IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

A Comparative Study of Precast Beam Column Connection and Conventional Beam Column Connection Using Ansys

Mr. Nishad Deshmukh[1], Dr. Sangketa Sangma[2]
[1]Student, Department of Civil Engineering, G. H. Raisoni College of Engineering and Management, Pune
[2] Assistant Professor, Department of Civil Engineering, G. H. Raisoni College of Engineering and Management, Pune

Abstract

This study investigates the effectiveness of precast beam-column connections compared to conventional beam junctions. Precast beam-column connections offer faster construction, lower labor intensity, and enhanced seismic resilience compared to conventional beam junctions. The prefabricated nature of precast elements allows for ease of assembly and disassembly, minimizing on-site labor requirements. Designed to provide effective stress transfer mechanisms, precast connections ensure structural integrity and stability under seismic loading conditions. These materials exhibit similar or even superior capabilities with regard to dissipating energy, load-bearing capacity, and deformation capacity. This research paper emphasises the contemporary and effective methodology of precast beam-column connections, which provide substantial advantages in terms of velocity, financial viability, and structural integrity. As a result, it contributes to the progression of norms and protocols within the construction sector. The objective of this study is to compare and contrast the cost-effectiveness, construction efficiency, and seismic performance of precast beam-column connections with those of conventional beam junctions.

Keywords: precast concrete, beam-column connections, seismic resilience, construction efficiency.

I. INTRODUCTION

The numerous benefits of precast concrete systems include rapid construction, high quality resulting from factory production, and cost-effectiveness through mass production. Despite its numerous benefits, precast concrete remains underutilised globally, particularly in areas prone to significant seismic activity. This is due to a dearth of knowledge and confidence regarding their performance in seismic regions, in addition to the absence of logical seismic design provisions in the building regulations for major model structures. The substandard performance of high-rise precast frame panel structures during the 1988 Spitak, Armenia earthquake can be attributed to inadequate seismic design considerations, including the absence of ductility in precast connections. During the 1994 Northridge earthquake, a considerable quantity of parking structures were severely damaged, and several precast concrete parking structures ultimately collapsed. The collapse was exacerbated, in part, by improper diaphragm connections. Aside from three structures that sustained severe structural damage, the majority of prefabricated prestressed concrete structures performed admirably during the 1995 Kobe earthquake. The structural damage was caused by inadequate detailing of the connections. As a result of past earthquakes, it has been determined that connections are the most vulnerable point. This necessitates further investigation into the subject of connections.

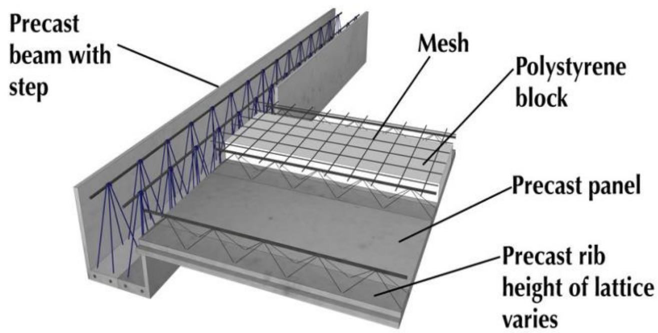

Fig 1: Precast beam

Rehabilitation and protection against seismic events pertain to a significant number of structures composed of precast and prestressed concrete components, which were originally constructed for industrial-manufacturing objectives. In the '50s, '60s, and '70s, during the post-World War II reconstruction and subsequent economic and social progress, a significant number of these structures were erected in Italy, where they are ubiquitous in many nations. During that era, structures were distinguished by their use of novel and even high-performance materials, as well as by their intricate structural arrangements that made use of innovative material and design techniques. However, these were not analogous to contemporary regulations and technical understanding; therefore, in order to evaluate current conditions, it is necessary to conduct distinct research on both local and global behaviour. Seismic risk analysis is more pertinent to this situation; in fact, numerous structures are situated in areas where they are known to be exposed to seismic risk after completion; consequently, the initial design solely accounts for gravitational loads, neglecting to incorporate lateral loads induced by earthquakes.

1.2 Precast Beam Column Connection

The intersection of a precast concrete column and beam exhibits a semirigid state due to the rotational characteristics of the material. When an application of force induces a moment in the connection, the connection rotates.

