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Relocation of plastic hinge in exterior beam-column joints using inclined bars

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Abstract. Recent earthquakes have demonstrated that even when the beams and columns in a reinforced concrete frame remain intact, the integrity of the whole structure is undermined if the joint where these members connect fails. A good seismic performance of reinforced concrete frames depends on their ability to absorb seismic energy through inelastic deformations and to avoid a sudden development of collapse mechanism in event of a strong earthquake shaking. The primary objective of this investigation is to move the plastic hinge away from the beam-column joint region and hence reducing the damage to the joint region. In this research, the seismic performance of exterior beam-column joints with four types of confinement in joint region and inclined bars from column to beam is investigated experimentally. Control specimens without inclined bars and four types of confinement Square Hoop, Square Spiral, Circular Hoop and Circular Spiral were tested along with inclined bars were tested. Seismic performance was determined via load-deflection response, ductility, stiffness, energy dissipation, strain of beam reinforcement and crack pattern. Out of the four specimens with inclined bars, seismic performance of joint with Square Spiral confinement gave the best performance in terms of all parameters.

Keywords: beam; column; confinement; hinge; joint; plastic

1. Introduction

The failure of several reinforced concrete structures during the recent earthquakes in India as well as in other countries causes concern about the performance of the beam-column joints. Post-earthquake analyses of structures, accidental loading or laboratory tests show that the distress in the joint region is the most frequent cause of failure rather than the failure of the connected elements. It is therefore important to evaluate the performance of beam-column joints under earthquake loading detailed according to the most recent code recommendations (IS 13920-2016) and to devise superior detailing techniques for improved behaviour of lateral load resisting moment frames. Seismic forces produce stresses that are cyclic and reversible in nature, unlike the gravity-induced forces which predominantly act in one direction. Various detailing requirements for the section must account for this difference. The design requirement for a beam-column joint in earthquake resistant frames is rather simple, that it must not yield before the joining members reach their capacities and also must not deform excessively.

The formation of plastic hinge at the face of column in beam results in high longitudinal steel strains developing in the immediate vicinity of joint (Fattah and Wight 1987). Bond degradation also occurs in the joint core due to yield penetration from longitudinal beam bars located in plastic hinges adjacent to the joint core (Paulay *et al.* 1978). It is necessary to force the plastic hinge in the beam to form away from the column.

The primary objective of this investigation is to investigate experimentally, the seismic performance of exterior beam-column joints detailed according to the most recent recommendations (IS 13920-2016) with four types of confinement (SH, SS, CH and CS) in the joint along with inclined bars from column to beam. The aim of providing inclined bars is to relocate the plastic hinge from beam-column joint region to beam region.

2. Review of previous works

Shen *et al.* (2022) examined the impact of shifting the plastic hinge's location on the seismic performance of beam-column joint (BCJ) that have diagonal bars that are mechanically anchored. Five interior BCJ specimens were tested under cyclic load, one as a control specimen reinforced with traditional stirrups and the other four as reinforcement with mechanically anchored diagonal bars. According to test results, plastic hinges can typically be moved to the anchorage ends of diagonal bars by varying distances. The loading capacity and stiffness of BCJs can be improved by increasing the relocation distance, but doing so also raises the risk of joint shear failure. As the relocation distance increases, BCJs' ductility, energy dissipation, and joint shear deformation first improve and then decrease. In order to benefit from less strain penetration, plastic hinges should have a lower bound on their relocating distance; however, an upper limit must be specified to prevent joint

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