



Influencing Parameters of Exterior Reinforced Concrete Beam-Column Joint Shear Strength: A Depth Review of Recent Advances

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ABSTRACT

Beam-Column Joints (BCJ) manage the structural behaviour and failure mechanisms under severe events, blast, earthquakes, and impacts. Thus, they are the critical constituents in a building. Disparate deficiencies, say beam weak on flexure, shear, and column weak in shear, are present in this joint assembly to account for limits in design rule. To analyze the Reinforced Concretes (RC) Beam-Column (BC) connections behaviour, systematic research was performed amid the past '20' years. The influence parameters in favor of the Shear Strength (SS) of external RC-BCJ are investigated here. (a) The Concretes Compressive Strength (CCS), (b) confinement joint by the beam, (c) anchorage length, (d) beam and column reinforcement, and (e) the columns axial load are the '5' main parameters intended for the joint SS, which is found through the outcome. The most considerable correlation to the joint SS was found with the CCS amongst the influence aspects. This study reveals the vital features of the RC-BCJ shear strength.

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NOMENCLATURE

M	Moment (kN.m)	Col, c	Column
T	Tensile force	s	Sagging
C	Compressive force	jh	Horizontal joint force

1. INTRODUCTION

Recently, numerous experimentation researches on the composite connection have focused on steel-RC column connection and RC column connection [1]. For carrying service loads and providing stress protection against bending, torsion, vibration, shear, impact, and fatigue under particular conditions, RC beams were created, which are Fibers-Reinforced Polymer (FRP) [2]. Lots of researchers analyzed the RC's performance in structural concrete. On an extensive scale, the RC beams' use was investigated. A 13%–18% decrease was seen on the SS of longitudinally RC beams [3]. If cracks occur in the BCJ region after the earthquake load, the BC adjoining to the joint won't work effectively. Significantly, the requirement of crack resistance capacity is high for the

structures in the corrosive surroundings [4]. The data were gathered from past earthquakes. It exhibited that the flawed model of the connections between the columns and beams and the bad design details for the structural members caused the precast and RC systems to collapse [5]. Vast dynamic loads, which might be more prominent, contrasted to the design loads of utmost structures rooted via the blast within or close to construction, could bring about catastrophic damage to structural frame systems structures [6]. High temperature has a huge role in the changes of material properties and strength diminution in reinforcement and concrete of RC column [7]. The construction engineers and steel fixers have to discover rebar spatial clashes and shun rebar clashes just once a spatial clash occurs. These clashes are tedious and impact the quality and construction expenditure [8]. Brittle

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failure occurs on the joints devoid of shear reinforcement under cyclic loading. However, with augmented concrete strength, their ductility increases [9]. Disparate parametric conditions, say beams longitudinal Reinforcements Ratios (RR), concrete strength, joint Aspects Ratio (AR), column RR, and also the joint stirrups impact at the joint were taken, and in that, '18' specimens were cast and tested [10]. The influence parameters of exterior RC-BCJ shear strength are exhibited in Figure 1. These studies' outcomes reveal the exterior RC-BCJ Shear Strength's behavior and contrast the behavior with the joints that lack shear reinforcement. The research also facilitates the methods to ascertain RC-BCJ's strength and identify the influencing parameters for an RC-BC shears strength.

2. LITERATURE SURVEY

The influence parameters of exterior BCJ-SS are surveyed here. The behavior RC-BCJ is surveyed in section 2.1. The strut and truss mechanism is elucidated in section 2.2. Section 2.3 illustrates the parameter influence of joint SS.

2. 1. Behavior RC Beam-Column Joint The seismic behavior of RC external vast BC connections is investigated. This study concentrates mainly on the load transfer paths and disparate performances of the joints with traditional and wide beams.

2. 1. 1. Behavior of Beam-Column Joint under Lateral (Seismic) Loading An essential factor that affects the utilization of vast beam systems in practice is the difference in Seismic Performance (SP) between a comprehensive BC system and a conventional BC system. This section surveys the SP of BCJ along with its drawbacks.

Kamakshi and Vinu [11] examined the structural activities of hybrid RC exterior BCJ. A hybridized

reinforcement system encompassed the on-sites fabricated, Hand Layup Carbons-FRP (CFRP-HL) stirrups, together with the customary steel reinforcements. Concerning ductility (2.19 times), load-carrying capacity (2.09 times), Energy Dissipation (ED) capacity (5.32 times), along with initial stiffness (2.29 times) high contrasted with the steel-RC specimen SJ, the hybridized reinforcement impact in joint HJ1 was comprehended. In addition, the greater complexity of on-site modifications was brought about by the constructability and the fabrication of FRP rebars.

Snehal and Dahake [12] elucidated the RC-BCJ analysis subjected to lateral seismic loading. The BCJ was a vital part of RC frames concerning lateral seismic loading. Amid severe earthquake shaking, the avoidance of anchorage in tandem with Shear Failures (SF) was not adequately addressed by design in addition to detailing provisions on BCJ in IS13920:1993. Failure might occur because utilizing the concrete does not encompass enough resistance. These were found via analyzing the damages that were incurred in an instant opposing RC framed structures that were subjugated to precedent earthquakes.

