Comparative Study of the Performance of BFRP and CFRP Cloth Restrained Cylinders under Impact Loading

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ABSTRACT. In this paper, ABAQUS software is used to study the mechanical properties of FRP cloth restrained reinforced concrete columns when subjected to impact loading. It aims to compare the effects of BFRP cloth and CFRP cloth on the performance of combined columns under the same impact conditions. The results show that under the same working conditions, BFRP fabric has a certain degree of flexibility, which can better resist damage, reduce the damage area, and protect the integrity of the structure when it is subjected to impact; in contrast, CFRP fabric is more prone to fracture and damage when it is subjected to impact, and BFRP fabric has a better advantage and prospect in the field of impact reinforcement of concrete structures.

Keywords: FRP Cloth; Impact Loading; Concrete Column; Plastic Damage

1 INSTRUCTION

Reinforced concrete columns present in locations such as roadways, bridges across rivers, and indoor parking lots are susceptible to impacts and damage from vehicle and vessel collisions [**Error! Reference source not found.**,**Error! Reference source not found.**]. According to data compiled by the New York State Department of Transportation over a 39-year period, vehicle and vessel collisions are the second leading cause of bridge damage in the state [**Error! Reference source not found.**,**Error! Reference source not found.**]. Impact loads are transient and incidental compared to common static loads and can be very harmful to concrete structures in general. Since the installation of impact protection devices in underground garages and multi-story parking lots will lead to a reduction in the use of space and will not be able to meet the use requirements [**Error! Reference source not found.**,**Error! Reference source not found.**]. Therefore, it is necessary to study the reinforcement of reinforced concrete (RC) columns that cannot be installed with crashworthy devices due to space constraints by fiber reinforced polymer (FRP) fabric. FRP is a composite material composed of fibers and matrix, which has the advantages of lightweight, high strength, corrosion resistance, and durability, and has been widely used in the reinforcement of reinforced concrete structures [**Error! Reference source not found.**,**Error! Refer-**

Z. Ahmad et al. (eds.), *Proceedings of the 2023 5th International Conference on Structural Seismic and Civil Engineering Research (ICSSCER 2023)*, Atlantis Highlights in Engineering 24,
https://doi.org/10.2991/978-94-6463-312-2_34

circular concrete columns, where BFRP was more effective for impact strengthening [7]. Current research has focused on axially impacted composite columns and laterally impacted FRP fabric reinforced plain concrete columns, while there is a relative lack of research on circular RC columns reinforced with FRP fabric in resisting lateral impacts. In this paper, a comparative study of BFRP cloth and CFRP (carbon fiber) cloth reinforced columns in terms of resistance to impact loading is carried out by means of the finite element software ABAQUS.

2 Modeling and validation

The structure studied in this paper is FRP cloth restrained reinforced concrete column. Among them, BFRP material has high strength, good corrosion resistance and other characteristics, and reinforced concrete columns composed of a combination of structures with better mechanical properties, and can effectively prevent the corrosion of steel reinforcement, enhance the durability of concrete components, the combination of structures as shown in Figure 1.

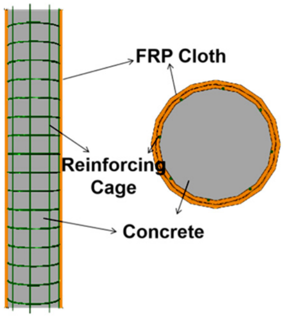


Fig. 1. Cross-section of member design

2.1 Establishment of Finite Element Model and Setting of Boundary Conditions

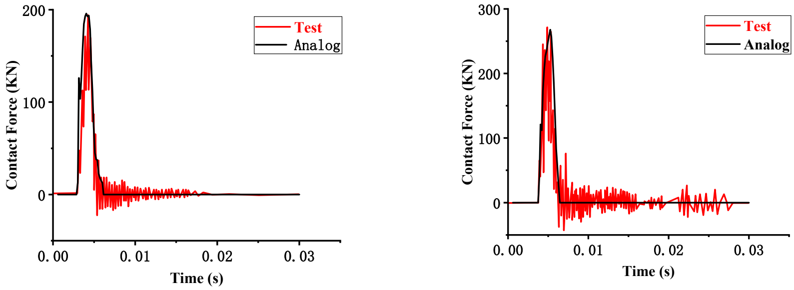
Use the PART function in ABAQUS software to establish the models of concrete, reinforcement, FRP cloth and punch, and then give the above components cross-section attributes as well as intrinsic relationships respectively, as shown in Table 1.

