



Analytical deformation characteristics and shear capacity of SRC-RC transfer columns



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ARTICLE INFO

Article history:

Received 15 May 2017

Received in revised form 9 August 2017

Accepted 22 August 2017

Available online xxxx

Keywords:

SRC-RC transfer column

Deformation characteristics

Transmission distortion

Inflection point

Shear capacity

ABSTRACT

In a steel reinforced concrete-reinforced concrete, SRC-RC, transfer column, the steel is truncated, and this leads to distortion of the internal force transmission. According to the internal force and deformation characteristics of transfer column, the location of the inflection point was studied. Then, the shear capacity of transfer column was investigated, and the results were compared with experimental results in references. The finite element model of SRC-RC transfer column was developed by ABAQUS, considering the effect of different confinement around concrete. The model has been validated against published experimental results. Finally, parametric studies were performed to evaluate the security and rationality of the shear capacity formula in Chinese code by FEM. The results indicated that the shear capacity calculated by the existing specification is unsafe, and a modified formula was proposed by considering the internal force and deformation characteristics of transfer column.

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1. Introduction

Steel Reinforced Concrete-Reinforced Concrete (SRC-RC) transfer column behaves as the connection between the upper and lower members by extending the steel of the SRC or steel column to the adjective members. The SRC-RC transfer column investigated in this study comprises of two parts, the SRC part and the RC part, as shown in Fig. 1.

The steel is truncated in the SRC-RC transfer column, which will lead to a distortion of the internal force transmission. Experimental investigations on SRC-RC transfer columns have been conducted by Suzuki et al. [1] to investigate the influence of the extending height of steel on the mechanical behavior of transfer columns. Low frequency cyclic tests of 3 SRC-RC transfer columns and 1 RC column were conducted to compare their behavior. Yamamoto et al. [2] tested 13 specimens of transfer members under cyclic load to obtain the seismic performance of transfer columns. Cyclic tests of 7 SRC-RC transfer columns were performed by Kitamura et al. [3], in order to evaluate the effects of the enhanced reinforcement and extending height of the steel on the seismic performance and mechanical behavior of the transfer columns. Wu et al. [4] tested 21 SRC-RC transfer columns under cyclic load. The results found that the specimens were mostly dominated by shear failure, and the flexural failure and bond failure were mainly observed in specimens with greater extending height of steel. Zhao and Shao [5]

studied the influence of different structural measures on the seismic performance of transfer columns by the cyclic tests of 8 SRC-RC transfer columns. These tests were carried out on SRC-RC transfer columns having different extending height of steel, different axial load ratio, and different the shear span ratio. However, the number of the tests and the experimental conditions are limited, no systematic results have been achieved.

Current design rules specified in the national standard of the People's Republic of China: Design of Concrete Structures (GB 50010-2010) [6] and technical specification for Steel Reinforced Concrete Composite Structures (JGJ138-2001) [7], only a few structural measures are presented. Specifically, calculation methods of transfer columns, such as the formula of flexural capacity and shear capacity, are not provided. The shear capacity formula of transfer columns in AIJ Standard for Structural Calculation of Steel Reinforced Concrete Structures [8,9], which is derived by the ultimate flexural capacity, is not able to consider all kinds of failures of transfer columns. Thus, it is difficult for engineers to evaluate the performance of transfer columns in structural design.

The main objective of this study is to generally investigate the behavior of SRC-RC transfer columns. The location of the inflection point of SRC-RC transfer column was studied by considering the internal force and deformation characteristics. Then, the shear capacity of SRC-RC transfer column was investigated by carefully considering mechanical behaviors, and a formula of shear capacity was validated against published experimental results. Additionally, the security and rationality of shear capacity calculation of SRC-RC transfer column in Chinese code are explored. Finally, the shear capacity of SRC-RC

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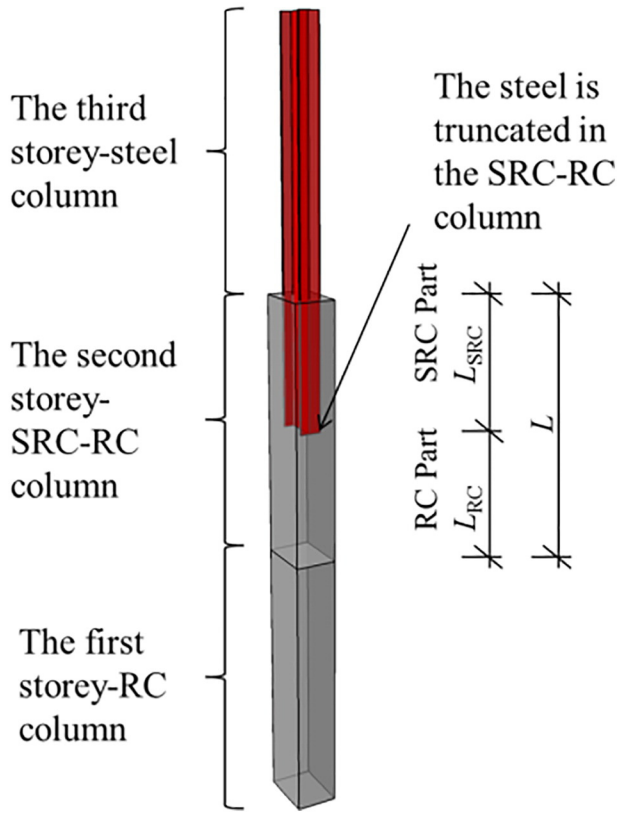


Fig. 1. SRC-RC transfer column.

transfer column obtained from the finite element analysis were compared with the shear capacity calculated using the national standard of the People's Republic of China and a modified formula with detailed discussion.