Marimuthu and Kothandaraman [13] illustrated the reverse cyclic behaviors of RC external BCJ with coupler anchors. In reversed cyclic loading conditions, '2' groups of joint specimens were cast as well as tested. The '1st' crack load of the coupler fitted specimen was enhanced. However, on account of the effectual anchorage of longitudinal beam bars via coupler arrangements, the '1st' crack load was delayed. Some drawbacks in RC BCJ with coupler anchors were the bad behavior of epoxy resins at temperatures over the glass transitions temperature in addition to the comparatively higher price of epoxy together with polymer materials.

Khan et al. [14] generated ultra-high performances fiber RC (UHPFRC) to SP of shear-deficient BCJ. Aimed at strengthening the concrete BCJ specimens, '2' disparate methods were employed. It comprised of: a) sand-blasting the usual concrete substrates surface of

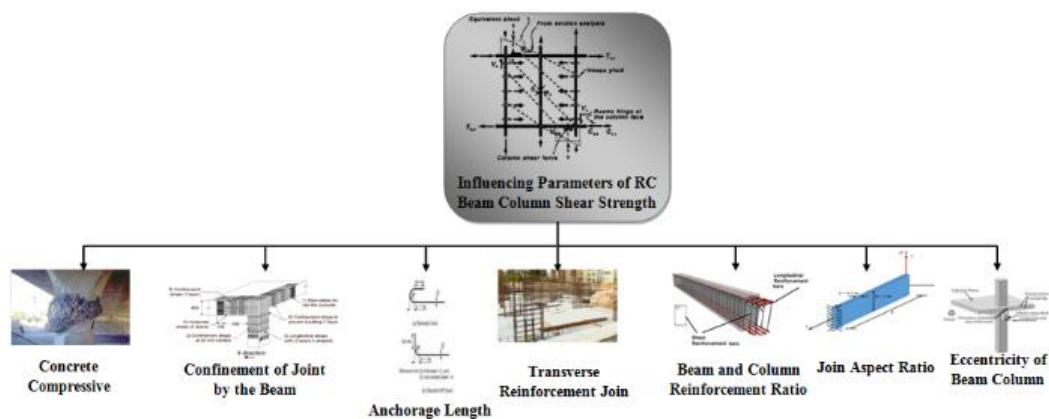


Figure 1. Influence parameters of exterior RC-BCJ shear strength

BCJ together with in-situ casting of a thirty mm thick UHPFRC and b) bonding thirty mm thick pre-fabricated UHPFRC plates for deficient BCJ utilizing epoxy resins together with special fillers. In contrast with the 2nd method, the 1st technique of strengthening was highly effective regarding shear capacity, stiffness, deformation capacity, and ED capacity. On the other hand, strength degradation and sudden diminution in the ductility were brought about by the issues of the detachment of pre-fabricated UHPFRC plates fixed to the joint utilizing epoxy.

Mosallam et al. [15] studied the RC-BCJ's structural behavior retrofitted with disparate sorts of FRP composites laminates together with hybridized connectors. Non-linear numerical simulations were evaluated aimed at the RC-BCJ behavior. A numerical appraisal of the behavior of an '8' full-scale interior RC-BC specimens was done. Simulated gravity in tandem with lower-frequency full-cyclic reversal, a load was carried out on the interior RC-BCJ specimens. A good correlation was attained between numerical and experimentation outcomes, in contrast to wood or unpainted lower-carbon steel.

Pimanmas and Chaimahawan [16] rendered the strengthening intended for an interior RC-BCJ centered upon the joint expansion conception. Cast-in-situ concrete expanded the BCJ two-dimensionally around the joint's corners. Interior BC specimens with the extended joint zone were taken to experiment. A good performance in upgrading the joint SS, ED, and ductility was found. The joint SF could be averted by augmenting the joint size. The joint expansion lessened the joint shear stress. It effectively changed failure mode as of brittle joint SF to flexural failure in beams. The corrosion was increased on account of the materials used.

Pampanin [17] illustrated the slab's impact on the seismic responses of sub-standard meticulous external RC-BCJ. Centered upon equations derived as of modern detailed BCJ subassembly test, the impact of the cast-in-situ slab and transverse beams was gauged. A minimal of about 2.2 times the beam depth was the effectual flange width while gauging the negative beam instant aimed at the seismic appraisal of non-ductile external b-c joints. Equal participation was not rendered by the reinforcement on the whole width of the slab in opposing the exterior instant with high strain levels close to the beam interface.

Santarsiero and Masi [18] examined an Italian seismic code mechanism for slab contribution to the BCJ's strength. The motivation was obtained on the apparent discordance between the findings of precedent experiments and analytical research and the rules rendered in present seismic codes considering the RC-BC connections' design for complying with capacity model principles. This effect represented the slab steel quantity

function. The slab reinforcements orthogonal to the beam were also highlighted. The collapse mechanism would shift column flexure to joint shear with augmented shear stress. It was not favourable. All these researches have a common ideology on improving the performance on behaviour of beam-column joint through either materials, anchorage system through the experimental test, model or simulation. So there is the necessity to understand the joint behavior to improve the performance effectively.

