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# ICI

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INDIAN CONCRETE INSTITUTE



**SPECIAL EDITION**  
**ON**  
**'PRECAST CONSTRUCTION'**



## President's Message

Dear fellow members of ICI and readers,

It is my pleasure to share with you the successful completion of ACECON 2025 at Hyderabad. As planned, it had a battery of international and domestic speakers who shared their latest research findings and field practices. The annual Awards function of ICI was also conducted during this event.

I compliment and thank the ICI Hyderabad Centre for organizing and managing the events. Once again, I thank the recipients of ICI Awards.

This special edition of the ICI Quarterly Journal focuses on Precast Construction. Significance of precast construction is well

known and it is encompassing most facets of infrastructure construction. A Technological perspective on 3 D printing is also included.

My sincere thanks to the authors, reviewers, and the editorial team led by Prof. Kothandaraman, PEC, Puducherry for bringing out this edition.

May this edition inspire practical innovation and informed debate that advances the quality, efficiency, and sustainability of concrete construction in India.

With best wishes,

**Dr. Ramachandra. V**

President, ICI

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# From the Editor's Desk

## **Prof. S. Kothandaraman,**

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## **Preamble**

The current issue of the ICI Journal is dedicated to articles that highlight sustainable construction practices, with a special emphasis on precast systems. Traditional construction methods have burdened the planet in multiple ways, and the challenges associated with ensuring quality in construction continue to remain a persistent societal concern. Time and experience have repeatedly shown us that poor construction practices lead to far-reaching consequences. Both steel and concrete are highly energy-intensive materials, and every stage of their production depends heavily on natural resources. In return, our activities have unfailingly contributed to environmental degradation.

If we continue to follow the existing path, the future of sustainable living on this planet will be jeopardized. It is therefore imperative for all stakeholders to take part in the collective movement toward enforcing quality in construction. Even the smallest effort in this direction can create a multiplying, transformative effect.

This special issue comprises six insightful papers. The first paper, “Low-Pressure Epoxy Injection for Mitigating Precast Uneven Viaduct Interfaces Before Post-Tensioning,” authored by Dr. Sathyamoorthy Nandagopal, addresses a long-standing and unique problem that has challenged the precast industry for decades. Dr. Sathyamoorthy Nandagopal, an internationally recognized expert in structural repair and restoration, brings decades of experience in rehabilitation engineering to this contribution.

The second paper focuses on geopolymer concrete—an ideal and promising alternative to traditional concrete, particularly well-suited for precast applications. Although geopolymer technology offers tremendous potential, the precast industry has yet to fully embrace it. Prof. S. Thirugnanasambandam, a leading academician and

patent holder in geopolymer concrete, contributes a valuable paper that underscores its relevance and applicability.

In precast construction, the performance of joints is vital, with systems classified broadly as wet and dry connections. The third paper, by Dr. P. Revathy and Mr. Anbarasan, examines the behaviour of a rare category of dry joint known as the stiffened steel coupler. While numerous studies have been carried out on wet joints, Mr. P. Subharayan and Prof. S. Kothandaraman introduce an innovative wet-joint concept termed the sleeve column. Both papers offer significant insights and present fresh directions for future research.

Sustainability in construction remains a long-term global goal, and the use of non-conventional materials is central to achieving it. Prof. D. Rama Seshu and Dr. N. R. D. Murty have meticulously addressed this theme in their article, “The Need for Convention in Non-Conventionality in Sustainable Concretes.” Their paper is thoughtfully structured and emphasizes the importance of adopting non-conventional materials to advance sustainability in the construction sector.

The sixth and final contribution focuses on the rapidly evolving field of 3D printing of buildings. Precast construction was, in many ways, the earliest form of organized construction adopted by humankind, and it remains a technology with virtually no inherent disadvantages - although it has not been adequately acknowledged within the industry. Looking ahead, 3D printing technology has the potential to revolutionize the housing sector. It seamlessly integrates non-conventional materials, geopolymer concrete, and precast principles, offering a comprehensive technological pathway for future construction practices. Mr. Samuel Sivakumar et al., in their article “3D Printing of Buildings – A Technological Perspective,” present a concise review of current developments and outline future directions for sustainable built environments.

