Seismic Performance of Carbon Fiber Reinforced Concrete Bridge

Ge Hong

School of Business Administration
Nanchang Institute of Technology
Nanchang city, Jiangxi province, 330099, China.
email:634615114@qq.com

***Abstract* — The carbon fiber sheet reinforced concrete frame structure can effectively improve the ultimate bearing capacity and the entire energy dissipation capacity and maintain the frame rigidity and stability. It has more apparent reinforcement effect on the frame which gets the carbon fiber reinforcement directly. We take "the strong column weak beam, and strong node weak component" as the seismic design principle and design three reinforced concrete frames models according to the ratio of 1:2 of reduced scale. And the three frames models all should be designed according to the same size and section reinforcement so as to keep the loading systems consistent. Among them, KJ – 1 is the comparative frame model without any reinforcement, and KJ-2 is the frame model which gets the reinforcement and strengthening after we push and pull till the frame yields. It simulates the reinforced problems caused by the structure damages due to the accidental function and other factors. KJ-3 is the direct reinforcement frame model. It has the same reinforcement form with KJ-2. It simulates the reinforced problems caused by the insufficient bearing capacity for changing the use function of buildings and other reasons.**

Keywords - carbon fiber; reinforcement;bridge frame; bearing capacity; seismic performance

I. INTRODUCTION

In order to better learn the response of CFRP reinforced concrete frame structure under an outside load and its seismic performance, conducting low reversed cyclic load test to simulate the seismic response is an effective way. Reinforced concrete frame structure is the widely used aseismic structure form. We conduct the reinforcement and strengthening on the beams, columns and beam-column joints and other full scale and reduced scale structure models of reinforced concrete structure. The researchers at home and abroad have done many jobs on the test research of response and performance under all sorts of static and pseudo-static actions. However, we still haven't seen too much about the test research on low reversed cyclic load of reinforced concrete frame structure under the pseudo-static action yet. This test is proposed to design the three reinforced concrete model frames to conduct low reversed cyclic load test and for two frames among them we should conduct the reinforcement and strengthening on the carbon fiber sheet in different periods to analyze and discuss the mechanical performance of three frames[1].

In order to better learn the seismic performance of CFRP reinforced concrete frame structure, conducting low reversed cyclic load test to simulate the seismic response is an effective way. Reinforced concrete frame structure is the widely used aseismic structure form. The researchers at home and abroad have done many jobs on the test research of response and performance of beams, columns and frame joints under all sorts of static and pseudo-static actions. However, we still haven't seen too much about the response test research on the reinforced concrete frame structure under the pseudo-static action yet. Referring to the current design code of our country, we perform a simulation analysis of reinforcement problems brought by different reasons, and based on the actual working condition of practical engineering we make three reinforced concrete frames model with single span and single story in this paper. Then we discuss the change law of model characteristics, the framework's ultimate bearing capacity, the overall stiffness, the ductility and the energy dissipation capacity with the development of the cracks and elasticoplastic deformation. KJ – 1 is considered as the comparative frame model, so it doesn't need any reinforcement. KJ-2 stimulate the problems caused by the damages due to long-term use or occasional case so that we conduct the carbon fiber reinforcement and strengthening[2]. After the frame is loaded till it yields we conduct the carbon fiber reinforcement to be proposed to investigate the mechanical properties and reinforcement effect of the CFRP reinforced damaged reinforced concrete frame. KJ-3 simulates the reinforced problems caused by the faults in the design, the change of use function and others to make the direct reinforcement on the carbon fiber sheets. And we should make the reinforcement design and the paste location be all consistent with KJ – 2 to be proposed to investigate the mechanical properties and reinforcement effect of the CFRP reinforced damaged reinforced concrete frame.

II. THE DESIGN AND FABRICATION OF MODEL

A. The Design of Model

According to the current design specification of our country, we take "the strong column weak beam, and strong node weak component" as the seismic design principle and design this test model of reinforced concrete frame structure, taking the general building frame as the prototype with the ratio of 1:2 of reduced scale. We are proposed to design three frames with single span and single story which have the consistent material, the size, and the loading system in this test. The column grid layout diagram is shown in Figure 1, and the shaded part in the figure is the prototype of the obtained frame.