Table 1. Material properties of each component

Name of material	Calibre / mm	Poisson's ratio	Maximum intensity / MPa	modulus of elasticity / MPa
BFRP cloth	—	0.23	2100	9.1×10^4
CFRP cloth	—	0.3	3500	2.1×10^5
longitudinal bar	14	0.3	610	2×10^5
hoop	8	0.3	507	2.1×10^5

2.2 Finite element model validation

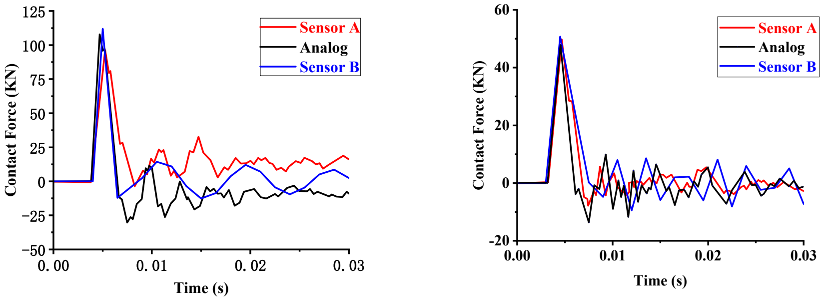
According to the data of experimental components in reference, a finite element model was established, and the experimental component was a double-layer CFRP cloth-constrained concrete cylinder with the dimensions of 150mm in diameter and 300mm in length; the mass of the punch was 66kg; the strength of the concrete was C40, and the prismatic length of the punch was 80mm in cubic shape. The experiment makes the punch from 0.3m, 0.8m free fall impact specimen, experimental contact instant impact velocity of 2.42m/s, 3.96m/s. Output simulation specimen contact force time curve and support reaction force time curve, and compared with the experiment, in order to verify the accuracy of the simulation experiment, the model verification results are shown in Figure 2. and Figure 3. Simulation and experimental curves are more consistent, peak comparison is shown in Table 2, Table 3, peak contact force and support reaction force error are within 7%, the model is consistent with the actual experiment.



(a) 0.3 m free-fall contact force time-range curve

(b) 0.8 m free-fall contact force time-range curve

Fig. 2. Comparison of contact force time-range curves



(a) 0.3 m free-fall support force time-range curves

(b) 0.8 m free-fall support force time-range curve

Fig. 3. Comparison of support reaction force time course curves

Table 2. Peak Contact Force Comparison

Impact Height / m	Analog value / kN	Experimental value / kN	Inaccuracies / %
0.3	193.6	194.1	0.26
0.8	313.2	327.9	4.48

Table 3. Comparison of Peak Support Reaction Forces

Impact Height / m	Analog value / kN	Experimental value A / kN	Experimental value B / kN	Inaccuracies / %
0.3	50.7	49.8	47.8	6.07
0.8	111.9	79.5	107.9	3.71

3 SIMULATION RESULTS AND ANALYSIS

3.1 Design of components

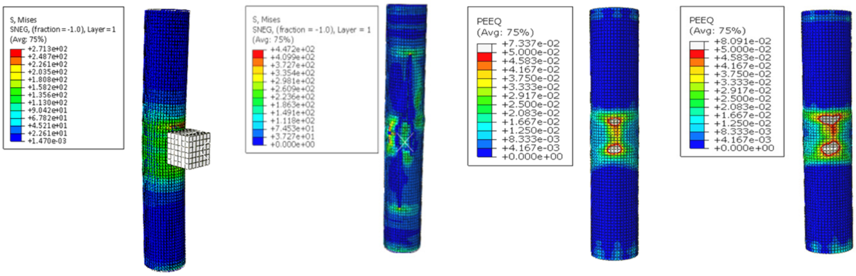
The mass of the punch for the simulation experiment is 500kg, and the size is 450*450mm cube; the cross-section diameter of the member is 600mm, and the length to slenderness ratio is 15.4; the parameters are designed as concrete strength C30, C40; RP types BFRP and CFRP. The specific parameters are shown in Table 4.