# Low-Pressure Epoxy Injection for Mitigating Precast Uneven Viaduct Interfaces Before Post-tensioning



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## Abstract

*Uneven interfaces between precast viaduct segments can severely compromise the structural performance and durability of post-tensioned bridge structures. This paper presents a case study from a metro viaduct project where an uneven segment interface was discovered after temporary erection but before post-tensioning. The two available options were either to dismantle the segments for rectification or to implement an in-situ mitigation technique. A novel low-pressure, low-viscosity epoxy resin injection method was proposed and successfully executed, ensuring the safety of post-tensioning ducts and maintaining the project schedule. This paper details the problem, solution development, demonstration, implementation, and outcomes, providing valuable insights for similar challenges in precast segmental construction.*

## 1. Introduction

Precast segmental construction (Fig. 1) is widely adopted for metro viaducts due to its speed, quality control, and reduced site disruption. A critical requirement for the success of such structures is the achievement of plane and uniform interfaces between segments, ensuring proper load transfer and the effectiveness of post-tensioning. Any deviation from planarity can lead to localized stress concentrations, incomplete and unequal force transfer, and long-term durability issues.

**Keywords:** Precast viaduct, post-tensioning, epoxy injection, interface repair, low-pressure injection, PT duct safety, construction schedule, Dubai



Fig.1: Viaduct segment

During the construction of a metro viaduct, it was discovered—after temporary erection but before post-tensioning—that one segment interface was uneven (Fig. 2).



Fig.2: Viaduct segments connected

This posed a significant risk to the structural performance and the safety of the post-tensioning system. The urgency of the situation, coupled with the need to avoid costly and time-consuming dismantling, prompted the development of an innovative in-situ mitigation method using low-pressure epoxy injection.

## 2. Problem Statement

Upon temporary erection of the viaduct segments, a routine visual and Feeler Gauge inspections revealed that the interface between the two segments was not sufficiently plane (Fig. 3). The unevenness threatened the uniform distribution of post-tensioning forces and raised concerns about the potential for stress concentrations during tensioning, incomplete grout filling due to gap-induced leakage paths, and long-term premature cracks resulting from cyclic loading and/or corrosion in voided areas.

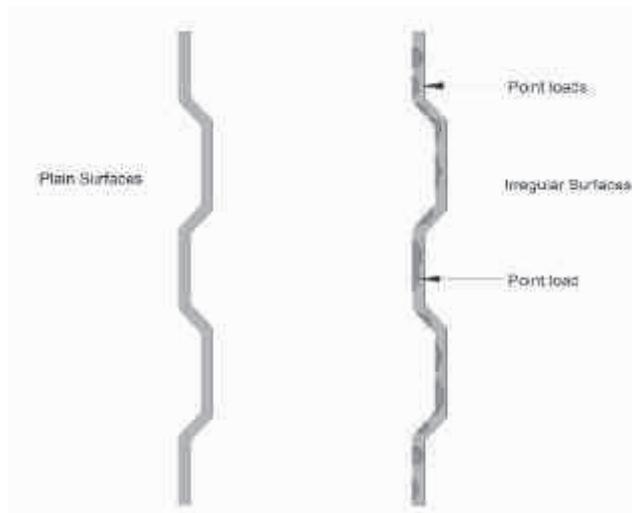


Fig.3: Irregular Interface

The project team faced two options:

### 1. Dismantle, Rectify, and Re-Erect:

This traditional approach would involve dismantling the erected segments, rectifying the interface on the ground, and then re-erecting the structure.

While technically sound, this method would incur significant costs, extend the construction schedule, and introduce logistical challenges.

### 2. In-Situ Mitigation:

The alternative was to address the uneven interface while the segments remained in their erected position.

This approach required a method that would not compromise the integrity of the post-tensioning ducts, the

precast segmental couplers, or the structural performance of the viaduct.

Given the substantial impact of dismantling, the team opted to explore in situ mitigation.

## 3. Proposed Solution: Low-Pressure Epoxy Injection

### 3.1 Rationale

Pressure injection of a low-viscosity epoxy resin was proposed to fill the voids at the interface, restore planarity, and ensure uniform load transfer. The method needed to be executed at a pressure low enough to avoid puncturing or damaging the post-tensioning (PT) ducts, which are critical for the subsequent tensioning operation.

### 3.2 Key Technical Challenges

#### PT Duct Safety:

Injection pressures above 5 bars could potentially puncture or deform the segmental duct couplers that are used to connect the PT ducts of the two adjoining viaducts, rendering the post-tensioning ineffective and risking catastrophic structural failure.