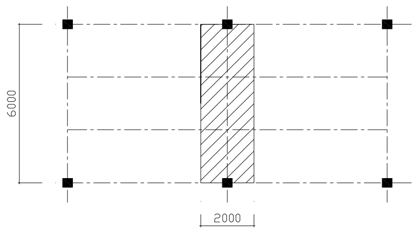


Figure 1 The column grid layout diagram of frame prototype.

1) The dimensional determination

Based on the similar theory of model test, we first determine the model geometry similarity constant $C_l = \frac{1}{2}$, and stipulate that the model material and the stress should be consistent with the prototype, namely $C_E = 1$， $C_\sigma = 1$ in the test. Then based on the corresponding relation of each physical quantity in the model and each physical quantity in the prototype, we can get the relation of each physical parameter between the model and the prototype. It is shown in TABLE I.

TABLE I THE RELATION OF EACH PHYSICAL PARAMETER BETWEEN THE MODEL AND THE PROTOTYPE

	Span	**Area**	**Stress**	**Elastic Modulus**	**Concentrated Force**	**Bending Moment**	**Deflection**
Prototype	L	A	σ	E	F	M	f
Model	$\frac{L}{2}$	$\frac{A}{4}$	σ	E	$\frac{F}{4}$	$\frac{M}{8}$	$\frac{f}{2}$

Known from the Table 1, there is a corresponding relationship between the similarity coefficient of the load, the bending moment and the deflection and the similarity coefficient of the length, namely $C_P = C_l^2$ ， $C_M = C_l^3$ ， $C_f = C_l$ .. According to the design regulation and the reduced scale proportionality coefficient of the general building space, we can get that the separation distance of the model frame's horizontal span on the axis among the columns model frame's horizontal span is 3m, the separation distance of the story height from the beam top of mudsill to the beam axis of frame is 1.5m, the cross-sectional dimension of beam specimens is 150mm×250mm, and the cross-sectional dimension of column is 250mm×250mm.

2) The arrangement of stress

In order to simulate the stress state of frame in the actual structure, according to the axial pressure arranged by the frame prototype on the capital, we take the axial compression ratio as 0.15 to calculate the axial pressure of the capital. We arrange the vertical concentrated load at the location of the third point make it be equivalent to the dead load of secondary beam transfer. We exert low reversed cyclic load in the horizontal direction to stimulate the horizontal seismic action under frequently occurred earthquake[3-4]. While designing we should calculate according to the size of frame prototype and then make the data be converted to the stress size of frame model through the similarity coefficient.

The specific calculation process is as follows:

The axial pressure of capital:

$$N = 0.15 f_c b h_0 = 0.15 \times 11.9 \times 500 \times 460 = 410.55kN$$

The vertical concentrated load at the third point among the beams:

We take the thickness of plate as $80mm$ and make the dead weight of plate be converted to the concentrated load and be transferred to the frame beam.

$$0.08 \times 2 \times 6 \times 25 = 24kN$$

The action of horizontal load:

By the calculation, we get the representative value of frame prototype gravity load $G = 890kN$ and the horizontal seismic force $P_{EK} = G_{eq}\alpha$.

The horizontal earthquake influence coefficient α has the relationship with the characteristic period value T_g and auto-oscillation period T . And it is shown as follows.

$$T_g = 0.65s \text{ ,}$$

$$T = 2\pi\sqrt{\frac{Wl^3}{3EIg}} = 2\pi\sqrt{\frac{0.89 \times 10^6 \times 3^3 \times 12}{3 \times 3 \times 10^{10} \times 0.5^4 \times 9.8}} = 0.45s$$

Next we take $\alpha = \alpha_{\max} = 0.08$ (According to the frequently occurred earthquake)

Then $P = \alpha G = 0.08 \times 890 = 71.2kN$ so we make $P = 72kN$.

Finally we calculate the design loads of model frame at each location according to the relations of physical parameters between the model and prototype.

The axial force of capital: $N = 100kN$

The vertical concentrated load at the third point among the beams: $F = 6kN$

The horizontal force: $P = 18kN$

The geometric dimension and stress arrangement of frame model can be seen in Figure 2.