2. 1. 2. Forces in the Joint The joint reaction force is the force produced in a joint in response to forces on the joint are shown in Table 1. Ms, Mh are sagging and hogging moment of lateral beams, T, C are Tension in bars and Compression in bars, and lc - length of column. The force developed during earthquake in the moment-resisting frame BC joint is complex, with shear force dominating, from the joint portion's static equilibrium. At the moment frame, the horizontal joint shear force is shown in Joint A (knee/corner), Joint B (exterior), and Joint C (interior). The disparate forces on the joints and drawbacks were elucidated here.

Najafgholipour et al. [19] generated the Finite Elements Analysis (FEA) of RC-BC connections with governing joint SF mode. The ductile model philosophy and the anticipated overall structure performance were compromised via the brittle activities on the joint area. The crushing of the concrete diagonal strut on the joint area led to the connection specimen's failure. Bond slip of reinforcing steel and the intrinsic interaction within reinforcement and concrete on RC members have not been considered by the utmost finite element examination of RC structures.

Najafgholipoura and Arabi [20] generated a semi-analytical constitutive design for implementing the joint core shear deformation and unwanted joint SF mode on the non-linear examination of RC moment-opposing frames. The influential properties of the joint core were regarded in the equation. It included CCS, joint panel ARs, BC dimensions, and beam flexural RR. The design execution was also done on non-linear frame examination software SAP2000. The simple method presented a simulation analysis of '3' connections with disparate governing failure modes. The competence of

TABLE 1. Column Shear & horizontal Shear force in joint

Joint Type	Shear in Column	Horizontal Joint Shear Strength
Interior Joint (IJ)	$V_{col} = \frac{M_s + M_h}{l_c}$	$V_{jh} = C + T - V_{col}$
Exterior Joint (EJ)	$V_{col} = \frac{M_h}{l_c}$	$V_{jh} = T - V_{col}$
Corner Joint (CJ)	$V_{col} = T$	$V_{jh} = T$

capturing disparate failure modes on the joint area was found. Nevertheless, the SF of the joint panels was given concentration by some numerical studies.

Pan et al. [21] illustrated the BCJ modelling for non-linear examination of RC frames. A devoid of holistic frame examination was found to simulate the joint behavior and vital worldwide failure modes, like column axial, beam shear, column shear, and soft story failure. The ratio of the envisaged to the observed peak load encompassed a 1.05 mean and a 16.3% coefficient of variation for the '9' interior joint subassemblies modelled. Nevertheless, the compressive stresses in reinforcing bars were not anticipated together with the tensile stresses.

2. 2. Strut and Truss Mechanism The truss assembly of beams or other constituents generates a rigid structure. In engineering, it is a structure that "comprises of '2'-force members only, wherein the structural members are assembled so that, it behaves as a single object". Together with the truss mechanism in BCJ, the strut is elucidated here.

Zhang and Li [22] exhibited a customized strut-and-tie model (S.T.M.) for corroded RC external joints. Under '2' levels of representative columns axial force ratio, '8' same RC external joints with disparate corrosion levels of reinforcements were tested. Lateral loading resisting, ED, ductility, and the stiffness of corroded specimens were elucidated and contrasted with un-corroded control specimens. Together with the development length of beam longitudinal reinforcements, joint shears stress were examined and contrasted with available model code. The examination of the joint interior force flow of the corroded joint was done. The reinforcement's corrosion had a strong adverse impact on the joints' strength and lateral drifts capability with other mechanical properties. Highly specialized equipment was utilized by STM, which was fragile and luxurious.

Choi et al. [23] estimated the equal diagonal strut mechanisms and SS of the URM wall in-fill RC frames. Utilizing principal compressive strains on the concretes block wall, the diagonal strut means of the concrete block wall were elucidated. The sum of SS of RC columns and CB wall did not align well with lateral strength recorded on specimens. The SS of CB wall on IFRB and IFFB specimens in cyclic loadings was somewhat lower than those under monotonic loadings.

Mansouri et al. [24] generated a Gene Expression Programming (GEP) aimed at the predictive formulation of the SS of RC exterior BCJ devoid of Transverses Reinforcement (TR). The contribution of every variable of the BCJ comprised on the GEP could be appropriately reflected via the model. The disparate parameters influencing the joint's SS, such as material features, model variables, and joint geometrical and detailing configurations, were evaluated. Compared to prevailing

models, the rendered GEP more precisely predicted the SS of RC-BCJ. However, the system encompassed slow convergence together with low solution accuracy.

Choi et al. [25] elucidated the diagonal Strut means of URM Wall in-fill RC Frame. Static cyclic loading tests to comprehend the lateral force resistances mechanisms in the in-plane direction. In specimen 1S-2B, the compressive struts were generated individually in both walls in a way similar to the strut generated on specimen 1S-1B. However, specimen 1S-1B did not exhibit good accord with the lateral length.