#### Complete Void Filling:

Ensuring the resin would fully occupy all voids and irregularities at the interface without bypassing narrow sections or leaving unfilled pockets.

#### Workability and Pot Life:

The resin required a sufficient pot life to allow for controlled and thorough injection, particularly under the high ambient temperatures typical of the region.

## 4. Demonstration and Validation

### 4.1 Consultant Requirements

The project consultant required a full-scale demonstration to validate the proposed method's safety and effectiveness before approving its use on the actual structure.

## 4.2 Model Construction and Testing

### Model Setup:

The contractor constructed a mock-up segment interface in the precast yard, replicating the actual site conditions and interface irregularities.

### Injection Procedure:

Surface packers were installed at close intervals of 100 mm (compared to the usual 200–300 mm) to ensure comprehensive coverage and minimize the required injection pressure.

### Pressure Control:

The epoxy was injected slowly and steadily, with pressure strictly maintained below 5 bars. The process was closely monitored and video documented.

### Pot Life Management:

To extend the working time of the resin, it was stored in ice containers prior to and during injection, ensuring consistent viscosity and preventing premature curing.

## 4.3 Testing and Results

### Interface Uniformity:

Non-destructive testing (NDT) and core sampling confirmed that the resin had entirely filled the interface, creating a uniform and plane surface.

### PT Duct Integrity:

Post-injection inspections and pressure tests verified that the PT ducts remained intact and undamaged.

The demonstration was successful, and the consultant approved the method for use on the actual viaduct.

## 5. Site Implementation

### 5.1 Preparation

#### Identification of PT ducts:

An Ultrasonic Tomography tool was used to identify and mark the position of the segmental duct couplers and the PT ducts, as these are areas where the injection

technician would be extra careful to avoid puncturing the couplers or the ducts.

#### Surface Cleaning:

The surface at the joint was thoroughly cleaned by light grinding and prepared to ensure optimal bonding of the epoxy putty.

#### Packer Installation:

Surface packers were installed at 100 mm intervals along the inner surface of the viaducts' joint using a two-part epoxy putty. The rest of the joint was fully closed using the same putty to a band width of 50mm.

The outer surface of the viaducts' joint was also fully closed with the same putty to a band width of 50mm.

### 5.2 Injection Process

#### Controlled Injection:

After the curing of the epoxy putty, the two-component low-viscosity epoxy was injected at pressures below 5 bars, progressing steadily from one packer to the next to ensure complete filling (Fig. 4).

#### Monitoring:

The process was continuously monitored for pressure, flow rate, and resin consumption. Any signs of abnormal pressure or leakage were immediately addressed.

#### Temperature Management:

The resin was kept chilled in ice containers to maintain a suitable pot life, allowing for careful and thorough injection.



Fig.4: Low-pressure injection

### 5.3 Quality Assurance

#### Post-Injection Inspection:

The interface was inspected using NDT methods such as Impact Echo to confirm complete filling and uniformity.

#### PT Duct Testing:

The ducts were checked for integrity and readiness for post-tensioning.

### 6. Outcomes and Benefits

#### Structural Integrity Restored:

The low-pressure epoxy injection successfully mitigated the uneven interface, restored planarity, and ensured uniform load transfer for post-tensioning (Fig. 5).



Fig.5: interface after the treatment

The use of close packer spacing, strict pressure control, and temperature management for pot life demonstrated a practical and effective approach for similar challenges.

### 7. Conclusion

This case study demonstrates that low-pressure, low-viscosity epoxy injection is a viable and effective method for mitigating uneven interfaces in precast segmental viaducts after the erection but before post-tensioning. Through careful planning, demonstration, and execution, the project team successfully restored the structural integrity of the viaduct, safeguarded the PT ducts, and preserved the project timeline. The methodology detailed

herein offers a valuable reference for engineers facing similar challenges in segmental viaduct construction.

### References:

1. ACI E 706 – Structural crack repair by epoxy injection.
2. CERL – 19960510074 – Guide for pressure grouting cracked concrete and masonry structures with epoxy resin.
3. ACI 546 – Guide for repair of concrete bridge structures.

## OBITUARY



### Er.R.Sundaram

With profound grief Indian Concrete Institute condoles the passing away of its past Vice-President, Er.R.Sundaram on Saturday, the 20<sup>th</sup> December 2025.