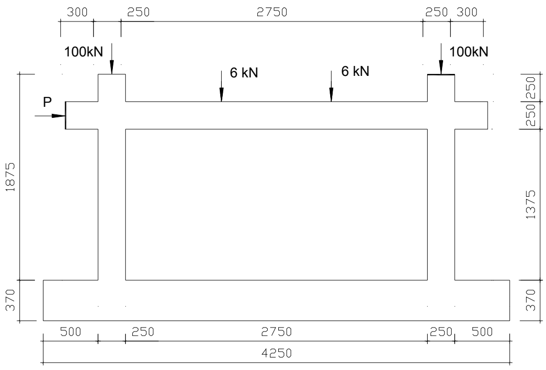


Figure 2 The dimension and stress arrangement of model

3) The cross-section reinforcing bars

For the frame prototype structure, based on the reinforcing bars of design loads on the cross-section of beam are all in the design scope of suitable reinforcement cross-section we should take "the strong column weak beam, and strong node weak component" as the principle to design. However, the bearing capacity of cross-section is relatively surplus and we carry on the enhancement processing on the beam column node area to prevent the node area from the shear failure[5-7]. And then we expect to form the plastic hinge at the frame beam end to constitute the mechanism form of beam failure. Finally according to the relationship of physical parameters between the prototype and the model, then we get the reinforcement quantity of model cross-section. The the reinforcement quantity of model can be seen in TABLE II.

TABLE II THE REINFORCING BARS OF FRAME MODEL

Frame Number	Main Bar of Beam	Beam Stirrups		Main Bar of Column	Column Stirrups	
		The Non-encryption Section	The Encryption Section		The Non-encryption Section	The Encryption Section
KJ-1,2,3	$\Phi 12$	$\varphi 6$ @100	$\varphi 6$ @70	$\Phi 18$	$\varphi 6$ @105	$\varphi 6$ @70

In order to prevent the concentrated force from crushing the local concretes in the frame node area, we make the concrete beam end stretch 250mm out of the node area to all guarantee that the stressed steel bar have enough anchorage length. So the size of mudsill cross-section is large enough so as to guarantee that the stiffness meets the requirements. The reinforcement scheme of test frame can be seen in following TABLE III.

TABLE III THE REINFORCEMENT SCHEME OF FRAME

THE FABRICATION OF MODEL

Frame Number	Reinforcement Scheme	Paste Parts and Scope of Carbon Fiber	Stories	Anchorage Arrangement
KJ-1	/	/	/	/
KJ-2	reinforcement after the yield	both 500mm near beam end and column end in the node area	one story	The lapped length is 150mm with the enclosed paste
KJ-3	direct reinforcement	both 500mm near beam end and column end in the node area	one story	The lapped length is 150mm with the enclosed paste

4) Model materials

We adopt the commercial concrete with the strength grade C25 commonly used in the project in the test model. For the model, three frames are casted during the same period. As far as the test specimens are concerned, we reserve a set of test specimen with three concrete test cubes of $150 \times 150 \times 150mm^3$ and a set of test prismoids of $150 \times 150 \times 300mm^3$. The ages of test cubes and prismoids are the same with the test specimens to determine the strength and elastic modulus of concrete materials. In the process of model fabrication the template adopts the vertical support so as to make it be consistent with the construction in actual engineering. We should maintain the test specimens and templates at the same time to make the material performance test be conducted in the structure laboratory. We should make the concrete test cubes be put on the standard pressure testing machine for loading. The indicators of the actual measured concrete strength are shown in TABLE IV.

The compressive strength of concrete cube test specimens with the actual measurement should calculate according to the following formula $f_{cc} = \frac{P}{A}$.

DOI 10.5013/IJSSST.a.17.11.10 ISSN: 1473-804x online, 1473-8031 print

TABLE IV HE COMPRESSIVE STRENGTH OF CONCRETE CUBE TEST SPECIMENS WITH ACTUAL MEASUREMENT

Test Specimen Number	1	2	3	Average Value
Failure Load$P(kN)$	449	477	447	457.7
$f_c(N/mm^2)$	$20.3N/mm^2$			

There are three kinds of frame reinforcing bars in the test, HPB235 Gradeφ6、HRB335 GradeΦ12 and Grade Φ18. For each kind of bar, we take three test specimens with the length of 400 mm respectively and at normal temperature we do the tensile test on the tensile machine till the bars are pulled off. The actually measured results are shown in TABLE V.

