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Numerical Model of square steel tubular and spiral stirrup composite confined-concrete stub columns under axial compression

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Abstract. To study the axial compression performance of square steel tubular and spiral stirrup composite confined-concrete stub columns, based on the composite confined mechanism of square steel tube and spiral stirrup, the numerical model of square steel tubular and spiral stirrup composite confined-concrete stub columns was established. The numerical model calculation results show that the calculation simulation curve is in good agreement with the test curve, which can be used for the stress analysis of this type of component.

Keywords: component; confined concrete; square steel tubular; spiral stirrup; numerical model

1. Introduction

Reinforced concrete filled steel tubular column is a new type of concrete filled steel tubular composite member formed by configuring reinforcement cage in concrete filled steel tubular column. Steel tubes and stirrups form a double composite confined effect on the core concrete, which delays the local buckling of steel tubes and enhances the fire resistance of components. Therefore, reinforced concrete filled steel tubular columns have better bearing performance than concrete filled steel tubular columns. The research on reinforced concrete filled steel tubular column can be divided into two aspects : circular steel tubular column and square steel tubular column. Square steel tubular column has the advantages of convenient connection and convenient structural construction. The mechanical properties of square steel tubular reinforced concrete column have become a hot topic of research.Chen analyzed the composite constraint mechanism through the axial compression test of concrete column confined by square steel tube and spiral reinforcement. Ding established the finite element model of the internally confined square steel tube by using the finite element software, and proposed the simplified design formula of the axial compressive bearing capacity of the internally confined concrete-filled steel tube column with stirrups. Wei discussed the influence of concrete strength, reinforcement ratio and steel tube size on the compressive performance of reinforced concrete. Xiamuxi studied the influence of reinforcement ratio and confined effect on the axial compression performance of reinforced concrete filled steel tubular columns through experimental research and numerical simulation.

In this paper, through the analysis of square steel tube, spiral stirrup composite confined mechanism, a numerical model was established of square steel tubular and spiral stirrup composite confined-concrete stub columns under axial compression.

2. Composite confined mechanism

Under axial compression load, the core concrete is in three-dimensional compression state due to the composite confined of square steel tube spiral stirrup concrete short column.Owe to the in-homogeneity of the square steel tube constraint, the concrete inside the square steel tube is divided into high confined area and low confined area, as shown in Figure 1. The concrete part in the spiral stirrup is a composite confined area. It can be seen from Fig. 2 that the area of weak confined area of some square steel tubes is reduced due to the existence of stirrups.

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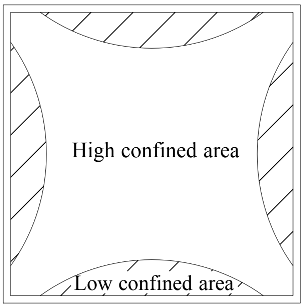

Figure 1. High and low confined area in square steel tube concrete

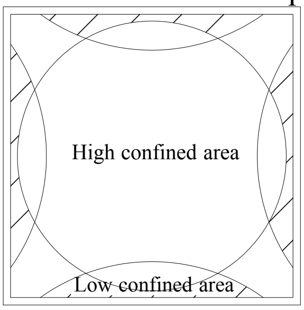

Figure 2. High and low confined area in square steel tubular and spiral stirrup composite confined-concrete

3. Numerical model

3.1 Constitutive mode

3.1.1 square steel tube confined concrete

The constitutive model of concrete in the low confined zone of square steel tube adopts the constitutive model of concrete` in square steel tube proposed by Han[5]. The meaning of specific parameters is shown in Reference[5] .

$$\sigma_c = \begin{cases} \sigma_0 [A \frac{\varepsilon_c}{\varepsilon_0} - \mathrm{B} \ (\frac{\varepsilon_c}{\varepsilon_0})^2] & (\varepsilon_c \le \varepsilon_0) \\ \sigma_0 \frac{\varepsilon_c}{\varepsilon_0} \frac{1}{\beta \ (\frac{\varepsilon_c}{\varepsilon_0} - 1)^\eta + \frac{\varepsilon_c}{\varepsilon_0}} & (\varepsilon_c > \varepsilon_0) \end{cases} \tag{1}$$

$$\sigma_0 = f_{co}[1.194 + (\frac{13}{f_{co}})^{0.45}(-0.01961\xi^2 + 0.1447\xi)] \tag{2}$$