ICI express its sorrow and condolences to his family.

**Er.R.Radhakrishnan**  
Secretary General

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# Geopolymer Concrete: A Promising Sustainable Material



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## Abstract

*The evolution of concrete technology from conventional Portland cement systems to sustainable, cementless binders marks a significant milestone in the pursuit of carbon-neutral construction materials. This paper presents a comprehensive experimental investigation on the mechanical and durability performance of geopolymer concrete (GPC)—a next-generation, cement-free material synthesized from industrial and sustainable by-products such as low-calcium fly ash and ground granulated blast furnace slag (GGBS). Concrete mixes of grades M10, M20, M40, and M60 were produced and evaluated under both ambient and oven curing conditions. The experimental program involved testing cubes, cylinders, and beams for compressive, tensile, and flexural strengths, along with assessments of acid resistance, sulphate resistance, and water absorption to evaluate durability characteristics. The results indicated that the inclusion of GGBS significantly enhanced early-age strength and reduced permeability, while ambient curing proved effective even for higher-grade GPC. These findings establish geopolymer concrete as a pivotal advancement in the transition from cement-based to cementless construction materials, underscoring its potential as a sustainable and eco-efficient alternative to conventional concrete.*

## 1. Introduction

The evolution of modern concrete has undergone several transformative phases—from conventional Portland cement-based systems to high-performance blended

**Keywords:** Geopolymer Concrete (GPC), Cementless Binder, Industrial By-products, Mechanical and Durability Properties, Sustainable Construction Materials.

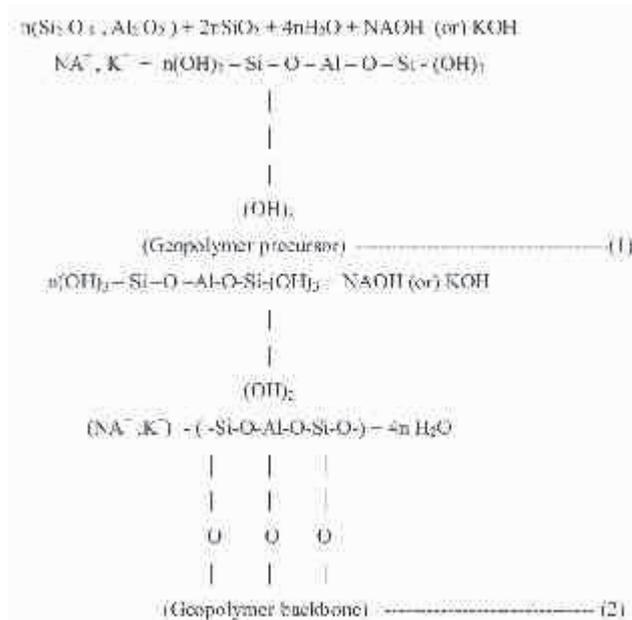
concretes, and more recently, to alkali-activated and geopolymer binders. Although conventional concrete remains the most extensively used construction material worldwide, its production contributes substantially to global CO<sub>2</sub> emissions due to the energy-intensive manufacturing of cement. To mitigate these environmental impacts, researchers have increasingly incorporated supplementary cementitious materials (SCMs) such as fly ash, ground granulated blast furnace slag (GGBS), silica fume, and alccofine as partial cement replacements, thereby enhancing both performance and sustainability.

The next major advancement emerged with the development of alkali-activated and geopolymer binders, which entirely eliminate the use of cement by forming aluminosilicate gel networks through the alkaline activation of industrial by-products. Geopolymer concrete (GPC) represents this advanced stage in the transition toward sustainable, cementless construction materials.

Davidovits [1] first proposed that an alkaline solution could react with silicon (Si) and aluminium (Al) present in source materials of geological origin or in industrial by-products such as fly ash and rice husk ash to form cementitious binders. Because this reaction involves a polymerization process and the raw materials are of geological origin, he introduced the term “geopolymer” to describe these novel inorganic binders.

Geopolymers belong to the broader family of inorganic polymers. The polymerization process entails a rapid chemical reaction under alkaline conditions on Si–Al minerals, resulting in a three-dimensional polymeric chain and ring structure composed of Si–O–Al–O bonds [1]. Hardjito and Rangan [2] later investigated fly ash-based geopolymer concrete using low-calcium ASTM Class F fly ash obtained from power stations, demonstrating its potential as a sustainable alternative to conventional concrete.

