

Numerical simulation of steel-concrete composite Vierendeel beam

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Abstract. In this paper, a new type of steel-concrete composite Vierendeel beam is proposed. The finite element analysis of the new type of steel-concrete composite Vierendeel beam is carried out by using ABAQUS. To compare the mechanical properties with traditional beam, the normal reinforced concrete beam with the same section size is also analyzed by using ABAQUS. The simulation results show that the material strength of the new type steel-concrete composite Vierendeel beam is fully utilized, and the flexural capacity and deformation performance of the new type of steel-concrete composite Vierendeel beam are greatly improved compared with normal reinforced concrete beam.

1. Introduction

Due to poor ductility of concrete, the reinforced concrete structure is difficult to meet the normal use limit state requirements of various special-shaped structure and bridge. Steel concrete composite structure is a new structural form, which can make full use of the compressive strength of concrete and tensile strength and ductility of steel [1,2].

A new steel-concrete composite vierendeel beam is proposed based on the mechanism of normal reinforced concrete beam. The new steel-concrete composite vierendeel beam (as is shown in Figure 1.(c)) consists of curved Steel Pipe; reinforced concrete; steel Plate Hoop and tension steel plate. Through reasonable design, the tension steel is failure under tension load when the upper concrete is crushed, which can make full use of the material strength. The new steel-concrete composite vierendeel beam is convenient for plumbing, so as to achieve the purpose of saving architectural space. Therefore, it has broad application prospects.

For the further study of the mechanical properties of the new steel-concrete composite vierendeel beam with ABAQUS, the material properties is obtained by experiment. At the same time, the mechanical properties of reinforced concrete beam and H steel beam are analyzed with large FEM software ABAQUS and compared to the mechanical properties of the new steel-concrete composite vierendeel beam.



Table1 Parameter of beams

Reinforcement	Diameter / Thickness (mm)	Yield strength (MPa)	ultimate strength (MPa)
HRB400	25	443	597
HRB400	10	527	659
Steel	15	360	450
HRB400	8	440	552

Table 2 Basic parameter of beams

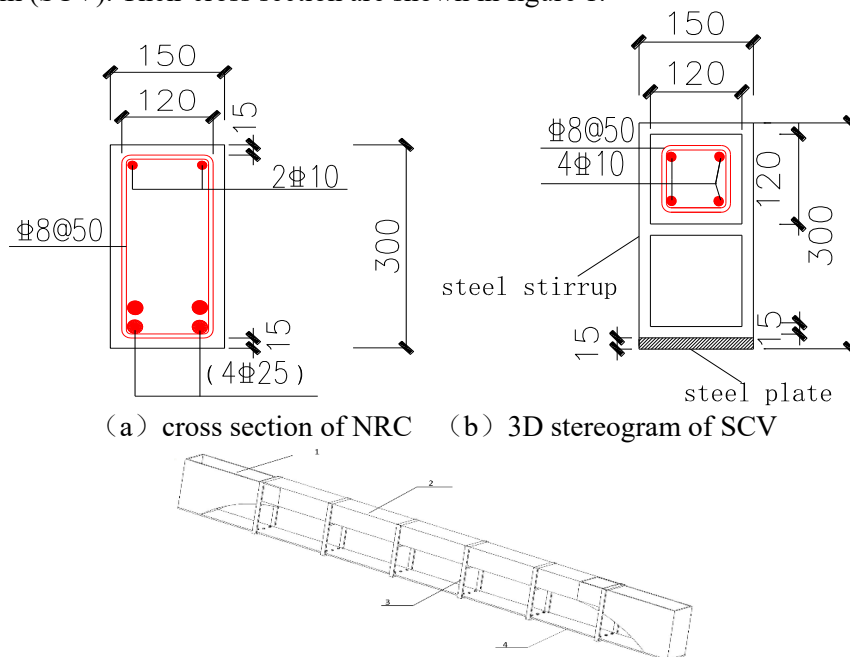
Beam	Concrete strength fcu/mpa	Ratio of reinforcement $\rho_s/\%$	Ratio of stirrup $\rho_v/\%$
NCC	54.42	5.39	0.021

2. Experienment and Numerical simulation of normal reinforced concrete beam

In order to get the accurate simulation results of steel-concrete composite vierendeel beam(CSV), the bending test of a normal reinforced concrete beam is carried out and some important parameters in ABAQUS is verified. The reinforcement of normal reinforced concrete beams is HRB400, the steel test indicators of steel-concrete composite vierendeel beam (CSV) and H type steel beam are shown in table 1. The basic parameters are shown in table 2.

2.1. Section of beam

There are a normal reinforced concrete (NCC), H type steel (HS) and steel-concrete composite vierendeel beam (SCV). Their cross section are shown in figure 1.



