

Experimental Investigation of the Seismic Performance of the Joint between a steel encased in reinforced concrete column and a reinforced concrete beam

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ABSTRACT

In recent years, the use of steel-reinforced concrete (SRC) columns, including composite connections, in high-rise structures has increased significantly. One of the key issues in connection design is the proper detailing of the interface between the steel section embedded in the concrete column and the reinforced concrete beam. This study experimentally investigates the seismic performance of the connection between a reinforced concrete beam with a transition steel part (TP) and an SRC column, and compares it with other types of connections. Three experimental specimens were constructed: (i) a reinforced concrete beam (RC)–column joint, (ii) an reinforced concrete beam–steel reinforced concrete (SRC) column joint, and (iii) an reinforced concrete beam with a transition part (TP)–SRC column joint. All specimens were subjected to cyclic lateral loading on the beams and axial loading on the columns. The main experimental parameters include the effects of the steel section on load-bearing capacity, ductility, and stiffness, as well as the influence of the transitional part on ductility and stiffness. The results indicate that the incorporation of the TP substantially enhances the performance of the beam–column joint. Specifically, lateral load capacity increased by 1% and 15% in tension, and by 20% and 8% in compression, compared to the reinforced concrete beam–column and reinforced concrete beam–SRC column specimens, respectively. Additionally, ductility improved by 44% and 24%, respectively, compared to the same specimens. The results highlight the effectiveness of the TP in enhancing the load-bearing capacity and ductility of RC beam–SRC column joints.

KEYWORDS

Composite Connections, Seismic Performance, Transition Part (TP), SRC Column, Cyclic Load

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1. Introduction

This paper investigates Steel Reinforced Concrete (SRC) composite members and their connections. SRC columns, due to the combination of steel sections and concrete encasement, possess high load-bearing capacity, ductility, and resistance to fire and corrosion, making them suitable for tall structures and seismic zones [1-3]. Previous studies have shown that these columns have favorable seismic performance [4-6], and their connections play a crucial role in structural stability [7-15]. This research specifically focuses on the connection between an SRC column and an RC beam using a “Transitional Piece” (TP) [16, 17]. The primary objective is to prevent premature beam failure and limit damage in the connection region. The results indicate that the use of a transitional piece, which connects the beam’s reinforcement to the steel section of the column, significantly improves the load-bearing capacity, ductility, and stiffness of the connection under seismic loading. This approach is proposed as an effective solution for enhancing the safety and seismic performance of structures.

2. Methodology

In this study, three types of beam-column connections were fabricated, investigated, and tested. Each specimen was designed based on the ACI318-19 [18] standard. The RC specimen features a reinforced concrete beam and column. Both the SRCC-RCB and SRCC-RCB-TP-Hooked specimens have a steel column encased in reinforced concrete with a reinforced concrete beam. In the latter specimen, a steel section was utilized in the beam to column connection region (transition part). According to the design based on the ACI318-19 standard, the spacing of the stirrups in the critical region was considered. The longitudinal reinforcement bars for all three specimens are 14Φ , and their transverse reinforcement bars are 10Φ . Furthermore, the percentage of steel used in all three specimens, in accordance with the standard, ranges between 1% and 8%. In the design of the experimental specimens, scaled models were not based on the classic principles of similitude; rather, their dimensions were selected based on the limitations of the experimental equipment and the capacity of the loading system. The specimens were designed such that a strong column-weak beam mechanism governs the behavior, ensuring that damage, failure, and plastic hinging occur within the beam. Consequently, no significant damage or yielding is observed in the joint region (the panel zone) or the column. To facilitate better shear transfer between the steel and concrete, shear studs were employed on the steel sections (Figure 1). The concrete used for

fabricating the specimens was cast in place and monolithic. Its mechanical properties, including a compressive strength of 35 MPa, were determined through relevant tests. For all three specimens, a constant axial compressive load of 400 kN, equivalent to 0.8% of the column’s axial capacity, was applied. Subsequently, a cyclic lateral load was imposed at a point on the beam’s end according to a specific loading protocol. The testing of the specimens followed the ACI374-1-05 [19] protocol, and the specimens were investigated until a 15% reduction in load-bearing capacity was observed.