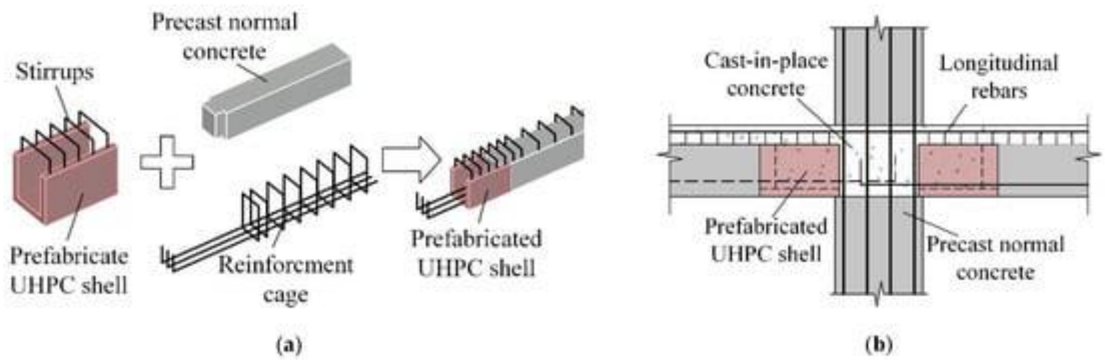

Figure 2: Schematic of the novel precast beam-to-column connection. (a) Precast beam, (b) connection.

The schematic representation of the precast beam-to-column connection, which is a novel concept presented in this research, is depicted in Figure 2. During the design phase, careful consideration was given to the connection interface of the precast beam (a) in order to ensure compatibility with the subsequent connection element. The implementation of a connection (b) that is straightforward to assemble and disassemble results in a reduction in construction labour and an increase in overall efficiency. The connection design is critical for ensuring effective tension transfer between the beam and column, thereby enhancing the structural integrity of the system as a whole.

1.3 Precast concrete products

1.3.1 Agricultural products

Precast concrete products are impervious to severe weather conditions and can withstand decades of continuous use. Agricultural fencing, bunker silos, cattle feed bunks, feed troughs, concrete panels, sewerage channels, livestock slats, livestock irrigation troughs, H-bunks, J-bunks, and livestock slats are among the many products offered by the organisation. Prestressed concrete panels find extensive application across diverse sectors in the United Kingdom. These sectors comprise agricultural structures, cereal storage facilities, livestock enclosures, silage clamps, effluent storage, and general retaining walls. Panels may be positioned either before or within the webbings of RSJs (I-beam) when utilised horizontally. Conversely, cantilever retaining walls may be assembled using modules that are inserted into position using concrete as the foundation.

1.3.2 Building and site amenities

Precast concrete is commonly utilised in architectural applications for site amenities and building components, such as curtain walls, fireplace mantels, cladding and trim products. Precast concrete finds application in the construction of a variety of structural elements, including pillars, walls, floors, and foundations. It is crucial to conduct comprehensive design and evaluation of every structural element in order to guarantee its capacity to endure the tensile and compressive stresses that the member will encounter during its operational lifespan.

1.3.3 Retaining walls

The utilisation of precast concrete enables the fabrication of an extensive variety of engineered earth retaining structures. Segmental retaining walls, mechanically stabilised earth (MSE) panels, commercial and residential retaining walls, and marine walls are among the products offered. Counterfort retaining wall, buttress retaining wall, cantilever retaining wall, and gravitation retaining wall are the five distinct types of retaining walls.

1.3.4 Sanitary and storm water

The purpose of structures intended for subterranean installation of storm water management products and sanitary water discharge is to eliminate and neutralise contaminants.

1.3.5 Utility structures

Critical connections and controls associated with the distribution of gas, electricity, steam and communications systems are protected by precast concrete utility structures. Precast concrete is environmentally safe and non-hazardous.

1.3.6 Water and wastewater products

To facilitate the subsequent refinement process of precast water and wastewater products into non-contaminating soil products and liquids, the products retain or contain liquids such as oil and water.