TABLE V HE MECHANICAL PROPERTIES OF BARS WITH ACTUAL MEASUREMENT

The Types of Bars	Specification	Yield Strength $f_y(N/mm^2)$	Ultimate Strength $f_u(N/mm^2)$	Elasticity Modulus $E(\times 10^5 N/mm^2)$
HPB235 Grade	ϕ6	/	653	2.116
HRB335 Grade	Φ12	358	542	1.994
HRB335 Grade	Φ18	343	535	2.056

We adopt the carbon fiber structure adhesive for building with the type of DL-JGW-D in the test. All the carbon fiber sheets are produced by Japan Toray Company. The performance indicators of carbon fiber sheet, base adhesive, structural adhesive, dipping glue and others used in the test refer to the indicators of material factory. These indicators can be seen in TABLE VI.

TABLE VI THE PERFORMANCE INDICATORS OF CARBON FIBER SHEET

Type	**FiberWeight** (g/cm^2)	**Calculation Thickness （mm）**	**Tensile Strength （MPa）**	**Elasticity Modulus （MPa）**	**Breaking Elongation （%）**
UT70-20	200	0.111	3550	2.35×10^5	≥1.5

5) The fabrication of test model

a). The Reinforced Concrete Frame. The steel bar skeleton of frame adopts the bound connection. Tensioned bars in the beams and columns go through the node area. And we ensure that they have enough anchoring strength. The model adopts the wooden template and the vertical casting which are similar with the casting in practical engineering. It shall conduct the cast in place in the Structure Laboratory of Shanghai Research Institute Of Building Sciences. They should be cured for 28days after the forms are removed. Model KJ – 1 is the non-reinforced concrete comparative frame structure model. Model KJ – 2 is the reinforced model which uses the CFRP to reinforce the areas of column foot and beam-column joints after we push and pull the non-reinforced concrete structure till it reaches the yield strain. Model KJ – 3 is the reinforced model which uses the CFRP to reinforce the undamaged reinforced concrete frame in the areas of column foot and beam-column joints[8].

b). CFRP Reinforcement. We use the carbon fiber sheet to reinforce the areas of column foot and beam-column joints of frame column. In actual construction, these steps should be operated by the personnel of the specialized construction team who are familiar with the reinforced construction technology of carbon fiber and have rich construction experience. The special steps are as follows[9].

Construction Preparation: As far as the frame concrete model which needs the reinforcement and strengthening are concerned, if we want to get the surface treatment, resin painting, the paste of carbon fiber sheet, maintenance and local process, all these steps should comply with the corresponding design and construction specification requirements. And then we deal with all the materials and tools to do the preparation work well, such as surface grinding, surface cleaning treatment, uneven treatment, the painting of base resin and the paste of carbon fiber sheet.

c). The Reinforcement Scheme of the Carbon Fiber Shee. According to the existing reinforcement materials and referred to the Concrete Structure Technical Specification of Carbon Fiber Sheet Reinforcement and Repair and the related anti-seismic design code, we caculate the paste dosage of carbon fiber sheet[10-12]. After the caculation, in order to facilitate the comparison of test data we should make the special concret reinforcement scheme of KJ-2 and KJ-3be completely the same.

III. THE TEST SCHEME

A. The Loading Scheme and Loading Equipment

The Vertical Axis Pressure of Capital. We stimulate the vertical load from the superstructure and exert the axial load on the frame capital. The axial force exerted by us should be realizedby the separating hydraulic jack. We should put the spherical hinge between the jack and the capital to keep the axial force unchanged vertically in the process of test.

The Concentrated Force of the Third Point among the Beams. In order to better simulate the floor load situation in the actual construction use passed from the support of the frame main beam on the transverse secondary beam. We arrange the concentrated load at the third point of model frame beam in the test. Exerting the concentrated force of the third point can be realized by distributing the small beams and putting the irons with the equivalent weight in the basket.

B. The Horizontal Force of Beam End in Node Area.

Although the influence of earthquake action on the buildings is essentially dynamic load, its frequency is relatively low and the cost of simulating earthquake to get the large vibration table is relatively larger. Therefore, we adopt the pseudo static load to simulate the earthquake action in this test and use the static method to get the vibrating effect. The main characteristics of the pseudo static test are shown as follows. (1) Conduct many repetitive and cyclic actions on the test specimen; (2) Make the test specimen into the inelastic phase and simulate the stress and large deformation process in the reciprocating vibration during the earthquake.