1- Curved Steel Pipe; 2-Reinforced concrete; 3- Steel Plate Hoop; 4-Tension steel plate;

(c) cross section of SCV

Fig.1 Cross sections of beams

Table 3 materials content		
beam	steel (m^3)	Concrete (m^3)
NRC	0.023	0.111
SCV	0.023	0.022

Table 4 materials content		
Name	Bearing capacity (KN)	Difference
NRC	330.42	0
SCV	556.35	68.38%

2.2. Test of NCC

In this paper, the static loading test is carried out by two point loading method, as shown in figure 2.

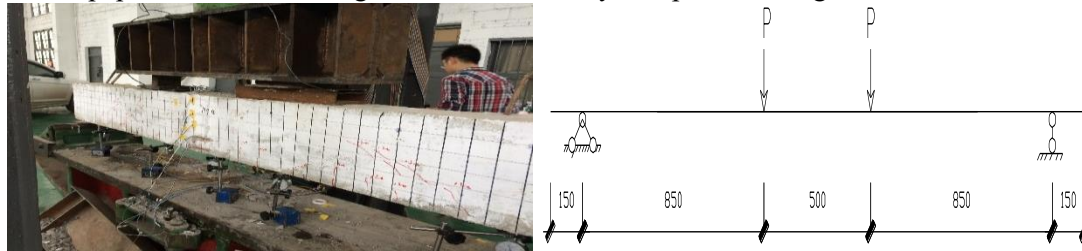


Fig.2 Test setup

2.3. Experimental phenomena

When the load was 35KN, the middle span displacement of NRC is 0.12mm. When the load increased to 80KN, a large number of cracks can be seen in middle span of NRC. While load was up to 220KN, a big sound can be heard. When the concentrated load is 320KN, the concrete was badly torn, the upper concrete of NRC was seriously crushed, NRC lost its bearing capacity. The failure phenomenon is sudden. The failure mode is shown in figure 3. In the course of the experiment, the load at all levels and its corresponding middle span deflection was recorded and drew a curve, as shown in figure 4.



Fig. 3 Failure mode of NRC

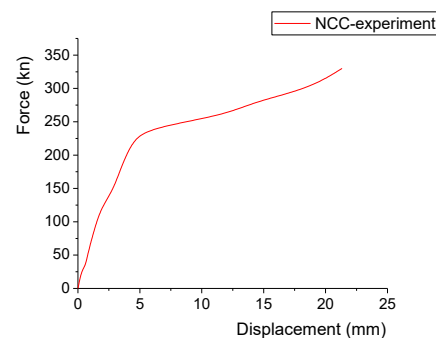


Fig. 4 load-deflection of NRC

2.4. Numerical simulation

After determining the parameters of the corresponding finite element model[3,4], the numerical simulation of the NRC is carried out and load-deflection curve of NRC is obtained (as shown in Figure 6). By comparing the experimental and simulating load-deflection curve of NRC, the difference between

simulation values and experimental values is not more than 10%. It can be concluded that the finite element simulation results are in good agreement with the experimental values.

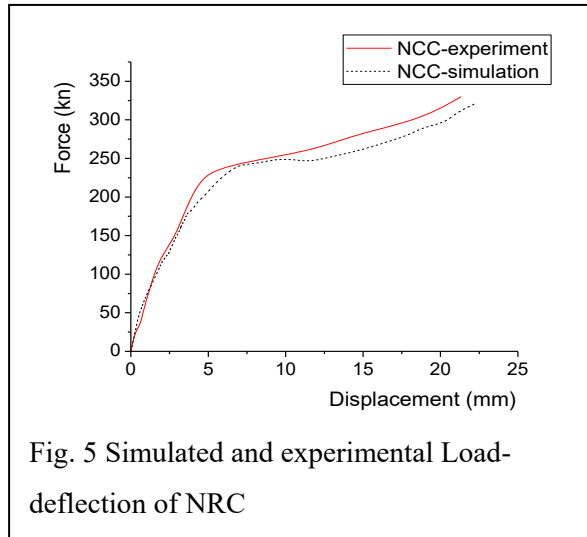


Fig. 5 Simulated and experimental Load-deflection of NRC

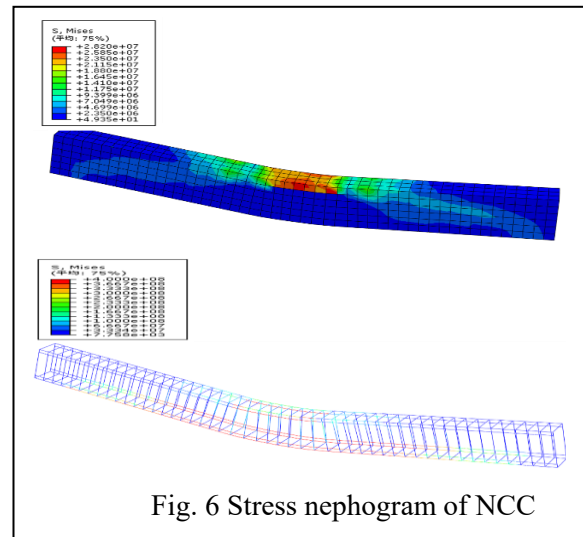


Fig. 6 Stress nephogram of NCC

By setting the same parameters and CDP mode of concrete in ABAQUS model of SCV, the simulation results of SCV are obtained (as shown in Figure 7 and 8).

