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Stimulation Analysis of High Temperature Bearing Capacity of Steel Reinforced Concrete Column Strengthened by CFRP

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Abstract. The steel reinforced concrete column is one of the important members for structures, it is essential to study the high temperature performance of concrete column. The numerical simulation research is done using finite element software ANSYS. Under the high temperature, the analysis of the compressive bearing capacity and flexural capacity of the concrete columns strengthened by CFRP is done, and the compressive bearing capacities of different cross-section concrete columns strengthened with CFRP are tested.

Introduction

The structure performance will sink rapidly under high temperature stems from the occasional fire accidents caused by various types of natural or human factors, and even the structure will be partially damaged or collapsed which may lead to enormous economic loss[1]. At present, the research on high temperature performance of concrete column strengthened by CFRP is rare, the stimulation calculation for high temperature property of concrete column strengthened by CFRP has not be reported. In view of the importance of high temperature property of concrete column, The influence analysis of the high temperature bearing capacity of concrete column with CFRP sheets is done by numerical simulation method in this article. Under the high temperature, The compressive capacity, flexural capacity of the concrete column strengthened with different thicknesses CFRP is analysed, and the influence of different cross-section shape is also analysed. so the analytical data and conclusions about the high temperature bearing capacity of concrete column strengthened with CFRP are obtained.

1 Performance of Materials

1.1 High temperature performance of steel reinforced concrete column

Under high temperature, the mechanical property of the materials that constitute concrete column degrades as temperature rising[2]. ①concrete: The stress-strain curve of concrete becomes more flat and the summit descends and move right evidently with the rising of temperature, it indicates compression strength degrades, the strain peak amplifies rapidly and the elastic modulus reduces significantly, as is shown in Fig 1; ②reinforced bar: the elastic modulus and the proportional limit of reinforced bar gradually declines with the rising of temperature, the yield stress of reinforced bar descends sharply when the temperature reaches 400℃,and it drops to one third of the yield stress under normal temperature, as is shown in Tab1.

So the reducing of mechanical property for the above two materials leads to the declining of concrete column's bearing capacity. Take concrete column under axial load as an example, the change of column's bearing capacity with the temperature rising is presented in Fig2.

Tab1 The reduction ratio of bucking strength, proportional limit and elastic modulus of steel bar under high temperature

T(℃)	20	100	200	300	400	500	600
f_{yT}/f_y	1.000	1.000	1.000	1.000	1.000	0.780	0.470
f_{pT}/f_p	1.00	1.000	0.807	0.613	0.420	0.360	0.180
E_T/E	1.00	1.000	0.900	0.800	0.700	0.600	0.310

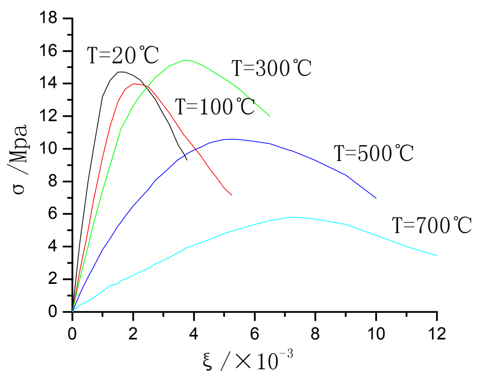


Fig.1 Gragh on the strain-stress of compressive concrete under high temperature

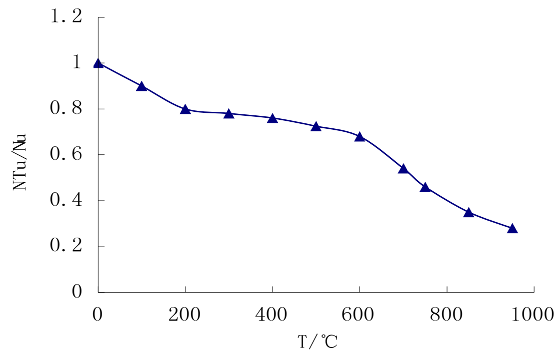


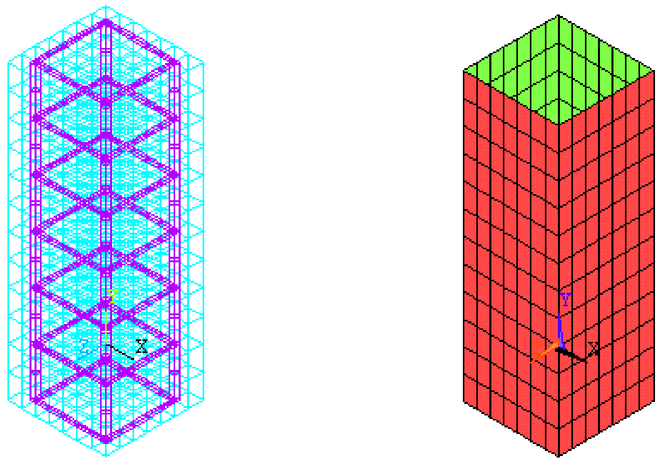
Fig.2 Bearing capacity of axial compressive pile heated on three surfaces