When we realize the low reversed cyclic load, we should exert the horizontal force on one end of frame beam and put the equal section steel plate with the thickness of 10mm at each end of the beam to prevent the local concrete be crushed. And we set two pull rods with the diameter of 28 mm among the steel sheets. We realize the horizontal pull action on the far force end by the rods to prevent the longitudinal carrying bar among the frame beams skid off from the concrete. We put the spherical hinge between the near force end of frame beam and the power-assist head. The effect of the spherical hinge here is the same with the spherical hinge at the role of jack.

Load Site Figure and its detailed node are shown in Figure 3.

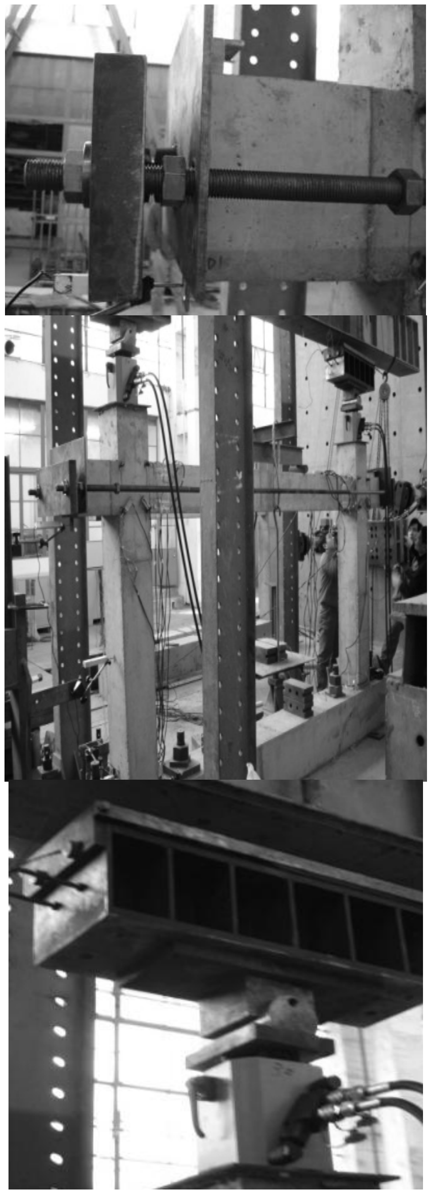


Figure 3 Loading Device Site Figure

The Arrangement of Measuring System and Measuring Points

1. The Measuring System. We adopt the dynamic and static strain test system with the type of DH – 3817 in the test which is produced by Jiangsu Donghua Testing Technology Co., Ltd. Some of its technical indicators are as follows.

The Number of Measuring Points: Each collection box has 8 points, and each computer can control 16 sets of collection boxes;

The Bridge Voltage: 2V (DC);

The Sampling Rate of Each Measuring Point: 1、2, 5,10, 20, 50, 100, 200 (times per second);

DOI 10.5013/IJSSST.a.17.11.10 ISSN: 1473-804x online, 1473-8031 print

The Resolution Ratio of Indicating Value: 1 με (Voltage Input 1 μV);

The Zero Drift: 1 με/1h (have short circuit at the input end, maximum sensitivity, and constant temperature.);

The Auto Balance Range: ±10000 με (strain gauge resistance value error±2%);

The Applicable Strain Gauge Resistance Value: 50~10000 Ω;

The Resistance Strain Gauge Type: BF120-3AA, The Resistance Value: 120 ± e2 Ω , The Sensitivity Ratio: 2.12±2%, Gate Length ×Gate Width 3×2mm.

The Strain Displacement Meter Sensor Model: PX - 30 type, The Output of Sensitivity: $358.5\mu\varepsilon / mm$, The Displacement Meter: YHD-200, YHD-100, YHD-50.

The Output of Sensitivity of YHD-200: $120\mu\varepsilon / mm$.

