness degradation and analyze the stiffness degradation law. From the load displacement hysteretic curve, it can be seen that the stiffness of the member is related to the number of repeated loading and stress level. Due to the loading, unloading, forward and reverse repeated tests, and stiffness degradation, the stiffness problem is very complex. According to the load displacement skeleton curve, the stiffness degradation curve of FRP reinforced concrete frame model is drawn and compared, as shown in Fig. 1.
By analyzing and comparing the stiffness degradation curve characteristics of the above several FRP reinforced concrete frame models, the following laws can be obtained:

(1) The trend of stiffness degradation curve of FRP reinforced concrete frame model is consistent. When the displacement load is small, the stiffness of the structure is large; with the increase of the load, the stiffness begins to degrade, and the stiffness degradation is rapid in the early stage, which is mainly due to the continuous emergence of new cracks in concrete and the continuous development of shear cracks, resulting in the increase of concrete damage; in the later stage of loading, due to the stability of concrete damage, the degradation of model stiffness tends to slow down;

(2) In comparison, the stiffness of the CFRP reinforced concrete frame model is significantly greater than that of the GFRP reinforced concrete frame model. In the final analysis, the elastic modulus of CFRP bars is relatively large.

3. Strength attenuation analysis

Strength attenuation refers to the phenomenon that the strength of concrete structure will decrease with the increase of the number of cycles under the action of low cycle repeated load. The faster the strength attenuation is, the faster the bearing capacity of the components decreases. In the earthquake, the ability of the structure to continue to resist the earthquake action decreases. The degradation coefficient of bearing capacity is usually used to evaluate the attenuation of structural strength. The degradation coefficient of bearing capacity is the ratio of the peak load of the second cycle to the peak load of the first cycle when the structure reaches the same displacement, which is calculated according to formula 1.

$$\lambda = \frac{P_{2 \text{max}}}{P_{1 \text{max}}} \quad (1)$$

According to formula 1, the bearing capacity degradation coefficient of two types of FRP reinforced concrete frame models at partial displacement position is calculated, and the specific calculation results are shown in Table 1.

| model | 10mm | 25mm | 50mm | 100mm | 150mm |
|-------|------|------|------|-------|-------|
| CFRP  | 0.973| 0.965| 0.952| 0.948 | —     |
| GFRP  | 0.979| 0.969| 0.961| —     | —     |
According to the analysis of bearing capacity degradation coefficient of FRP reinforced concrete frame model in Table 1, it can be seen that:

(1) At the beginning of loading, the value of $\lambda$ is larger, which indicates that the strength of the model decreases slowly; with the increase of load, $\lambda$ decreases, which indicates that the damage of concrete is aggravated and the strength attenuation is increased; from the degradation coefficient of bearing capacity of CFRP bars, in the later stage of loading, $\lambda$ increases, at this time, the degradation attenuation of FRP bars is slowed down;

(2) Overall, the bearing capacity of GFRP reinforced concrete frame model is slightly larger than that of CFRP reinforcement, which indicates that the strength attenuation of GFRP reinforced concrete frame structure is better than that of CFRP reinforced concrete frame structure.

4. Analysis of energy consumption capacity

The energy dissipation performance of a structure is an important basis for its seismic performance evaluation. If the structure has good energy dissipation performance under a certain strength guarantee, a large part of the energy absorbed by the structure can be consumed in the earthquake process, so that the structure will not produce serious damage. The energy dissipation capacity of the structure is generally measured by the area surrounded by the hysteresis loop. If the area surrounded by the hysteresis loop is large, the energy consumption capacity of the structure is good; on the contrary, if the area surrounded by the hysteresis loop is small, the energy consumption capacity of the structure is poor. The viscous damping coefficient $h_e$ can be used to evaluate the energy dissipation capacity of the structure or member. The specific calculation of $h_e$ can be calculated according to figure 2. The equivalent viscous damping coefficients of two kinds of FRP reinforced concrete frame models are calculated respectively. The calculation results are shown in Table 2.

![Figure 2](image_url)

**Table 2 calculation results of equivalent viscous damping coefficient**

| model   | CFRP | GFRP |
|---------|------|------|
| $h_e$   | 0.315| 0.374|

Comparing the equivalent viscous damping coefficient of two kinds of FRP reinforced concrete frame models, it can be seen that the GFRP reinforced concrete frame model is slightly larger than the CFRP reinforced concrete frame model, which indicates that the GFRP reinforced concrete frame structure has strong energy dissipation capacity, while the CFRP reinforced concrete frame structure has poor energy dissipation capacity.

5. Conclusion

Through numerical simulation of two kinds of FRP reinforced concrete frame models under horizontal load, the seismic performance characteristics of hysteretic curve and skeleton curve, ductility
performance, stiffness degradation, strength degradation and energy dissipation capacity of the models are analyzed.

1. The stiffness degradation curves of two kinds of FRP reinforced concrete frame models are consistent. The stiffness of CFRP reinforced concrete frame model is obviously higher than that of GFRP reinforced concrete frame model. The stiffness of CFRP reinforced concrete frame model is obviously higher than that of GFRP reinforced concrete frame model;

2. The strength attenuation of GFRP reinforced concrete frame structure is better than that of CFRP reinforced concrete frame model;

3. The energy dissipation capacity of GFRP reinforced concrete frame structure is stronger than that of CFRP reinforced concrete frame structure.

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