Paul et al. [26] posited the diagonal Strut Mechanism of URM Wall Infill RC frames intended for Single and Double-Bays. A simple technique was discussed for estimating the lateral response of the URM in-fill RC frame. All through the loading cycle, the wall response for '1' bay and '2' bay specimens was accurately estimated by the equal diagonal strut method. Treating in-fill walls as a non-structural element should be trounced well at the design phase as it was not right.

Xue and Lam [27] examined the plane equivalent micro-truss element intended for RC structures. It was cost-effective to properly replace the continuum design with micro-truss elements, particularly for automatically forming the STM. The relative error of deflection designed with '2' elements with augmenting element number quickly decreased. The solution agreed with the theoretical value having the element size around 1/10 to 1/15 height of the beam. However, presenting the concrete modeled with the utilized-defined element was hard.

Lee et al. [28] suggested the diagonal strut actions on masonry in-fill RC frames. Customized Compressions Field Theory together with Disturbed Stress Fields design was employed. However, the diagonal strut actions in the cracked masonry in-fill along with consequent failure mode relied on model variables, say the masonry thickness, cohesion on the mortar joint-bricks interface, together with the bad mortar filling presence. In addition, the columns and beams were lightly reinforced members and did not satisfy the needs of intermediary and special instance frame members.

Wu et al. [29] elucidated the mechanical performances of steels truss RC transfer beam. It analyzed the development of crackdown the beam, strains of reinforcements, and steel truss, together with force transference mechanisms of the deep beam. In contrast to the normal RC transfer beam, the bearing capability and the rigidity of the STRC transfers beam were ameliorated considerably. In the STRC transfer beam, the STM force transference mechanism was generated. The diagonal shear cracks chiefly appeared down the diagonal strut on account of the STM force transferences mechanism of the deep flexural members.

Van den Hoogen [30] explicated the beam truss mechanism aimed at shear on concrete. Beam or truss

mechanism in concrete for shear was discussed. Higher load failure was brought about by the artificial cracks (i.e.) by crushing the concrete instead of SF. Additionally, the truss mechanism occurred in this circumstance. The regular beam bending or shear cracks, when occurred, would result in the failing of the beam without the truss mechanism's occurrence. However, the crack is not straight in reality. It would be curved via the influence of shear stresses. Additionally, the actual depth is hard to predict.

Abdul-Razzaq et al. [31] illustrated the concrete and steel strengths endeavour on deep beams with reinforced struts. The experimentation tests were executed on '9' specimens. These specimens were split into '3' groups. The outcomes showed that in the specimens, merely the STM was reinforced. The augmentation in the ultimate capability and diminish on mid-span deflection were around 26-40% and 19-28% correspondingly, for the RC frames. The model's capacity seemed lower because of a lessening midspan deflection.

Wang and Hsu [32] estimated the activities of RC moment-opposing frames with badly reinforcing details. The main aim was to predict the RC moment-resisting frames' behaviour, particularly for the joints with badly reinforcing details utilizing truss mechanism examination. However, the reinforcement strain forecast on the column seemed better than that on the beam compared to the detailed comparison between experimentation and analytical outcomes. The reason could be in the joint modelling aimed at the beam prediction with lesser accuracy.

3. PARAMETER INFLUENCE OF JOINT SHEAR STRENGTH

The research community still debates the influence of disparate parameters on the joint SS. Therefore, the critical aspects of the joint SS of BCJ and the significance of these factors are elucidated. Various researchers developed empirical research on the joint shear strength model prediction and discussed their limitations, the empirical-based joint shear strength models derived with various parameter. On comparisons of those models, significant difference identified between among various models to predict joint shear strength. The difference in prediction models with experimental results caused due to non-uniformity on selection of actual influence of parameters of joint shear strength.

3. 1. Concrete Compressive Strength The capacity of failure under the action of compressive forces is termed the compressive strength of a material. Compressive strength is vital for ascertaining the material's performance amid service conditions, particularly concrete.

Murad [33] research carried out a model for predicting joint shear strength using the GEP technique. For the model, the following parameters were considered compressive strength of concrete, amount of transverse reinforcement, geometric property of joint panel (width and depth), concrete strength, the ratio of reinforcement, and axial column load. The results confirm that concrete compressive strength after the crack and the contribution of concrete in resisting shear force was significantly reduced.

Pauletta et al. [34] proposed semi-empirical models to find the shear strength capacity of the joint with the parameters of axial load on column with formation concrete strut. Concrete strut strength mainly depends on concrete compressive strength. The shear strength depends on the concrete strut transverse and longitudinal reinforcements. The reinforcement with proper transverse reinforcements gives the confinement effect to achieve higher ductility.

3. 2. Confinement of Joint by the Beams This section surveys the different confinements of joints. The joint is controlled via the longitudinal reinforcing steel and the confinement provided by the TR. Wu et al. [35] conducted their work on curing process optimization based on curing degree considered the shear strength of joints.