1.2 High temperature property of CFRP

CFRP(CF-1) has excellent mechanical properties, it has a high melting point, a high elastic modulus and a good high temperature strength(as is shown in Fig3), in addition, CFRP has a low coefficient of expansion, a good heat stability and can be wrapped on different members or structures, and CFRP can not influence the appearance of structure or increase the size of structure[3]. The weight of CFRP sheets is usually neglected in design because it's lighting weight. So CFRP is used to confine the deformation of concrete column and make it bear larger load,hence, CFRP can raise the deformability of structure under high temperature[4].

2 Building of ANSYS Analysis Model

The finite model was built using a large scale finite numerical simulation software ANSYS. the model of compression column was stimulated by the discrete method. The concrete was built with solid90 elements, the reinforced bar was built with link8 elements, the CFRP was built with flat shell elements. The size of concrete column was 200mm×200mm×600mm, the bottom had a fixed joint and the top was free. the concrete strength grade was C30, the steel bar used HRB335, the tensile strength of CFRP was 3400Mpa, the elastic modulus of CFRP was 235Gpa or 500Gpa[5]. The direction of carbon fiber was parallel or vertical with the axis of concrete column. Assumption conditions in the calculation: the reinforced bar and concrete was rigidly cohered with neglecting their boundary slipping, CFRP and column were entirely cohered, the fire-proofing was painted on the CFRP, the model was presented in Fig3.



a steel reinforced concrete column model   b CFRP finite element model

. Fig.3 Finite element model

3 Analysis for High Temperature Capacity of Concrete Column Strengthened with CFRP

3.1 Impact of CFRP's thickness on bearing capacity of concrete column

In the computational model, the CFRP's thickness was changed by setting the shell element's thickness. The elastic modulus of CFRP was 500Gpa, the direction of carbon fibre was transverse, the thicknesses of CFRP were respectively 0.176mm, 0.334mm and 0.501mm. The impact of CFRP's thickness on high temperature capacity was got by loading analysis under high temperature, as was shown in Fig 4.

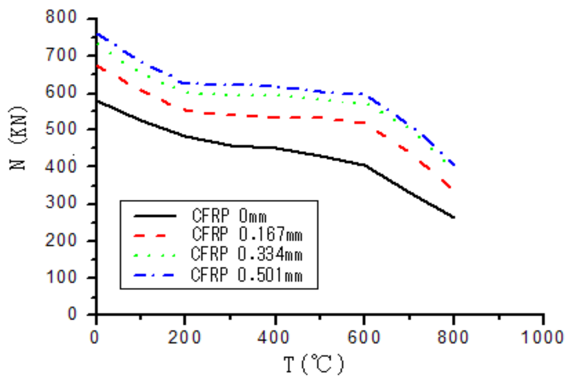


Fig.4 Influence of CRFP's thickness on column bearing capacity under high temperature

Analysis showed: The high temperature capacity of concrete column strengthened by CFRP was obviously increased. The effect of using CFRP increases with the temperature rising within the scope of 0℃-600℃. The increasing coefficient of concrete column bearing capacity separately were 25% , 36% and 41% with using one, two and three layers of CFRP. After this, the increasing coefficient increased slowly by thickening CFRP, and even the increasing coefficient stopped growing with rising the thickness of CFRP in numerical simulation experiments. The reason for The increasing coefficient of concrete column capacity began to decrease when temperature exceeded 600℃,the cause was that: ① the yield stress and ultimate stress of reinforced bar decreased to 1/3 of that under normal temperature when temperature exceeded 600℃, so the bearing capacity of reinforced bar obviously decreased; ②the high temperature compressive intensity of concrete decreased to 40%-60% of that under normal temperature when temperature exceeded 600℃, the above reasons led to the decreasing of high temperature capacity of the concrete column.