The schematic formation of geopolymer material can be shown as described by equations (1) & (2) [3].



The last term in equation (2) reveals that water is released during the chemical reaction that occurs in the formation of geopolymers. This water expelled from the geopolymer matrix during the curing and further drying periods, leaves behind discontinuous nano-pores in the matrix, which provide benefits to the performance of geopolymers.

A critical feature is that water is present only to facilitate workability and does not become a part of the resulting geopolymer structure. In other words, water is not involved in the chemical reaction and instead is expelled during curing and subsequent drying.

This is in contrast to the hydration reaction that occurs when Portland cement is mixed with water, which produce the primary hydration products calcium silicate hydrate and calcium hydroxide. This difference has a significant impact on the mechanical and chemical properties of the resulting geopolymer concrete, and also renders it more resistant to heat, water ingress, alkali-aggregate reactivity, and other types of chemical attack.

In this context, the present research focuses on developing geopolymer concrete using low-calcium fly ash, GGBS, recycled waste glass, and steel slag as primary ingredients. The experimental investigation explores the effects of binder composition, aggregate replacement, and curing regime (ambient and oven curing) on the mechanical and durability properties of GPC. The results contribute to understanding the transition from traditional cement concrete to geopolymer systems, establishing GPC as a viable and

environmentally responsible material for future infrastructure development. Figure 1 outlines the Route to Geopolymer Concrete.

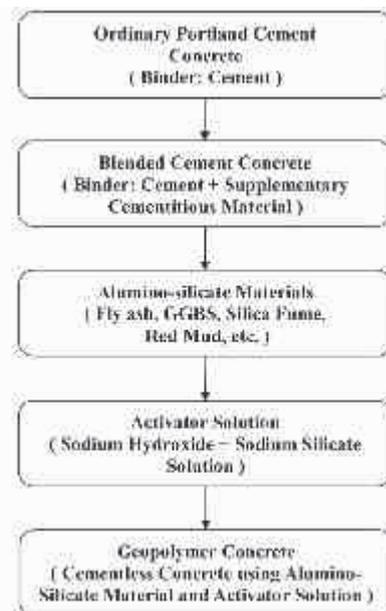


Fig.1. Route to Geopolymer Concrete

## 2. Materials Used

The materials employed in the production of geopolymer concrete (GPC) included low-calcium fly ash (Class F) as the primary binder. Crushed stone fine aggregate, recycled waste glass along with steel slag were utilized as coarse aggregate. Sodium hydroxide (NaOH) and sodium silicate (  $\text{Na}_2 \text{SiO}_3$  ) solutions served as the alkaline activators.

The fly ash used consisted predominantly of silicon and aluminium oxides, which together accounted for approximately 80% of its mass, with a preferred Si/Al ratio of about 2. The iron oxide content ranged between 10% and 20% by mass, while the calcium oxide content was below 5%. The carbon content was less than 2%, indicating good pozzolanic reactivity. A high-range water-reducing admixture (superplasticizer) was incorporated to achieve the desired workability of the fresh mix.

The mix proportions were designed in accordance with IS 10262:2019 for different grades of conventional cement concrete, and equivalent proportions were adopted for geopolymer concrete by adjusting the binder combinations, activator-to-binder ratios, and molarity levels. The concentration of sodium hydroxide solution typically ranged from 8 M to 16 M, with 8 M being

sufficient for most applications. The required mass of NaOH solids was calculated based on solution concentration; for example, an 8 M NaOH solution contains  $8 \times 40 = 320$  g of NaOH solids per litre of solution, where 40 represents the molecular weight of NaOH.

The alkaline activator (Figure 2) solution was prepared in proportion to the total binder content and thoroughly mixed with the aggregates to ensure a homogeneous and cohesive matrix. The constituents of binder and aggregate (Figure 3) replacements were optimized to achieve maximum strength, durability, and overall performance of the geopolymer concrete.