Karthik et al. [36] formed a Compatibility-STM (C-STM) for tested C-beam specimens. It was subjugated to differing degrees of ASR or DEF deterioration together with differing degrees of related corrosion of the rebars. The simulation accounted for age-modified cover in tandem with core concrete material properties. Additionally, the resultant passive prestress took endeavor on the longitudinal together with T.R. With an augmentation on the passive prestress effect, an augmentation in strength and the stiffness of the specimens was observed. The progression of non-linear events brought about the large BCJ failure. Differing levels of ASR or DEF deterioration affected it, which was tracked successfully via the C-STM. However, the system encompassed inadequate anchorage lengths.

Khan et al. [37] rendered a simplified BCJ modeling method aimed at the inelastic examination of RC moment-opposing frames. A zero-length link constituent with an instant-rotation lumped plasticity hinge was presented in the joint model. To simulate the non-linear shear activities of the joint panel, it was rendered at the intersection of BC elements. '2' portal frames were tested on quasi-static cyclic loads. To envisage the cyclic force-displacement hysteretic response, the modeling technique was implemented. Nevertheless, critical damage wasn't attained via the shear strains of the joint panel.

Gao and Lin [38] posited that XG Boost intended for exceptional classification outcomes of the BCJ's failure

modes. The SHAP was employed to explain the features' endeavors in the envisage models. An accurate envisage of the interior BCJs' failure mode was done. The change of failure mode from brittle to ductility failure was suggested for the BCJ. SHAP was used to consider feature interactions and render an impact examination of every feature. Nevertheless, for adjusting the failure mode of a BCJ, the model could not render the changing magnitude of the influencing parameters.

Massone and Orrego [39] formed an analytical model for SS assessment of RC-BCJ. For envisaging the non-linear activities of RC-BCJ, the execution of the model was done while considering axial together with shear stresses. It was centered on a plain formulation which regarded an average strain together with the stress field of an RC panel signifying the joint. The equilibrium was satisfied in the longitudinal direction. There was a difference in the total specimens with SF.

3. 3. Anchorage system for RC Beam-Column Joint

Development length, termed anchorage length, is rendered for transferring steel to concrete. Anchorage system in RC BC with different materials is were discussed in this section.

A suitable anchoring length must be given for the longitudinal beam bar at the connection. In previous earthquakes, numerous reinforced concrete structures have been badly damaged or collapsed due to insufficient joint detailing (no transverse reinforcing in the joints) and longitudinal beam bar anchoring. Additionally, the longitudinal beam bar is exposed to alternate compression and tension loads during reverse cyclic loading, resulting in bond weakening and diagonal tension cracking in both directions. As a result, the whole structure rapidly loses strength and rigidity. Rather than these, increased joint performance should be achieved via new design strategies or enhanced details.

Park and Paulay [40] examined thirteen full-scale reinforced concrete beam-column connections subjected to reversed cyclic stress. The method by which the beam steel was secured inside the joint, the presence of "U" bars, and the quantity of transverse reinforcement were crucial factors. As a consequence of diagonal stress cracking and anchoring failure, the joint progressively degenerated. Additionally, the fast degeneration of joints is accelerated by crack opening and closure during seismic excitation. As a result, effective anchoring and confinement of beam-column joints are critical for increasing their seismic performance. After extensive research, Park and Paulay [40] proposed a few approaches and processes, that fulfill the joint core's anchoring, shear, and confinement requirements. All used bend-up bars, bent-up bars incorporated into stub beams, and mechanical anchoring to the bar's end.

Leon [41] determined the anchoring length by examining the behavior of four half-scaled internal joints

with varied anchoring lengths. Significant factors were column depth, anchoring length (between 16 and 28 times the diameter of the bar), and changing joint shear stress (between 11.5 and 18.5 of compressive strength of concrete). The results indicate that 24db (dia of bars) of anchorage is required to achieve the beam's maximum strength, whereas 28db of anchorage enables adequate energy dissipation and the formation of plastic hinges (strong column and weak beam concept). However, the usage of smooth bars and conventional practice techniques contribute significantly to joint problems (inadequate detailing of reinforcement, instead of providing anchoring, hook-end was utilized).

Pampanin et al. [42] investigated the behaviour of three different types of beam-column joints when subjected to reverse cyclic load to demonstrate joint inefficiency. Each specimen was cut in half and revealed smooth bars, insufficient reinforcing features (i.e., no transverse reinforcement in the joint), and hook-ended bars (deficiencies in the anchorage). The use of smooth reinforcing bars with end-hook anchorage in the absence of transverse reinforcement results in brittle damage mechanisms, and the use of older details results in concrete "wedge" spalling, brittle local failure, and loss of bearing capacity in the exterior joint.

Adopting outmoded structural characteristics results in a shear hinge mechanism in the joint region, which results in rapid strength degradation and increases local deformation, ultimately failing the entire frame system. Additionally, the anchoring of main beam bars, the transverse strengthening of joints, and the placement of lapped splices substantially affected the joint's effectiveness.