The Arrangement of Displacement Meter Measuring Points

a) The Horizontal Sidesway of Frame: We put the horizontal displacement meter at the axis height of the frame beam cross-section to measure the sidesway of frame.

b) The Shear Deformation of Core Area: We paste the fixed points of displacement meter at the four corners of concrete surface in the core area, install the displacement meter along the diagonal direction to measure the change of core diagonal length and compare the change of shear deformation in the core areas of different frames.

c) The Cross-section Curvature of Column Base Plastic Hinge Region: We paste the fixed points of displacement meter at the equal height of two stress sides of column to keep the equal distance between the displacement meter and the side of column. By measuring the elongation and shortening amount among the displacement meters we calculate the corner per unit length.

The arrangement figure of actual displacement meter can be seen in Figure 4.

Figure 4 The displacement meter (the rotation of column base)

C. The displacement meter(the shear deformation of node area)

1) The Arrangement of Strain Measuring Points

a) The Longitudinal Steel Bar: We arrange two strain gages on each same side of column base bearing main steel bar to keep the same height with the surface of mudsill. We arrange two strain gages on each same side of column end near node area bearing main steel bar to keep them be at the

DOI 10.5013/IJSSST.a.17.11.10

ISSN: 1473-804x online, 1473-8031 print

same height. We arrange two strain gages on each upper and lower position of beam end near node area bearing main steel bar. We compare the frame stress state with the strain measuring points (12 points).

b) The Stirrup: We arrange two strain gages on each axis of beam-column nodes core area and three strain gages on each axis of column end near node area. We compare the stirrup stress state with the strain measuring points (10 points).

c) The Concrete: We arrange five strain gages on each concrete side of beam end near node area. We arrange one strain gage on each inner side of column base concret. We compare the frame cracking state with the strain measuring points (12 points).

d) CFRF Sheet: We arrange one strain gage on each upper and lower surface of beam end near node area. We arrange one strain gage on each column end near node area and each inner and outer side at column base. The strain measuring points (12 points).

The specific arrangement diagram of the strain measuring points can be seen in Figure 5-7.

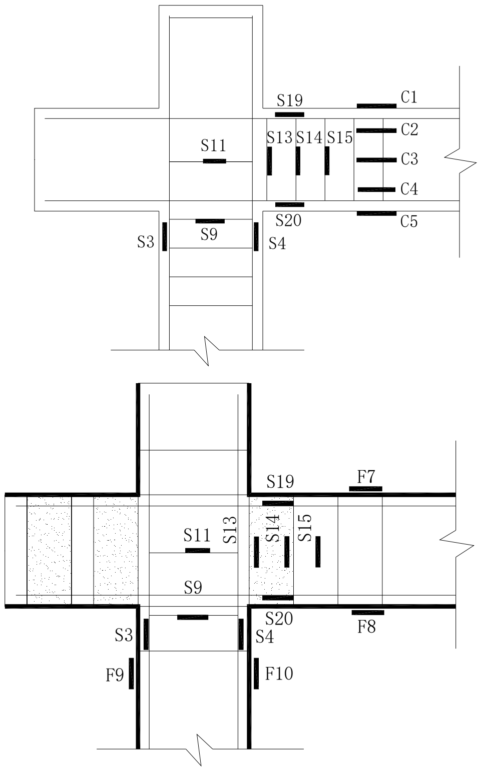


Figure 5. The schematic diagram of strain measuring points in node area

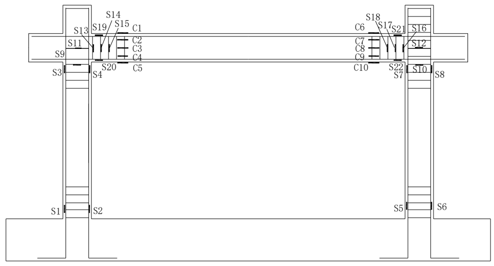
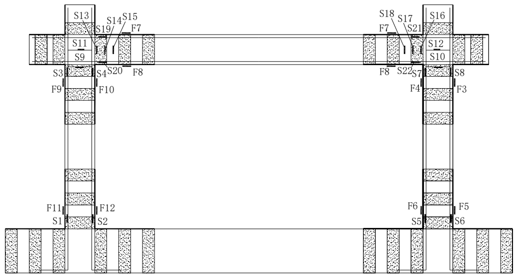