1.4 Effectiveness of precast beam-column connections compared to conventional beam junctions

The efficacy of precast beam-column connections in contrast to traditional beam junctions is attributed to a number of significant benefits. Precast beam-column connections offer faster construction speed, lower labor intensity, and enhanced seismic resilience. The prefabricated nature of precast elements allows for ease of assembly and disassembly, facilitating rapid construction and minimizing on-site labor requirements. Moreover, precast connections can be designed to provide effective stress transfer mechanisms, ensuring structural integrity and stability under seismic loading conditions. In terms of energy dissipation, load-bearing capacity, and deformation capacity, precast connections exhibit performance levels comparable to or surpassing those of conventional beam junctions. In general, the utilisation of precast beam-column connections signifies a contemporary and effective methodology towards constructing edifices, presenting notable advantages over traditional beam junctions in terms of expediency, economic viability, and structural integrity.

II REVIEW OF LITERATURE

Ruijun Zhang et.al (2022), exhibits an innovative dry-connection precast beam-column coupling that reduces labour intensity, improves assembly and disassembly, and facilitates assembly and disassembly. Comparing its seismic performance to that of cast-in-place joints, pseudo-static tests reveal that it possesses a similar bearing capacity and adheres to the strong column, feeble beam principal. Beam corrosion is most pronounced at steel connectors. Finite element modelling verifies simulations of mechanical behaviour. Dry connections promote building industrialization and resilience in regions characterised by extreme cold and high seismic activity, thereby providing advantages for construction.

Hector Guerrero et.al (2019), An experimental comparison is carried out to assess the seismic performance of beam-column connections made of monolithic and precast reinforced concrete (RC). A set of seven specimens, including a standard monolithic connection and various precast configurations, were assessed in total. Results show that precast specimens exhibit slightly lower stiffness but comparable load-deformation capacity to monolithic ones. Precast connections demonstrate higher deformation and energy dissipation capacities after yielding, with less damage and stiffness degradation. Overall, precast connections exhibit acceptable seismic behavior, closely resembling monolithic connections, suggesting their viability in seismic applications for the precast construction industry.

Haider Hamad Ghayeb et.al (2020), proposes innovative hybrid connections for precast structural buildings, utilizing steel tubes, plates, and couplers. These connections demonstrate enhanced seismic performance in comparison to monolithic connections when subjected to reversed cyclic loading. In particular, they exhibit enhanced energy dissipation, ductility, strength, load capacity, and displacement ratio. Failure modes involve yielding steel reinforcement and plates with less extensive damage than monolithic joints. Enhanced plastic hinges prevent sudden collapse, and improved crack resistance is observed. Results suggest potential for increased load capacity and improved structural integrity, particularly in high seismic zones, meeting seismic code requirements.

Kewei Ding et.al (2021), Utilising finite element simulations and full-scale experiments, the seismic performance of a bolt-connected prefabricated concrete beam-column joint is investigated. An evaluation is undertaken to ascertain the performance of the joint in comparison to grades 5.6 and 8.8, with specific focus on the effects of axial compression ratio and fastener strength. The outcomes of the simulation indicate that grade 8.8 fasteners have greater ultimate and yield bearing capacities, in addition to improved initial stiffness and energy consumption. Furthermore, it has been observed that joints featuring greater axial compression ratios undergo a more rapid decline in bearing capacity while maintaining an elevated initial stiffness. In general, the prefabricated joint exhibits exceptional resistance to seismic activity, efficiency in assembly, and capability to be repaired after a catastrophe. These qualities provide valuable knowledge for the design and execution of forthcoming prefabricated beam-column joints.

Jianxin Zhang et.al (2020), showcases a novel hybrid beam-column joint that has undergone evaluation using reversed cyclic loading. I-shaped steel connectors and energy dissipated connection panels comprise the joint. The seismic behaviour of one monolithic specimen and four hybrid precast connections was assessed during an evaluation. The test variables consisted of the implementation of steel fibre concrete, connection forms, and flange cover plates. The hybrid joint demonstrated enhanced seismic performance in comparison to the monolithic specimen, as evidenced by its stable hysteretic responses, increased strength, and enhanced energy dissipation. By efficiently transferring plastic hinges, minimising damage, and mitigating rigidity deterioration, the hybrid joint provides a feasible substitute for moment-resisting frameworks made of precast concrete that is also simple to assemble.