2. Deformation characteristic of transfer column

Continuous beam loading system and the so-called Kenken-style shear-bending loading system can both realistically present the mechanical behavior of column ends. But the continuous beam system, which is adopted here to analyze the behavior of transfer column, can clearly show the force of the column ends [10]. Fig. 2 presents the moment, shear and deformation view of the continuous beam type member.

Based on the principle of the deformation and second-order effect of transfer column, the force of the column ends can be obtained by the theory of structural mechanics, as follows:

$$M_{SRC} = \frac{L}{8}(3P_1 - P_2 + 2NR) - \frac{l}{4}(P_1 + P_2 - 2NR) \quad (1)$$

$$M_{RC} = \frac{L}{8}(3P_2 - P_1 - 2NR) - \frac{l}{4}(P_1 + P_2 + 2NR) \quad (2)$$

$$Q = \frac{1}{4}(P_1 + P_2) + N \cdot R \quad (3)$$

where $R = \delta/H$ is the inter-story drift, δ is the relative displacement between the column ends, H is the clear height of SRC-RC transfer column.

As indicated in Eqs. (1) and (2), the flexural deformations of steel and concrete don't coordinate at the SRC part end. The moment changes at the column ends under axial load, thus changing the location of the inflection point. The ratio of the distance H_c from the inflection point

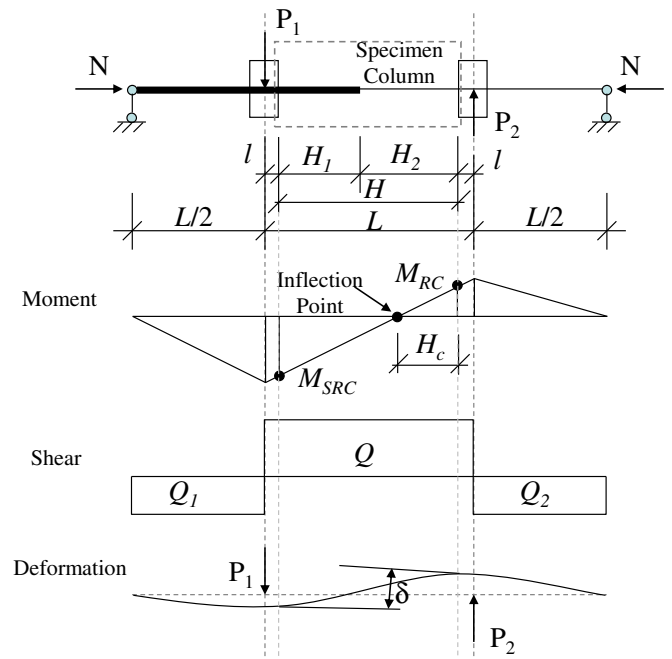


Fig. 2. Force and deformation of transfer column in continuous beam test.

to the top of the reinforced concrete part and the column height H can be calculated by:

$$\frac{H_c}{H} = \frac{\chi L - l}{L - 2l} \quad (4)$$

$$\chi = \frac{3P_2 - P_1 - 2NR}{2P_2 + 2P_1} \quad (5)$$

The value of H_c/H with the tests by Suzuki et al. [1] can be calculated by putting the test statistics into the formula above, which is shown in Table 1. As illustrated in the formula above, there is a sudden change of the stiffness along the height of the column caused by the local existence of the steel. Thus, the moment distribution changes at the column ends and the inflection point moves near to the RC part. With the extending height of the steel increases, the inflection point is located at about 0.4 of the column height near the RC part.

3. Shear capacity of transfer column

As shown above, the change of the stiffness caused by the local existence of the steel results in the change of location of the inflection point which is located at about 0.4 of the column height near the RC part, thus easily generating a short-column shear failure. The steel and concrete in SRC part behave together by mutual squeezing along the height of the column. The concrete transfers part of the shear and axial force to the steel. The co-working of the concrete and steel is based on the force transfer between them which also results in the distortion of the internal force transmission. Fig. 3 shows the ideal failure surface of SRC-RC transfer column under compound stress condition. Fig. 4 presents the stress distribution of the RC part. According to Figs. 3–4, the ideal failure surface angle θ ($\theta \leq 45^\circ$) between the column axis and the trace of the principle tension stress can be obtained by Eqs. (6) and (7). The lower limitation of θ is determined by $\cot \theta = 2$, which is provided by Tong [11]. The minimum value of θ is 26.6° .

$$\tau = \sqrt{f_t^2 - \sigma_0 f_t} \quad (6)$$

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