

## **INVESTIGATION OF REINFORCED CONCRETE BEAM COLUMN JOINTS WITH PLAIN REBAR UNDER CYCLIC LOADING**

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### **ABSTRACT**

The seismic resilience of moment-resisting frames relies heavily on the structural performance of reinforced concrete beam-column joints, particularly in low- to mid-rise structures that are typical in developing nations. Due to material and financial limitations, building materials like brick aggregate concrete and plain steel reinforcement bars were frequently used in the past. There is a noticeable lack of reported literature on joints made entirely of brick aggregate concrete and plain reinforcement in old RC structures. Therefore, in this study an exterior beam-column joint specimen at full-scale was used to assess the seismic performance of such joints. A quasi-static reversed cyclic loading was applied to the joints. Throughout the loading cycles, the experimental setup was set up to track energy dissipation capacity, displacement ductility, stiffness degradation, hysteresis behavior, crack patterns, and failure modes. The results showed a notable variation in seismic performance, especially, early stiffness degradation and premature cracking were caused using plain rebar and brick aggregate concrete. Poor seismic resilience was indicated by the joints' decreased ductility and limited energy dissipation capacity. The pinched behavior shown by the hysteresis loops further supported the low energy absorption capacity and quick strength degradation over numerous load cycles. The observed behaviors offer a fundamental understanding of how these materials affect joint performance. Additionally, the study provides information that may help shape future local design regulations and retrofit plans for already existing structures made of comparable materials.

**Keywords:** *beam-column joint; brick aggregate; plain rebar; cyclic loading; hysteresis loop*





Figure 3: Test setup for the experiment

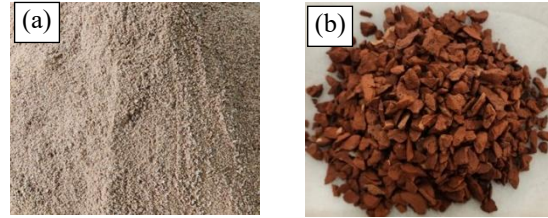


Figure 4: (a) Fine aggregate; (b) Coarse aggregate (locally available brick aggregate).

### 3. ILLUSTRATIONS

#### 3.1 Analysis of Cracking Characteristics and Failure Patterns

The structural performance of reinforced concrete beam-column joints under seismic loading was gleaned from their failure and cracking behavior (Zhang & Li, 2020), as shown in Figure 5. Due to push-pull loading, tensile cracks were observed on the beam faces perpendicular to the loading direction. The first crack was observed within one-eighth length from the joint. Cracks were then propagated to the other surfaces. Concrete spalling and crushing were observed on the column face opposite to the beam. The lack of yielding in plain bars resulted in buckling failure and an abrupt loss of stiffness following the peak load. These results highlight the need for retrofitting or more ductile alternatives due to the seismic vulnerability of such construction, which is prevalent in older buildings.



Figure 5: Cracks and failure zones of the beam-column joint in different locations.

#### 3.2 Beam Column Joint Analysis Under Cyclic Load

As shown in Figure 6, under cyclic loading the beam-column joint can carry a peak load of  $\pm 22$  kN at  $\pm 40$  mm displacement. The hysteresis loops show that the stiffness and strength decrease, with a 20–25% drop in peak load over twenty-four cycles and a lot of pinching because of bar buckling and bond failure. This means that the material is brittle and does not dissipate energy well. Figure 7 shows a typical nonlinear load-displacement response. It starts with a linear elastic phase and then cracks and yields at a peak load of 22 kN and a displacement of 40 mm. Damage like concrete cracking, crushing, and bar slip causes post-peak softening. The curve shape that isn't symmetrical shows that

the material behavior is non-linear and that the strength changes depending on the direction. The residual strength and displacement before failure show that the joint isn't very ductile and doesn't transfer energy well when it's loaded from the side.

The loop energy went up from about 20 kN-mm at loop one to about 1,430 kN-mm at loop twenty-one as shown in Figure 8. This shows that the behavior changed from elastic to inelastic. The rising trend indicates progressive damage and energy dissipation, while the slight decline after loop twenty-one suggests stiffness degradation or localized failures. The accumulated energy ratio steadily rose from 0% to 100% by loop twenty-four, showing a clear change from elastic response to failure as per Figure 9. The exponential rise in the last loops shows that damage is building up quickly and a lot of inelastic energy is being lost.