From figure 7 and figure 8, we can see that when the tensile steel is yield, the concrete stress reaches its ultimate stress value and the upper part of the longitudinal reinforcement and stirrup yield at the same time, the strength of materials can be fully utilized.

3. Analysis of load-deflection curve

3.1. Analysis of bearing capacity

3.2. Analysis of load-deflection curve

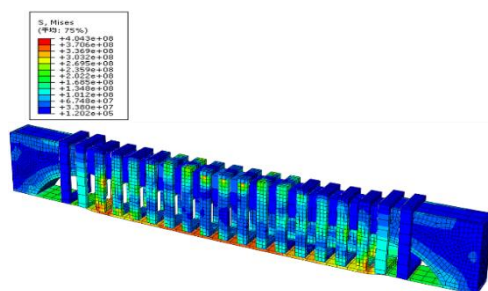


Fig. 7 Stress nephogram of SCV

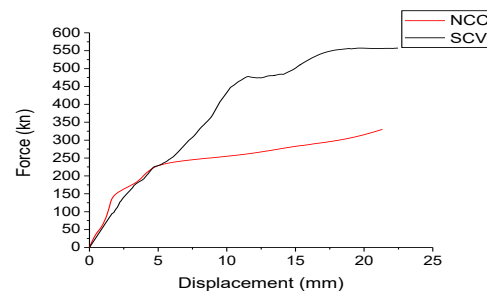


Fig. 8 load-deflection of NRC

The theoretical calculation value of the ultimate bearing capacity of NRC beam is 363.29KN, the numerical simulation analysis value is 330.42KN, the experimental value is 334.24KN (the difference between the theoretical value and the finite element simulation value is 8.7% and 1.2%), respectively.

The difference between the theoretical calculation value (508.24) and the finite element simulation value (556.35) of SCV is 9.98%. When compared with NRC, the ultimate bearing capacity of SCV is increased by 68.38%

3.3. Analysis of deformation capacity

As an important indicator of structural deformation capacity[5], ductility coefficient is defined as the chlorophyll of ultimate deformation and the yield deformation. The formulas shown in the formula (1).

In this paper, ductility coefficient is based on the method of energy equivalence principle (as shown in figure 9)

$$\mu = \Delta_m / \Delta_y \quad (1)$$

$$E = (P_y \Delta_y / 2 K_1) + 1/2 (P_y + P_m) (\Delta_m - P_y / K_1) \quad (2)$$

$$P_y = K_1 \Delta_y$$

$$P_m = K_2 (\Delta_m - \Delta_y) \quad (3)$$

$$K_2 = 0.05 K_1, P_y = 0.75 P_u$$

E—the area of the load deflection and the transverse coordinate; Δ_y —Simplified yield displacement

Δ_m —Simplified limit displacement; P_y —Simplified yield load; P_m —Simplified limit load

K_1 —Simplified initial stiffness; K_2 —Simplified degenerated stiffness

By the formula (1) (2) (3), the ductility coefficient can be obtained. The ductility coefficient of steel-concrete composite viereendeel beam (SCV) and normal reinforced concrete (NRC) are presented in table 5.

From table 5, we can see that the ductility coefficient of SCV increased by 46.85% when compared with NRC.

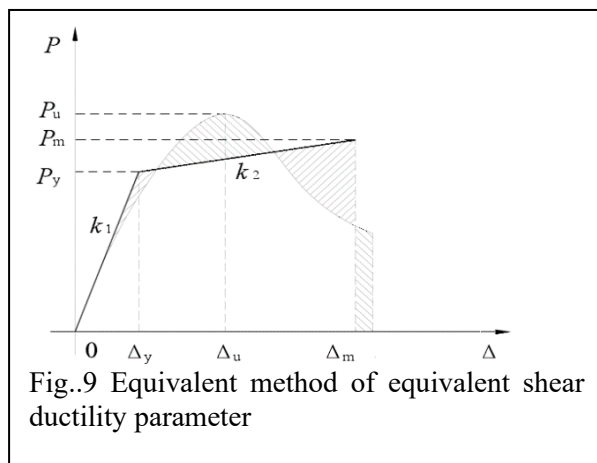


Table.5 Ductility coefficient of beams

Name	ductility coefficient	Diiference
NRC	2.75	0
SCV	4.03	46.85%

4. Conclusion

The Numerical simulation results of bending performance of the new steel-concrete composite viereendeel beam and normal reinforced concrete beam (NRC) show that: With the same total material consumption and cross section, the SCV can make full use of all kinds of material strength and has the higher bearing and deformation capacity when compared with normal reinforced concrete beams (NRC).

References

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