Fig.2. Preparation of Alkaline Activator Solution



Fig.3. Constituents of Geopolymer Concrete

### 2.1 Casting and Curing

The geopolymer concrete was prepared using conventional mixing procedures analogous to those employed for Portland cement concrete. Initially, the fly ash and fine aggregates were dry-mixed in a pan mixer for approximately three minutes to ensure uniform dispersion of the binder. Subsequently, saturated surface-dry (SSD) coarse aggregates were added and mixed until a consistent blend was achieved. The alkaline activator solution, prepared by thoroughly mixing sodium hydroxide and sodium silicate in the required proportions, was then introduced into the dry mix. The mixing process continued for an additional four minutes to obtain a homogeneous and workable geopolymer concrete. The fresh concrete was placed into moulds in layers and compacted using a table vibrator to remove entrapped air and achieve proper consolidation. The casting procedure closely followed the standard practices used for ordinary

Portland cement concrete to ensure uniformity and comparability of results.

#### A. Hot/ Steam Curing of Geopolymer Concrete

After casting, the specimens were left undisturbed at room temperature for 24 hours, designated as the rest period, representing the interval between casting and the commencement of elevated-temperature curing. Following this period, the specimens were demoulded and transferred to a hot-air curing chamber (autoclave) maintained at a constant temperature of 60 °C for 24 hours. Steam generated from a controlled boiler system was used to sustain uniform temperature and humidity conditions throughout the curing cycle (Figure 4). The geopolymer concrete specimens exhibited significant early-age strength development, with compressive strength recorded at 24 hours. The average density of the GPC was approximately 2350 kg/m<sup>3</sup>, marginally lower than that of conventional Portland cement concrete. The elevated-temperature curing process effectively accelerated the geopolymerization reaction, resulting in a dense, stable matrix and enhanced early strength. This method of thermal curing was found to be particularly beneficial in promoting rapid strength gain and improving the overall structural integrity of geopolymer concrete.



Closed View Open View

Fig.4. Curing Chamber

#### B. Ambient Curing of Geopolymer Concrete

The incorporation of ground granulated blast furnace slag (GGBS) (Figure 5) in geopolymer concrete enables effective curing at relatively low temperatures of 25–30 °C, unlike low-calcium fly ash-based systems that typically require elevated-temperature curing. Consequently, GGBS-based geopolymer concrete can be successfully cured at ambient room temperature for approximately 24 hours (Figure 6). Geopolymer concrete can be formulated using a blend of low-calcium fly ash and GGBS as the binder system, with the optimal ratio between the two determined based on their chemical composition and reactivity. These binders react with the alkaline activator solution to form a polymerized

aluminosilicate matrix, which, when combined with aggregates, results in a dense and durable geopolymer concrete.



Fig.5. GGBS



Fig.6. Ambient Curing of GPC Specimens

### 3.Experimental Investigation

#### a. Development of Ambient Cured M20 Grade GPC

Geopolymer concrete (GPC) and conventional cement concrete of M20 grade were produced and tested for comparative evaluation [4]. The conventional concrete mix was designed to achieve a target compressive strength corresponding to M20 grade, in accordance with IS 10262:2019. Based on the mix proportions derived from this design, the cement component was completely replaced with a combination of fly ash and ground granulated blast furnace slag (GGBS) in the geopolymer concrete. Through a series of trial mixes, the optimal binder ratio for M20 grade GPC was determined to be

70:30 (fly ash:GGBS), activated using a sodium hydroxide (NaOH) solution of 8 M concentration. The quantities of materials required to produce one cubic metre of M20 grade GPC are presented in Table 1.

The alkaline activator solution—comprising sodium silicate and sodium hydroxide—was prepared 24 hours prior to mixing to ensure complete dissolution and uniformity. The dry constituents, namely fly ash and aggregates, were first mixed in a pan mixer for about three minutes to achieve uniform distribution. The pre-mixed alkaline activator solution was then added, and wet mixing continued for approximately four minutes, resulting in a cohesive and homogeneous mix. The workability of the fresh GPC was evaluated using the standard slump test, which yielded a slump value of 80 mm, indicating medium workability suitable for casting. Cubes of size 150 mm × 150 mm × 150 mm were cast and demoulded after 24 hours of rest at room temperature. The specimens were then cured under ambient conditions for 24 hours and tested for compressive strength. The measured workability and compressive strength of the M20 grade GPC are summarized in Table 2.