Figure 1. Details of Shear Studs

3. Discussion and Results

The parameters investigated in this study include the cracking behavior, the mode and location of specimen failure, the use of the transition part (TP) and its effect on plastic hinge formation, the lateral load-bearing capacity, the hysteresis (force–displacement) curves, and the secant stiffness. The cracks observed in the specimens occurred at the end of the beam and away from the joint region, with no cracking or damage detected in the joint core or the column. The maximum compressive and tensile load capacities at 1% drift were +43.5 kN and –45.7 kN for specimen RCC-RCB, –50.1 kN and +38.8 kN for SRCC-RCB, and –54.6 kN and +45.3 kN for SRCC-RCB-TP-Hooked, respectively. With increasing lateral displacement, the load-bearing capacity gradually decreased. Figures 2 to 4 show the hysteresis curves of the specimens. The cracking patterns, failure modes, and load-bearing capacities of the three specimens (RCC-RCB, SRCC-RCB, and SRCC-RCB-TP-Hooked) differed from one another. Due to the use of an embedded steel section within the reinforced concrete column in specimens SRCC-RCB and SRCC-RCB-TP-Hooked, the compressive load-bearing capacity of these specimens increased compared with that of the RCC-RCB specimen. Moreover, the crack distribution in SRCC-RCB-TP-Hooked was more uniform and extensive than in the other two specimens. The plastic hinge length in SRCC-RCB-TP-Hooked was also longer than in the other specimens. The lateral

ductility of each specimen was calculated as the average of the compressive and tensile lateral ductilities. The ductility values for RCC-RCB, SRCC-RCB, and SRCC-RCB-TP-Hooked were 6.9, 9.3, and 12.3, respectively.

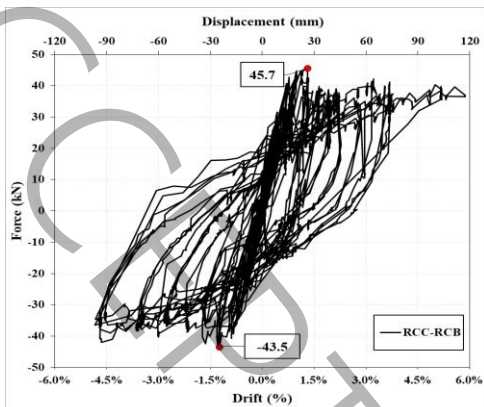


Figure 2. Hysteresis Curve RCC-RCB Specimen

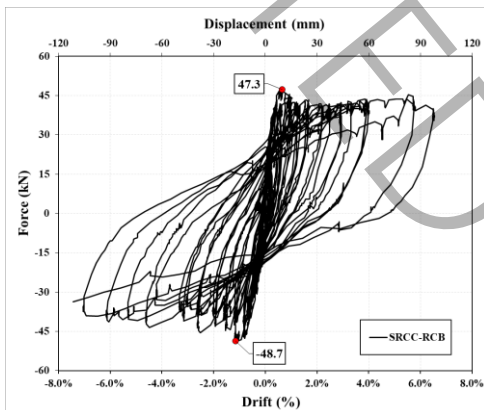


Figure 3. Hysteresis Curve SRCC-RCB Specimen

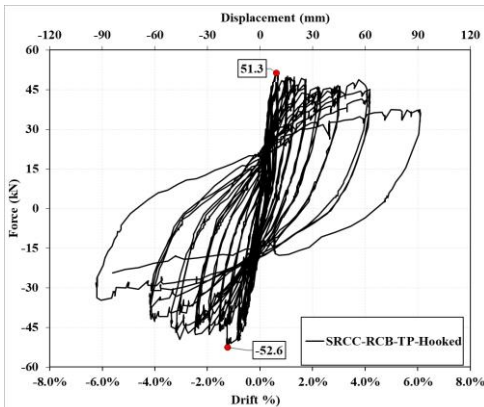


Figure 4. Hysteresis Curve SRCC-RCB-TP-Hooked Specimen

Since the columns in all specimens remained within the elastic range, cracking occurred in the beams, and the stiffness degradation curves were nearly identical. According to the results, the SRCC-RCB specimen showed an increase in stiffness of 13.5% and 37.5% in the tensile and compressive loading directions, respectively, compared with RCC-RCB, due to the use of the embedded steel section in the column. Similarly, the SRCC-RCB-TP-Hooked specimen exhibited increases of 50% and 45% in stiffness under tensile and

compressive loading relative to RCC-RCB, and 46% and 12% compared with SRCC-RCB, respectively, indicating the significant influence of embedded steel sections within both the column and part of the reinforced concrete beam.

4. Conclusions

Based on the conditions of each specimen and the investigations conducted in this article, the following conclusions can be drawn:

- The hysteresis curves indicate that the SRCC-RCB-TP-Hooked specimen exhibits superior performance in terms of lateral load-bearing capacity and energy dissipation. The presence of I-shaped sections in the reinforced concrete column and the transition part in the reinforced concrete beam has contributed to the increased energy absorption in this specimen.
- The results show that the secant stiffness of the SRCC-RCB-TP-Hooked specimen increased by 46.5% and 12.1% in the tension and compression directions, respectively, compared to the SRCC-RCB specimens. Furthermore, compared to the RCC-RCB specimen, the sectional stiffness increased by 51.2% and 45% in the tension and compression directions, respectively.
- The presence of steel sections encased in reinforced concrete column and a transition part of the beam in the SRCC-RCB-TP-Hooked specimen has led to increased energy dissipation. Consequently, the shear force acting on the joint's panel zone has also increased.

5. References

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