Figure 6. The schematic diagram of strain measuring points before the reinforcement of the reinforced concrete frame



Fiqure7. The schematic diagram of strain measuring points of Carbon fiber reinforced concrete frame

D. The Test Condition and Loading System

For the plane frame structure in the test, we adopt low reversed cyclic loading program to mainly investigate the entire effect of energy dissipation and stiffness degradation before and after the reinforcement of frame carbon fiber sheet. The principle of loading system is the displacement control. It can be divided into the following conditions concretely. Before the main steel bar of column yields, if each grade increases 2mm in the elastic range, each grade circulates three times next step. After the main steel bar of column reaches the yield strain, each grade controls the load with the multiple of the yield displacement. And each grade circulates three times next step till it gets destoried.

1) The specific load system is described as follows.

(1) After the frame model is hoisted in position, a pair of dragon gate column the is installed in the axis of capital. By the axial force from the hydraulic jack, we put the spherical hinge on the capital to keep the axial force unchanged in the process of test.

(2) We put a distribution beam at the third point in the frame beam to caculate the weight of required iron when we remove the weight of distribution beam and put it in the hanging basket stably.

(3) The Preload: We conduct the preload with the displacement control of 0.5mm to make each part of each test specimen have good contacts and enter the normal working state so that the relationship between the load and the deformation becomes stable gradually. And we should inspect the reliability of each test device and check all the observation instruments work normally or not.

(4) The Load: At the stage of elastic stress of frame structure, we conduct the load with the displacement control.

We take the displacement of 2mm as one grade and make each grade circulate three times.

(5) After the main steel bar of frame model column base stress reaches the yield strain, we should control the load according to the multiple of the yielding deformation till it is destoried.

2). The analysis of test results

(1) The carbon fiber materials have good constraint effect on the concret and delay the concrete cracking as as to guarantee the good bonding between the concretes and the steel bars is good. This improves the rotation capacity of plastic hinge and the entire energy dissipation capacity of frame components. Using the carbon fiber materials to conduct the reinforcement on the intact structure can significantly enhance the circulation resistance ability of the components. It can have apparent effect to maintain the stability of the hysteresis curve under the cyclic load.

(2) The carbon fiber reinforced frame components imrove all their ultimate bearing capacities. They have more apparent reinforcement effect on carbon fiber frame components with direct reinforcement. It improves the initial stiffness of the components. It has an apparent inflection point on the skeleton curve. The ultimate bearing capacity of frame and deformation capacity both have a great improvement.

(3) We make the strengthening and reinforcement of carbon fiber on the frame structure. After the structure components yield, compared with the frame structure without any reinforcements, the strength degradation reduces under the control circulation of displacement of each grade. The reinforcement frame structure which we use the carbon fiber to reinforce is beneficial to maintain the stiffness in the late period of structure components.

(4) For the reinforcement frame structure which we use the carbon fiber to reinforce, the improvement of loop stiffness after the reinforcement frame structure yields is not big, but it plays an important role in maintaining the integrity in the late period. What's more, the reduction rate of structure stiffness after the reinforcement frame structure yields reduces. And the hysteresis curve is relatively stable and the energy dissipation is relatively good.

(5) The reinforcement frame structure which we use the carbon fiber to reinforce can better improve the ductility of the frame and improve the anti-seismic property of frame. As far as the reinforced frame structure after the damage, the strengthening and reinforcement of carbon fiber has relatively large improvement effect on the ultimate bearing capacity. While it doesn't have good improvement effect on the ductility.