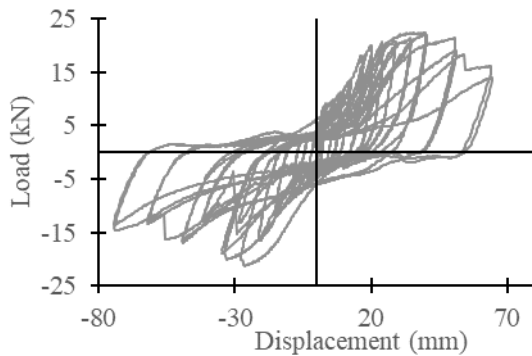


Figure 6: Hysteresis curve (Load-Displacement)

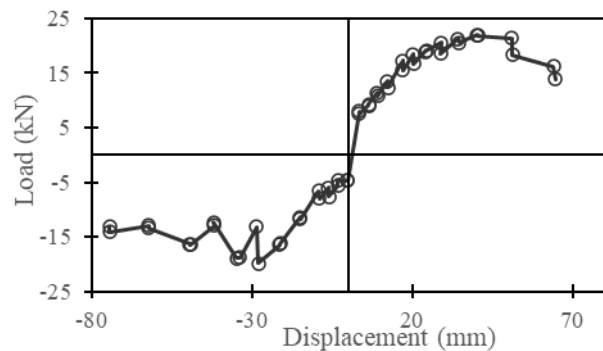


Figure 7: Load-displacement response of the specimen

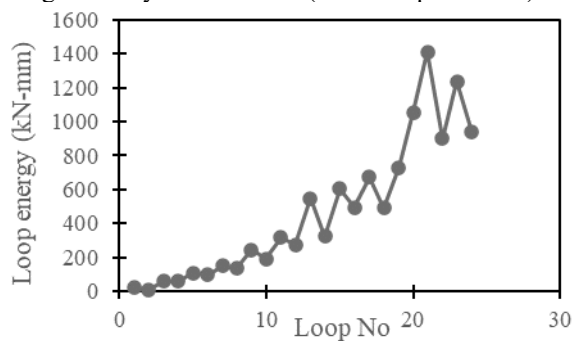


Figure 8: Loop Energy vs Loop Number of the Specimen

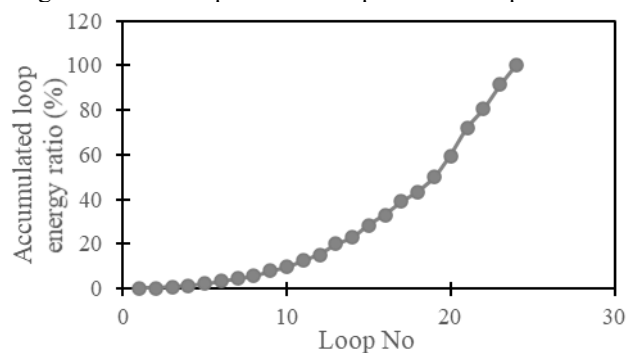


Figure 9: Accumulated Loop Energy Ratio concerning Loop Number

#### 4. CONCLUSIONS

The purpose of this study was to examine the way beam-column joints made of brick aggregate concrete and plain reinforcement bars would fare structurally under cyclic loads. Several key findings regarding the test results are:

- i. Due to their poor confinement and low bond strength, joints made with plain rebar exhibited early cracking, particularly in the beam and beam-column interface areas.
- ii. With increasing load cycles, hysteresis curves showed significant pinching and strength degradation, suggesting inadequate energy dissipation and a lack of ductile behavior by the brick aggregate concrete.
- iii. Significantly lower displacement ductility values were discovered, indicating insufficient post-yield deformation capacity, a crucial aspect of seismic resilience.
- iv. The risk of bar slippage under cyclic tension-compression cycles increased due to the use of plain reinforcement bars, which lack surface deformations and provide inadequate anchorage and poor bond-slip characteristics.

- v. Although locally accessible and reasonably priced, brick aggregates resulted in reduced compressive and tensile strength, which compromised the joint's overall integrity.
- vi. The brittle nature of the failure patterns and the lack of plastic hinge formation in the beam regions suggested that the strong-column weak-beam philosophy was not feasible.

These results provide important new insights into the potential and limitations of utilizing non-traditional materials in seismically active areas (Corinaldesi et al., 2011). Due to financial limitations, these materials are frequently used in buildings; however, their use in seismic zones without retrofitting or additional strengthening raises serious safety concerns.

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