Kuang [43] investigated the behaviour of RC exterior beam-column joints using a variety of different types of anchoring in the beam reinforcement and laps in the column bar's lower zone. The results reveal that external beam-column joints' hysteretic behaviour and shear resistance are mostly governed by the beam's reinforcing details and anchoring length. Even in places with low to moderate seismic activity, it is critical to pay attention to the design of the RC beam-column junction. Apart from anchoring the beam's primary longitudinal bar, joint confinement is a critical feature that significantly affects cooperative behaviour.

Murty et al. [44] investigated twelve RC beam-column joint subassemblies with varying details of beam bar anchoring and transverse reinforcement at the joint core. The study's results indicated that the specimen combination of full anchoring and ACI standard hook with hairclip provides excellent energy dissipation and hysteretic loop and may be used in structures located in low seismic zones.

3. 4. Transverse Reinforcement in Joint TR should be rendered within the joint region to resist shear

forces and confined concrete. Disparate TR joints are elucidated.

Adib et al. [45] examined non-linear designing of cyclic response of RC-BC joints reinforced via plain bars. Linear elastic elements represented the BC components. Rigid elements defined the dimensions of the joint panel. At the beam's end, the non-linear rotational spring took into deliberation the slip's effect. The BC connections that had bar slippage failure mode were considered. However, a lower moment capacity with a lower axial load was there.

Said et al. [46] elucidated the outcome of replacing the TR with cementitious composite in RC-BCJ subjugated to cyclic loading. For testing, '2' specimens of whole-scale RC-BCJ were cast and prepared. At a 5% drift ratio, the joint was damaged. At the drift ratio of 7%, the ECC specimen was damaged. Lastly, the failure happened in the joint zone due to the localization of '2' prominent cracks.

Marimuthu and Kothandaraman [47] explored the TR methods in RC-BCJ. Throughout the years, numerous techniques of reinforcing techniques were developed. Enhanced performance, lessened congestion, effortless fabrication; in addition, the simple placing of concrete on the joint was found. Superior performance was attained by headed studs aimed at the joint's conventional shear reinforcement. Headed stud joint's behavior was very close to convention behavior. When there were issues with the reinforcement congestion in the joints, the diagonal collar stirrups were not helpful.

Sengupta and Li [48] formed a customized Bouc–Wen design aimed at the hysteresis behavior of RC-BCJ with restricted TR. For solving the differential equations accompanied by executing a systematic appraisal of the parameters associated with the model, Livermore Solvers for Ordinary Differential Equations together with the Genetic Algorithm was employed. Centered on the broad parametric study, the impact of the joint physical parameters, say the column axial load ratio, plain or deformed bars aimed at longitudinal reinforcement, the joint AR, the BC longitudinal RR, concrete compressive cylinder strength, on the parameters were meticulously studied. However, the sensitive ranking of every parameter could easily be deduced after every parameter to a definite gamut of gauging error happened because of every variation.

Kotsovou and Mouzakis [49] generated a seismic design of RC exterior BCJ. The diagonal strut mechanism predominantly resisted the HDC exterior BCJ, centered on the supposition that the load transferred to the joint as the BC elements. The method's validity was experimentally verified via a comparative study of the performance of '7' full-size BCJ sub-assemblages. In accord with the present European Codes, '3' were designed along with four in compliance with the technique. Those modeled to comply with the

specifications completely fulfilled the code performance needs compared to the specimens modeled in compliance with the present code provisions. However, it was hard to place on compacting concrete.

3. 5. Beam and Column Reinforcement Ratio

For preventing concrete crushing, the maximum RR for beams is rendered. The minimal RR for columns is needed for providing resistance in opposition to bending that might occur regardless of analytical outcomes. The researched-on RR of disparate materials utilized in BC-SS is discussed here.

Wang et al. [50] studied the RR's effect on the competence of the RC column to oppose lateral impact loading. It discussed the consequence of lateral impact loading rates, longitudinal RR, and stir-up ratios on the failure mode, lateral load-bearing capacity, et cetera. The ultimate load-bearing capacity of columns would be the augmentation in longitudinal RR. The longitudinal RR and loading velocity did not significantly influence it. However, the column would be susceptible to SF if the stirrup space was larger or else to flexural failure.

El-Gendy and El-Salakawy [51] elucidated the flexural reinforcement sort's consequence together with the ratio on the punching activities of RC slab-column edge connections subjugated to reversed-cyclic lateral loads. Doubling GFRP-RR of 0.7 to 1.4% brought about 43 and 63% amelioration in the initial stiffness and the connections' ED capacity. However, the stiffness degradation was not significantly affected. As the strain gauge malfunctioned after the 1.00% drift ratio, the ratio couldn't be gauged to connect ES-0.7.