Abtin Baghdadi et.al (2020), Analyses the tensile strength of nine connections made of dry precast concrete that are frequently compromised by "cut-offs." Post-tensioning was utilised in conjunction with self-compacting Ultra-High Performance Fibre Reinforced Concrete (UHPFRC) reinforced with stained glass to assess intricate geometries resembling construction sites. The specimens, which were shaped like wooden puzzle pieces when bent, were subjected to bending stresses. Subsequently, load-displacement measurements were compared with numerical models. Based on the findings, specific beam connections attain a strength of intact sections equivalent to 85 percent. This research emphasises the capacity of precast concrete elements to perform better when combined with novel construction techniques; it provides valuable insights that can be utilised to enhance the structural integrity and efficiency of buildings.

De-Cheng Feng et.al (2018), Describes a finite element modelling approach for analysing the cyclic behaviour of precast beam-to-column connections, taking into account compression-softening of concrete, bond-slip effects, and post-cast concrete interface representation. To explain the cyclical behaviour and substantial bond-slip effects observed in reinforcement bars, a modified M-P stress-strain model is devised. A novel damage-plasticity model is applied to the concrete case. The method is validated through the simulation of experiments that encompass both interior and exterior precast connections.

Mr. Kalyana Chakravarthy P R et.al (2018), The strength properties of beam-column connections reinforced with precast material are assessed through the utilisation of AnsysCivil and a three-dimensional nonlinear finite element model. The monolithic connection is contrasted with five precast connections that employ distinct methodologies: J-Bolt, Cleat Angle, Dowel Bar, Dowel Bar and Cleat Angle, and Tie Rod. An axial loading nonlinear finite element analysis is performed on one-third of the models. The findings suggest that monolithic connections are more efficient in terms of ultimate load carrying capacity and energy dissipation, whereas precast connections demonstrate superior ductility, especially when dowel bar and cleat angle are utilised. With the selection of appropriate material properties and failure criteria, the performance of precast connections can be precisely predicted.

Rohit B. Nimse et.al (2014), Comparative analysis of damp precast beam-column connections and monolithic connections in the face of progressive collapse scenarios. In an era of increasing precast concrete construction, it is vital to ensure the dependability of connections in order to avert disproportionate collapse. An analysis is conducted on three distinct 1/3rd scaled precast connections that feature a variety of connection details, including steel billets and reinforced concrete corbels. The ultimate load-bearing capacity, maximal deflection, and deflection along the beam span are all factors considered when assessing performance. The findings suggest that precast connections demonstrate superior ductility and load-bearing capacity in comparison to monolithic connections. This research highlights the importance of connection detailing in bolstering the resilience of structures. It provides valuable insights that can inform the design of sturdy precast concrete structures, thereby reducing the likelihood of progressive collapse and protecting both human lives and resources.

Jang-Woon Baek et.al (2020), examines a half-scaled precast concrete (PC) double-beam system, developed to enhance economy and construction efficiency in industrial facilities. Cyclical lateral loading and gravity loading were applied to the PC double beam-column connection during testing. At the juncture, parameters including spliced PC columns and reinforcement were assessed. Results show satisfactory flexural capacity and seismic performance, comparable to conventional reinforced concrete (RC) systems. The PC double-beam connection meets ACI 374.1-05 provisions for moment frames. While the study focuses on interior joints, attention to exterior joints, prone to seismic excitations, is recommended for future research to ensure comprehensive understanding and reinforcement design in PC construction methods.

Lorenzo Hofer et.al (2021), presents the findings of an empirical inquiry concerning the cyclic characteristics of a column-to-foundation joint composed of precast concrete elements. By embedding corrugated steel conduits in the foundation and utilising high-performance mortar to secure column rebars, the joint is achieved. A total of six square-section columns made of reinforced concrete were loaded quasi-statically cyclically laterally while axial compression remained constant. Experimental variables, including rebar diameter and anchorage length, were ascertained through bond experiments. Upon comparing the results of precast joints and cast-in-place specimens, it was ascertained that their ductility, energy dissipation, and hysteretic behaviour were all comparable. Plastic hinge heights were determined using experimental concrete strains as the premise for the calculation and comparison with current code formulations. This study offers significant insights for the evaluation of the structural resilience of precast concrete connections.