IV. CONCLUSION

Before the 1980s the project quality problems exsit in the concrete structure widely. In addition, the projects get the erosions from all kinds of environmental media so as to cause the severe corrosions of concrete structure, such as concrete cracking, concrete spalling, the corrosion of steel bars, etc. Even it causes the components to lose the orginal bearing capacity. Facing these problems which remain to be solved, we do the reseach and analysis of the reinforced concrete frame which we use the carbon fiber sheet to reinforce and strengthen and the improvement of structure mechanical properties, and find the reliable basis for the popularization and application of this reinforced technology in the reinforcement and repair of buildings. The carbon fiber materials have good constraint effect on the concret and delay the concrete cracking as as to guarantee the good bonding between the concretes and the steel bars is good. This improves the rotation capacity of plastic hinge and the entire energy dissipation capacity of frame components. The carbon fiber reinforced frame components imrove all their ultimate bearing capacities. They have more apparent reinforcement effect on carbon fiber frame components with direct reinforcement. It improves the initial stiffness of the components. It has an apparent inflection point on the skeleton curve. The ultimate bearing capacity of frame and deformation capacity both have a great improvement. The reinforcement frame structure which we use the carbon fiber to reinforce can better improve the ductility of the frame and improve the anti-seismic property of frame. As far as the reinforced frame structure after the damage, the strengthening and reinforcement of carbon fiber has relatively large improvement effect on the ultimate bearing capacity. While it doesn't have good improvement effect on the ductility. Before we conduct the reinforcement of the damaged frame we do not fill and repair the existing cracks in the test so that the bonding effect between the carbon fiber sheet and the concret may be reduced. The lateral displacement resistant rigidity of frames may be influenced too. Therefore, we suggest that it is necessry to fill the existing cracks under the condition of permission in the actual reinforcement projects.

ACKNOWLEDGMENT

1. Jiangxi province university humanities and social science research base project: (Research of reservoir tourism in Poyang lake region in the view of water cluture).

2. Jiangxi province university humanities and social science research base research project (JD1176) and Jiangxi province university humanities social science key research base project:(Research of reservoir tourism in Poyang lake region in the view of water cluture).

REFERENCES

[1] Chen Fengshan, Zhao Guofan et al. "Experimental Investigation on Contribution of CFRP Attachment to Durability of Reinforced Concrete Structure Subjected to Chloride Attack". Journal of Southwest Jiaotong University, vol.14, No.1, pp. 73-78, 2006.

[2] G.P. Lignola,A. Prota,G. Manfredi,E. Cosenza. "Non-linear modeling of RC rectangular hollow piers confined with CFRP". Composite Structures, vol.56, pp.881-890, 2008.

[3] Lijuan Cheng. "Flexural fatigue analysis of a CFRP form reinforced concrete bridge deck". Composite Structures, vol.23, pp. 198-205. 2011.

[4] Pedro J.D. Mendes,Joaquim A.O. Barros,José M. Sena-Cruz,Mahsa Taheri. "Development of a pedestrian bridge with GFRP profiles and fiber reinforced self-compacting concrete deck". Composite Structures, vol.12, pp. 451-458, 2011.

[5] Ariela Astorga,Hernan Santa Maria,Mauricio Lopez. "Behavior of a concrete bridge cantilevered slab reinforced using NSM CFRP strips". Construction and Building Materials, vol.40, 2013.

[6] Yu-ye Zhang,Kent A. Harries,Wan-cheng Yuan. "Experimental and numerical investigation of the seismic performance of hollow rectangular bridge piers constructed with and without steel fiber reinforced concrete". Engineering Structures, vol.48, pp. 345-352, 2013.

[7] Gaetano Russo,Margherita Pauletta. "Sliding instability of fiber-reinforced elastomeric isolators in unbonded applications". Engineering Structures, vol.48, pp.125-132, 2013.

[8] Ruili He,Stephen Grelle,Lesley H. Sneed,Abdeldjelil Belarbi. "Rapid repair of a severely damaged RC column having fractured bars using externally bonded CFRP". Composite Structures, vol.101, pp. 623-630, 2013.

[9] A.H.M. Muntasir Billah,M. Shahria Alam. "Seismic performance evaluation of multi-column bridge bents retrofitted with different alternatives using incremental dynamic analysis". Engineering Structures, vol.63, pp. 216-225, 2014.

[10] A. Ismail. Non linear static analysis of a retrofitted reinforced concrete building. HBRC Journal, vol.101, pp.89-96, 2014.

[11]]Yail J. Kim,Seung Won Hyun,Jae-Yoon Kang,Jong-Sup Park. "Anchorage configuration for post-tensioned NSM CFRP upgrading constructed bridge girders". Engineering Structures, vol.79, pp. 312-320, 2014.

[12] Zhang Ningning, He Dengfa, Sun Yanpeng, et al., "The global giant carbonate field distribution characteristics and controlling factors of", Chinese petroleum exploration, vol. 2, No. 07, pp. 54-65, 2014.