$$\xi = \frac{A_s f_y}{A_c f_{co}} \tag{3}$$

$$\varepsilon_0 = \varepsilon_{cc} + [1330 + 760(\frac{f_{co} - 20}{20})\xi^{0.2}] \tag{4}$$

$$A = 2 - k \tag{5}$$

$$B = 1 - k \tag{6}$$

$$k = 0.1\xi^{0.745} \tag{7}$$

$$\varepsilon_{cc} = 1300 + 14.93 f_{co} \tag{8}$$

$$\eta = 1.6 + 1.5\frac{\varepsilon_c}{\varepsilon_0} \tag{9}$$

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$$\beta=\begin{cases}\dfrac{0.75}{1+\xi^{0.5}}f_{co}^{0.1} & (\xi\le 3)\\ \dfrac{0.75}{(1+\xi^{0.5})^{\eta}+(\xi-2)^{2}} & (\xi>3)\end{cases} \tag{10}$$

3.1.2 spiral stirrup

The constitutive relationship of concrete confined by spiral stirrups adopts the Mander model[6], and the confined force generated by square steel tube and stirrups are superimposed in the calculation.The meaning of specific parameters is shown in Reference[6].

$$\sigma_{cc}=\sigma_{c1}\frac{\varepsilon_c}{\varepsilon_{c1}}\frac{r}{r-1+(\frac{\varepsilon_c}{\varepsilon_{c1}})^{r}} \tag{11}$$

$$\varepsilon_{c1}=\varepsilon_{cc}[1+5(\frac{f_{cc}}{f_{c0}}-1)] \tag{12}$$

$$f_{cc}=f_{co}(-1.254+2.254(1+7.94\frac{f_l}{f_{co}})-2\frac{f_l}{f_{co}}) \tag{13}$$

3.1.3 square steel and longitudinal bar

Considering the buckling of steel and longitudinal bars in the later stage, the ideal elastic-plastic model is employed for longitudinal bars and square steel.

3.2 Calculated result

Under axial compression load, the compressive bearing capacity N of square steel tubular and spiral stirrup composite confined-concrete stub columns is composed of high confined area concrete compressive force Ncc, low confined area concrete compressive force NC, square steel tube compressive force Ns1 and longitudinal reinforcement compressive force Ns2. The stress corresponding to axial strain is calculated by the constitutive relation of each material, and the compressive force of each part can be obtained by multiplying the corresponding area. The comparison between the calculated curves and the experimental results in the literature[1] is shown in Figure 3. It can be seen from the figure that the stiffness of the numerical model calculation curve is slightly larger, and the overall trend is in good agreement with the experimental curve.

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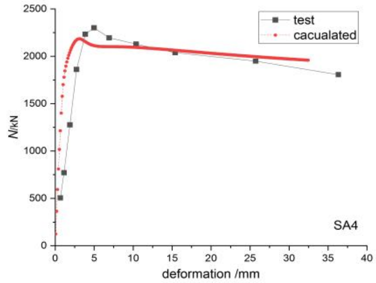
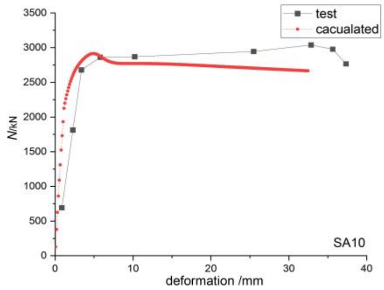
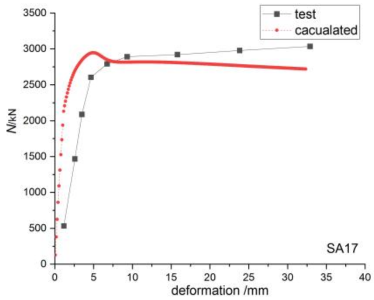


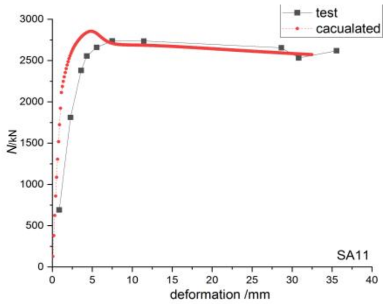
(a)SA4



(b)SA10



(c)SA11



(d)SA17

Figure 3. Comparison of calculated curves and the test results

4. Conclusion

In this paper, the confined concrete section of square steel tubular spiral stirrups is divided according to the different confined mechanism. Each part adopts different constitutive relation models. The axial force-deformation curve calculated by the numerical model is in good agreement with the experimental results, which can be used to analyze the compression performance of this type components.

Acknowledgments

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