Ibrahim et al. [52] illustrated the steel-to-FRP RR as a tool managing the SFRC BCJs' lateral response. The outcomes displayed that instead of FRP RR, utilizing the steel RR could improve the administration of the SFRC BCJs' serviceability state. However, preventing breakage in non-structural elements was a highly complicated task worth 3 to 5 times the expense. Consequently, the non-structural elements' breakage in FRP-RC models might be higher.

Tobbi et al. [53] explicated the Concentrically Loaded Fibers-Reinforced Polymer RC Columns' activity with several reinforcement kinds together with ratios. The outcomes displayed that the FRP bars had been utilized as longitudinal reinforcement aimed at concrete columns intended for the concentric compression; in addition, the FRP transverse reinforcement's amalgamation and steel longitudinal bars provided suitable strength and flexible behavior. However, the stress computation did not consider the deprivation of concrete cover involvement following the breakage. Therefore, the concrete columns regarded the cross-sectional region from the elastic phase's start until failure was not precise.

Yavas and Goker [54] illustrated the RR's impact on shear behaviors of I-shaped UHPC beams and devoid of fiber shear reinforcement. The outcomes displayed that the SS in higher RRs via the SF-UHPC's mechanical features along with fibers' crack-bridging capacity was advanced if the steel fibers' insertion to the UHPC mixture with lower RRs adjusted the failure mode as of the shear to flexure. The present methodologies for the envisaging of SS were not employed to execute the SF-UHPC members.

Carmo et al. [55] analyzed the lightweight cumulative concrete BCJ with various strengths along with RR. The outcomes displayed that to get the benefits of tensioned rebar's capacity, a considerable quantity of concrete in compression along with concrete with higher strength was desired by the BCJs with higher RR. The proper casting of the concrete was highly complicated, with the small cross-sections possessing a higher number of rebar.

Hassan et al. [56] illustrated the column size and RR's consequence on SS of glass fiber-reinforced polymers (GFRP) RC 2-Way Slabs. The outcomes displayed the crucial factors influencing the punching shear capacities like the reinforcement and slab size, accompanied by the ratio of the slab critical section's perimeter to the effectual slab depth. The FRP grids might not provide a similar punching shear.

3. 6. Column Axial Load Ratio Axial load is a structural load of a beam slab and a brick wall that functions on a longitudinal axis on a column. The different methodologies aimed at increasing the axial load ratio were explicated in this section.

Karimi et al. [57] recommended an FRP-encased steel-concrete composite column for several slenderness ratios. However, the devise methodologies for Concrete-Filled Steel Tubes (CFSTs) or Concrete-Encased Steel (CES) columns were not applicable due to the FRP tube's existence. Therefore, an analytical methodology was produced to discover the composite column's activity for several slenderness ratios. The predicted values highly agreed upon the experiential outcomes from the appraisal of 6 columns between 500 mm-3000 mm in height. The parametric study was executed to scrutinize the effect of the diameter of column, FRP tube thickness, FRP tube's axial compressive modulus, steel-to-concrete region ratio on the capacity associations along with slenderness limit. Nevertheless, the composite column's constancy was reduced with an augmentation in diameter.

Mogili et al. [58] examined the impacts of BC geometry together with eccentricity on the seismic performance of RC BC knee joints. In consequence of the shortage of experiential outcomes, the performance of knee joints' impact and the beam axis's eccentricity with the column centerline was not recognized. To review the impact of the beam axis's eccentricity and the proportion

of BC flexural capacity, the 4 full-scale knee joint sub-assemblages were evaluated underneath the upturned cyclic loading. The outcomes displayed the knee joints' weaker performance. The eccentricity's declining consequence was noticed in the opening activities. To ameliorate the opening capacity, the stronger columns were employed effectively. However, the methodology possessed a torsional breakage.

Halahla et al. [59] examined Shapes Memory Alloys (SMA) on the springiness of external RC BCJs utilizing the damage plasticity method. The consequence of utilizing the SMA on the flexibility capability of exterior RC-BCJ at various column axial load levels was concentrated in this work. The experiential outcomes obtained from the literature for authentication reasons were correlated with the outcomes attained by the finite element examination; both were contrasted with theoretical solutions. The outcomes displayed that the use of SMA enhanced the springiness of RC joints without dropping load capacity. Furthermore, the finite element technique successfully executed the capture of huge strain accompanied by the super-elastic activity of SMA bars.

Zhao et al. [60] examined a macro BCJ element technique to deliberate the consequence of joint inelastic deformations aimed at an internal joint with stirrups. The force transfer methodologies and inelastic response methodologies were regarded for the evolvement of macro BCJ, utilizing axial springs demonstrating the bar-slip technique of longitudinal reinforcement, concrete, and reinforcement on the interface-shear together with joint core. Eight reinforcement materials and concrete components in the joint core were operated simultaneously to impact joint shear deformation. The outcomes displayed that the joint method could create the joint SS, hysteretic response, and BC sub assemblages' joint shear deformation. To estimate the relationship for interface-shear springs, merely small data are utilized. However, the lower ductility was possessed by the methodology.