Aman Agrawa et.al (2021), This study investigates the comparative merits of precast concrete and conventional cast-in-place building techniques in the context of a G+5 floor structure in India. By employing state-of-the-art technology and ETABS software, this study examines the performance of both categories of structures when subjected to inactive, live, and seismic pressures. An analysis is conducted on various factors, including external pressures, deflections, narrative deviations, mode morphologies, time-frames, frequencies, and base shears. The objective of this study is to assess the merits of precast construction in relation to traditional approaches with regards to velocity, effectiveness, and structural integrity. This research responds to the increasing need for expeditious and superior building methods in India's rapidly evolving environment.

M. N. KATAOKA et.al (2012), This study investigates the behaviour of beam-column connections in precast concrete structures, focusing on the continuity of reinforcement in the slab. An evaluation was conducted on two prototypes, each of which exhibited a unique distribution of reinforcement. As indicated by the results, connections featuring bars adjacent to the column demonstrated enhanced fracture control and increased rigidity, suggesting a semi-rigid behaviour. The experimental approach, which incorporated the utilisation of transducers and clinometers for rotation measurement, was deemed adequate and verified. Although Model 2 exhibited greater rigidity under service conditions, the secant stiffness of both models was comparable.

Hongtao Liu et.al (2016), To evaluate the seismic response of precast reinforced concrete structures, experimental procedures involve applying low reversed cyclic loading to beam-to-column connections. The axial compression ratio of the column was the principal determinant in the assessment of four joint specimens, comprising two precast joints and two cast-in-place joints. In an analysis that compared precast and cast-in-place joints, variations in fracture distribution and failure modes were discovered. It was observed that the axial compression ratio influences steel slippage in precast connections. The results emphasise the criticality of incorporating seismic resistance capacity into the stages of planning and execution. It is recommended that grouting sleeve splices be strategically placed in areas characterised by significant seismic activity to optimise operational efficiency.

H.-K. Choi et.al (2013), By applying interior configurations at a half scale, the seismic performance of beam-column connections can be assessed. In pursuit of this aim, a total of four precast specimens and one monolithic specimen are utilised. The joint detailing and special reinforcement type that are assessed as variables are employed to ensure the continuity of the beam reinforcement. The results indicate that plastic hinges installed at the beam ensured adequate connection strength, rigidity, energy dissipation, and drift capacity, in addition to preventing specimen failure. The joint strength surpassed monolithic construction expectations, and its behaviour remained ductile throughout a 3.5% drift. The research underscores the efficacy of precast connections under seismic circumstances, placing particular emphasis on their capacity to bolster the durability and security of structures.

Sang-Su Ha et.al (2014), Supporters of the implementation of an innovative precast concrete (PC) beam-column coupling that has been specifically engineered for areas susceptible to moderate seismic activity. Tightness transfer and workability are both enhanced through the implementation of a semi-PC connection comprised of U-shaped filaments. The system is composed of PC beams, columns, slabs, and capping concrete. By subjecting three exterior and three interior specimens to lateral cyclic load testing, their structural behaviour is assessed. As test variables, the number of strands and the presence of transverse reinforcements are considered. Based on an evaluation of the system's performance in compliance with ACI T1.1-01 (2001), it can be concluded that it is suitable for areas with moderate seismic activity.

Research gap

Despite the comprehensive exploration of precast beam-column connections in the reviewed literature, there remains a gap in understanding the long-term durability and performance of these connections under varying environmental conditions. Additionally, while the studies have focused on seismic performance, there is limited investigation into the impact of other external factors such as fire resistance and durability over time. Moreover, there is a need for further research on the integration of innovative materials and construction techniques to optimize the efficiency and resilience of precast concrete structures, especially in extreme climates and high seismic regions. Further research in these areas could provide valuable insights for optimizing precast construction techniques and enhancing structural resilience.

III CONCLUSION

In conclusion, the study underscores the significant advantages of precast beam-column connections over conventional beam junctions. Precast connections offer faster construction, reduced labor intensity, and heightened seismic resilience, thereby advancing the efficiency and safety of structural systems. Their prefabricated nature allows for seamless assembly and disassembly, minimizing on-site labor requirements and enhancing construction speed. Moreover, precast connections ensure effective stress transfer mechanisms, ensuring structural integrity and stability under seismic loading conditions. Precast beam-column connections are an innovative and effective solution for the construction sector, exhibiting comparable to or superior performance in defectsipersion capacity, load-bearing capability, and energy dissipation.