3.2 High temperature capacity for different cross-section columns strengthened by CFRP

In view of that the circular cross section and rectangular cross section were often used in concrete columns, the comparing of two cross section columns strengthened by CFRP was done. It was supposed that the column and CRFP cohered completely in the stimulation analysis. To keep section areas of two columns equal, the size of rectangular cross section was 200mmx200mm, and the diameter size of circular cross section was 220mm, the thickness of CFRP was 0.334mm, the height of concrete columns were 600mm. then the load was imposed under high temperature, the data was presented in Fig5.

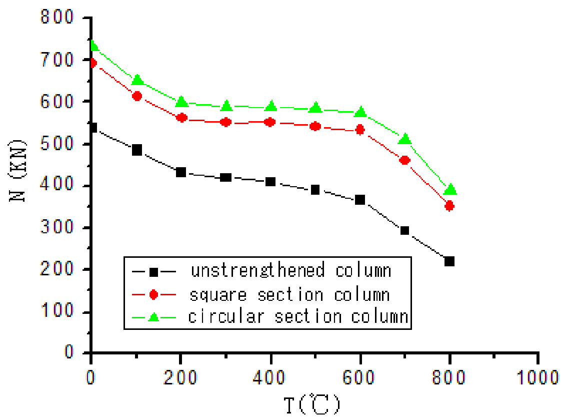


Fig.5 Bearing capacities of two shape columns reinforced by CRFP

The results showed that: The high temperature capacities of two cross section columns, in a manner, were increased using CFRP, the bearing capacity of circular shape column was bigger than that of square shape column, the increasing coefficient of circular shape column capacity was 9% larger than that of square shape column. Based on the analysis of section stress, the conclusion was found: the core concrete of circular shape column was well restrained by CFRP, but the core concrete of square shape column was not equally restrained, the reason was that the section stress wasn't uniform because of the existing of the column's four corners.

3.3 Analysis of high temperature flexural capacity of concrete column strengthened by CFRP

The stimulation model was built using the software ANSYS. The concrete column commonly bore the two actions which were axial force and bending moment[6], it was assumed the axial force applied on the top of the column was 500KN, the thicknesses of CFRP sticked on the concrete column separately were 0.167mm and 0.334, the direction was longitudinal, the effect of CFRP on the high temperature capacity of concrete column was shown in Fig6.

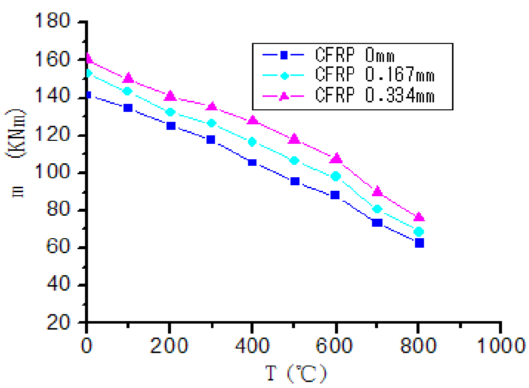


Fig.6 Flexural bearing capacity of longitudinal CFRP reinforced concrete column

The results showed that: The high temperature flexural capacities of concrete columns, in a manner, were increased using CFRP, the high temperature flexural capacity increased 17% using only one layer of CFRP, and the high temperature flexural capacity increased 33% using two layers of CFRP. By observing the enhancing curve, the enhancing effect of using two layers of CFRP was almost twice that of using one layer of CFRP. When the temperature exceeded 600℃, the enhancing effect decreased because of the falling of flexural capacity of concrete column. Above all, when the concrete column bore the axial force and bending moment, the transverse CFRP and longitudinal CFRP could be used to strengthened concrete column meanwhile.

4 Conclusion and Recommendation

Based on the numerical simulation analysis of ANSYS, the conclusions were obtained;

(1) The high temperature compressive bearing capacity of concrete column could be effectively increased using CFRP, the high temperature capacities respectively increased 25% and 36% using one and two layers of CFRP.

(2) The case of circular shape column was better than that of square shape column, the increasing coefficient of circular shape column capacity was 9% larger than that of square shape column.

(3) The high temperature flexural capacities of concrete columns were well increased using CFRP, when the concrete column bore the axial force and bending moment, the transverse CFRP and longitudinal CFRP could be used to strengthened concrete column meanwhile.

(4) The effect of using CFRP increased with the temperature rising within the scope of 0℃-600℃, when the temperature exceeded 600℃, the enhancing effect decreased rapidly.

The numerical simulation analysis for high temperature bearing capacity of concrete column strengthened by CFRP could offer important references for relevant experiments and designs.

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