Influencing parameters are analyzed for RC-BC joint SS Concerning RR; the BC ratio's result utilizing disparate materials and methods is estimated. Finally, the different methodologies utilized to augment the external RC-BCJ shear strength are analyzed with Figures 2 and 3.

The BC ratio's evaluation concerning RR is exhibited in Figure 2. Kaszubska et al. [61] investigated on the influence of longitudinal GFRP reinforcement ratio on shear capacity of concrete beams; GFRP has 1.85% of R.R. CFRP [62] and hybrid fiber [63] have 1.25% and 1.90%. Then, lightweight aggregate concrete (LWAC) [64] has 1.52% of RR. Then, CFRP [65] and Eurocode 8 (E8) [66] have 1.35% and 1.8%. Next, CFRP [67] has 0.68% RR, which is less RR than E8. Finally, FRP [68] has 2.01% of RR. Figure 3 shows the RR of various

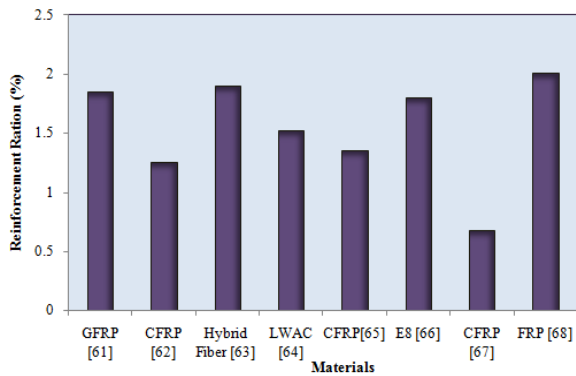


Figure 2. Evaluation of the BC ratio in terms of RR

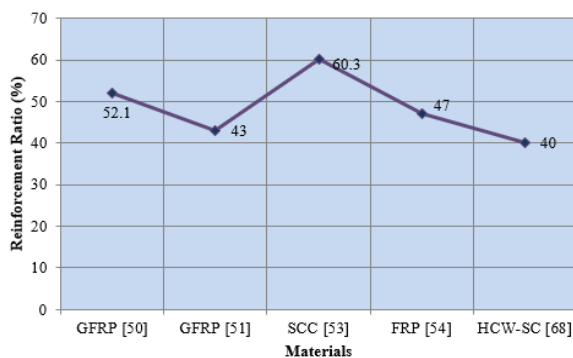


Figure 3. Evaluation of the BC ratio in terms of RR

materials used in SS GFRP [50] has 52.1% of DR. GFRP [51] and SCC [53] has 43% and 60.3% of DR. Then, FRP [54] has 47% higher DR than all other materials. Then, HCW-SC [68] has 40% of DR.

3. CONCLUSION

This study intends to comprehend the consequence of disparate parameters on the SS of exterior RC-BCJ. The experimentation tests' huge database is employed to assess the major role of parameter on the joint SS of exterior BCJ. The imperative levels of main parameters on the joint SS are exhibited in the data analysis. The CCS, the joint AR of the joints, anchorage of beam longitudinal reinforcement, and the number of stirrups in the joint are the most vital factors affecting the shear capacity of external RC-BCJ. The influence of higher strain rate loading on the specimens' flexural capacity modeled utilizing gravity and seismic considerations is investigated. The subassembly's ductility is enhanced with the amelioration of the reinforcement at the BCJ. The ductile subassembly exhibits high stiffness and ultimate strength under higher strain rate loading. A limited range of applicability is only there for most strengthening schemes developed so far. However,

additional research is needed to develop sufficient guidelines over a longer-term service for RC with transverse or lateral confinement.

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Persian Abstract

چکیده

اتصالات تیر-ستون (BCJ) رفتار سازه و مکانیسم‌های شکست را تحت حوادث شدید، انفجار، زلزله و ضربه مدیریت می‌کند. بنابراین، آنها اجزای حیاتی در یک ساختمان هستند. کمبودهای متفاوت، مثلاً تیر ضعیف در خمش، برش، و ستون ضعیف در برش، در این مجموعه مشترک وجود دارد تا محدودیت‌ها در قاعده طراحی در نظر گرفته شود. برای تجزیه و تحلیل رفتار اتصالات تیر-ستون (BC) بتن مسلح (RC)، تحقیقات سیستماتیک در میان ۲۰ سال گذشته انجام شد. پارامترهای تأثیر به نفع مقاومت برشی (SS) RC-BCJ خارجی در اینجا بررسی می‌شوند. (الف) مقاومت فشاری بتن (CCS)، (ب) اتصال محصور شده توسط تیر، (ج) طول لنگر، (د) آرمانور تیر و ستون، و (ه) بار محوری ستون‌ها پارامترهای اصلی 'ه' هستند. برای SS مفصل، که از طریق نتیجه یافت می‌شود. قابل توجه‌ترین همبستگی با SS مشترک با CCS در میان جنبه‌های تأثیر یافت شد. این مطالعه ویژگی‌های حیاتی مقاومت برشی RC-BCJ را نشان می‌دهد.