REFRENCES

1. Nimse, R. B., Joshi, D. D., & Patel, P. V. (2014). Behavior of wet precast beam column connections under progressive collapse scenario : an experimental study. 149–159. https://doi.org/10.1007/s40091-014-0072-3
2. Baek, J. W., Kang, S. M., Kim, T. H., & Kim, J. Y. (2020). Structural Performance of PC Double Beam – Column Connection under Gravity and Seismic Loading. *International Journal of Concrete Structures and Materials*. https://doi.org/10.1186/s40069-020-00439-4
3. Hofer, L., Angelo, M., Flora, Z., & Klajdi, F. (2021). Seismic behavior of precast reinforced concrete column - to - foundation grouted duct connections. *Bulletin of Earthquake Engineering*, *19*(12), 5191–5218. https://doi.org/10.1007/s10518-021-01133-w
4. Guerrero, H., Rodriguez, V., Escobar, J. A., Alcocer, S. M., Bennetts, F., & Suarez, M. (2019). Experimental tests of precast reinforced concrete beam-column connections. *Soil Dynamics and Earthquake Engineering*, *125*(June), 105743. https://doi.org/10.1016/j.soildyn.2019.105743

5. Ding, K., Ye, Y., & Ma, W. (2021). *Seismic performance of precast concrete beam-column joint based on the bolt connection*. *232*(June 2020). https://doi.org/10.1016/j.engstruct.2021.111884
6. Zhang, J., Ding, C., Rong, X., Yang, H., & Li, Y. (2020). Development and experimental investigation of hybrid precast concrete beam – column joints. *Engineering Structures*, *219*(May), 110922. https://doi.org/10.1016/j.engstruct.2020.110922
7. Baghdadi, A., Heristchian, M., Ledderose, L., & Kloft, H. (2020). Experimental and numerical assessment of new precast concrete connections under bending loads. *Engineering Structures*, *212*(January), 110456. https://doi.org/10.1016/j.engstruct.2020.110456
8. Ghayeb, H. H., Razak, H. A., & Sulong, N. H. R. (2020). Seismic performance of innovative hybrid precast reinforced concrete beam- to-column connections. *Engineering Structures*, *202*(November 2019), 109886. https://doi.org/10.1016/j.engstruct.2019.109886
9. Feng, D., Wu, G., & Lu, Y. (2018). Finite element modelling approach for precast reinforced concrete beam-to-column connections under cyclic loading. *Engineering Structures*, *174*(May), 49–66. https://doi.org/10.1016/j.engstruct.2018.07.055
10. Chakravarthy, k., janani, r., & ilango, t. (2018). Analysing the strength aspects of precast reinforced beam-column connections. March 2021.
11. Aman Agrawal , S.S. Sanghai, K. D. (2021). *Comparative Studies between Precast and Conventional Cast-In-Situ Structural Systems*. *November*. https://doi.org/10.1088/1757-899X/1197/1/012062
12. Kataoka, M., & Ferreira, M. (2012). A study on the behavior of beam-column connections in precast concrete structures : experimental analysis. January 2017. https://doi.org/10.1590/S1983-41952012000600008
13. Liu, H., Yan, Q., & Du, X. (2016). Seismic performance comparison between precast beam joints and cast-in-place beam joints. 100. https://doi.org/10.1177/1369433216674952
14. Choi, H., Choi, Y., & Choi, C. (2013). Development and testing of precast concrete beam-to-column connections. *Engineering Structures*, *56*, 1820–1835. https://doi.org/10.1016/j.engstruct.2013.07.021
15. Ha, S., Kim, S., Lee, M. S., & Moon, J. (2014). *Performance Evaluation of Semi Precast Concrete Beam-Column Connections with U-Shaped Strands*. *17*(11), 1585–1600.
16. Zhang, R. (2022). *Experimental study on a new type of precast beam-column joint*. https://www.sciencedirect.com/science/article/abs/pii/S2352710222002650