Table 4. Experimental parameters and grouping

Specimen number	FRP Type	Impact Velocity（m / s）	Layers of cloth	Concrete Strength	
B2C30V12	BFRP	12	2	C30	Group A
C2C30V12	CFRP	12	2	C30	
B2C40V12	BFRP	12	2	C40	Group B
C2C40V12	CFRP	12	2	C40	
B2C30V16	BFRP	16	2	C30	Group C
C2C30V16	CFRP	16	2	C30	

3.2 Simulation results and analysis

Taking the simulation cloud map of group A as an example, the overall stress cloud map of the combined column and the plastic damage cloud map of the concrete are extracted to analyze the stress distribution and damage distribution law of the structure. As shown in Fig. 4. , the CFRP cloth wrapped around specimen C2C30V12 has produced damage, and the stress produced is also larger than that of specimen B2C30V12; from the concrete damage map, the damage area of specimen C2C30V12 is larger because the fracture of the CFRP cloth in the process of impact led to the impact of the punch block acting directly on the surface of the concrete, which produced a larger damage. Because the fiber matrix material of BFRP has a certain degree of flexibility, it can provide additional impact toughness during impact to better resist damage and protect the structural integrity.

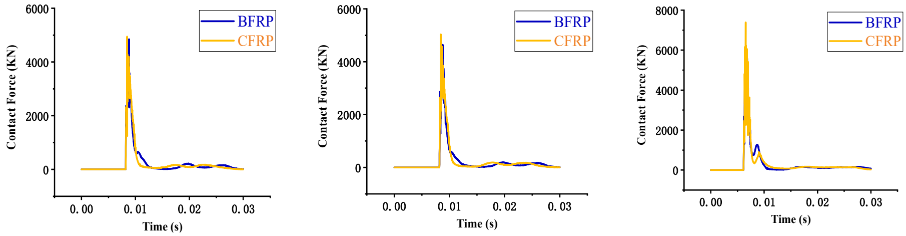


B2C30V12 C2C30V12 B2C30V12 C2C30V12

Fig. 4. Group E simulation cloud diagram

Note: The first two are overall stress clouds and the last two are concrete damage clouds.

As shown in Fig. 5, the three groups of contact force time-course curves have almost the same trend before reaching the peak value, and after the peak value, the curve of the BFRP-cloth reinforced members decreases more slowly than that of the CFRP-cloth reinforced members. The peak contact forces of the three groups of CFRP fabric reinforced members are 1.9%, 5.2% and 32.4% higher than those of the BFRP fabric reinforced members, respectively. Because CFRP cloth performs better in terms of strength and stiffness, the peak contact force of the CFRP cloth-reinforced members increases more rapidly when subjected to higher impact forces. From Figure 6, it can be seen that the three sets of mid-span displacement curves have the same trend, where the BFRP fabric-reinforced members arrive at a relatively slower time to the peak displacement, and the peak displacement is higher. The peak mid-span displacements of the three groups of BFRP fabric-reinforced members are 4.2%, 5.9%, and 4.1% higher than those of CFRP, respectively. Because the stiffness of BFRP matrix material is not as strong as that of CFRP, but it has good toughness and energy dissipation ability, which can effectively absorb the impact energy, from the point of view of contact force and mid-span displacement, the BFRP cloth can be used instead of CFRP cloth for the reinforcement of members to resist the impact loads.



Group A Group B Group C

Fig. 5. Contact force time course curve

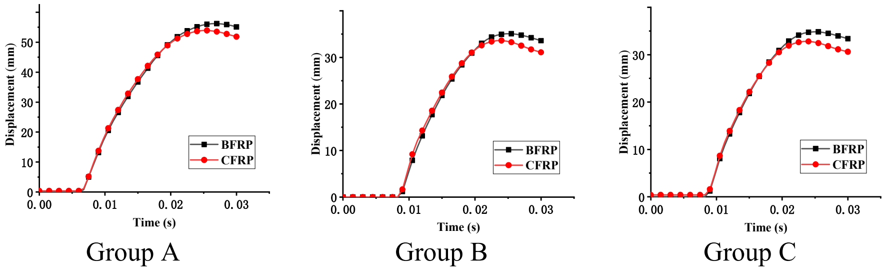


Fig. 6. Mid-span displacement time-course curve

4 CONCLUSION

1. The effectiveness of CFRP cloth and BFRP cloth reinforced members in resisting the mid-span displacement due to impact is basically the same, and the peak mid-span displacements of the BFRP cloth reinforced members are 4.2%, 5.9%, and 4.1% higher than that of CFRP cloth, respectively. However, from the stress damage cloud diagram, BFRP cloth has extra impact toughness to protect the structural integrity when subjected to impact, while CFRP cloth is more brittle and prone to fracture and damage when subjected to impact.
2. Compared with CFRP cloth, the manufacturing cost of BFRP cloth is relatively low, and it can also be recycled. With the increasing awareness of green environmental protection, BFRP cloth has better advantages and prospects in the field of impact reinforcement of concrete structures.

Acknowledgment

Natural Science Foundation of Heilongjiang Province of China（LH2020E018）

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