The compressive strength of conventional cement concrete with the same mix proportions, after 28 days of water curing, was found to be 30.97 N/mm<sup>2</sup>. The modulus of rupture for conventional concrete and geopolymer concrete (GPC) was observed as 4.17 MPa and 4.42 MPa, respectively, indicating a marginal improvement in flexural strength for GPC. The water absorption values for cement concrete and GPC were 5.63% and 3.09%, respectively, demonstrating the lower permeability and denser matrix of geopolymer concrete. When subjected to 5% sodium sulphate solution immersion for 28 days, the loss in compressive strength was recorded as 12.3% for conventional concrete and 8.61% for GPC. Similarly, exposure to 5% sulphuric acid

Table 1 Constituents of Geopolymer Concrete (kg per m<sup>3</sup>)

Sl. No.	Fly ash	GGBS	Fine Agg.	Coarse Agg.	NaOH (SH)	Water	Sodium Silicate (SS)	SS/SH
1	242	103	767	1194	15.26	32.44	119.27	2.5

Table 2 Workability and Strength Properties

Sl. No.	Mix Ratio	Molarity of NaOH Solution	Slump, mm	Curing Method	Curing Time	Average Comp. Strength, MPa
1	1:2.22:3.46	8 M	80	Ambient	24 Hours	33.99

solution for the same duration resulted in a strength reduction of 34.08% for cement concrete and 28.36% for GPC. These results clearly indicate that geopolymer concrete exhibits superior resistance to acid and sulphate attack, lower water absorption, and enhanced durability performance compared to conventional cement concrete.

#### b. Tests on GPC Beams

To investigate the flexural behaviour of conventional cement concrete and geopolymer concrete (GPC) beams, a series of reinforced concrete beams were cast and tested [5]. Each beam was reinforced with Fe415 grade steel, consisting of two 12 mm diameter bars as tension reinforcement at the bottom and two 10 mm diameter bars as compression reinforcement at the top. The reinforcement cage and casting process are illustrated in Figures 7 and 8, respectively. The conventional concrete beams were subjected to 28 days of water curing, whereas the GPC beams were ambient-cured at room temperature for 24 hours (Figure 9). All beams were tested under a two-point loading system, and the experimental setup is shown in Figure 10. The ultimate load-carrying capacity of the GPC beam was recorded as 45 kN, compared to 42.5 kN for the conventional cement concrete beam, indicating that the GPC beam sustained approximately 5.6% higher load. The crack patterns observed in the conventional and GPC beams are presented in Figures 11 and 12, while the load-deflection behaviour is compared in Figure 13. The test results clearly demonstrate that the geopolymer concrete beam exhibited superior flexural performance compared to the conventional cement concrete beam, as evidenced by its higher load capacity, improved stiffness, and better post-cracking behaviour.



Fig.7: Reinforcement Grills for Beams



Fig.8: Casting of Geopolymer Concrete Beams



Fig. 9: Ambient Curing of Geopolymer Concrete Beam

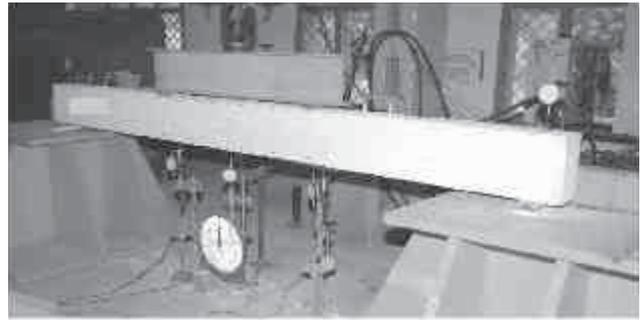


Fig.10: Testing of Geopolymer Concrete Beam



Fig.11: Crack Pattern of Conventional Cement Concrete Beam



Fig.12: Crack Pattern of Geopolymer Concrete Beam

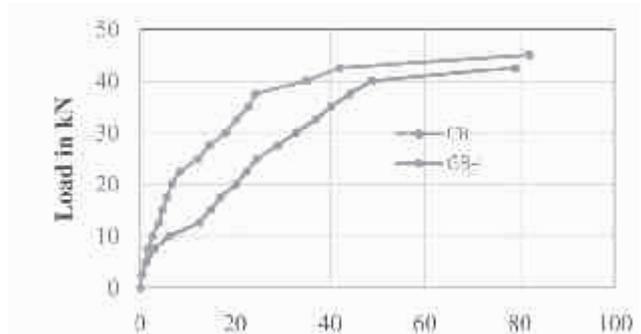


Fig.13: Comparison of Load Deflection Behaviour of Conventional Cement Concrete and GPC Beams

#### c. Railway Sleepers

Railway sleepers were cast using both conventional cement concrete and geopolymer concrete (GPC) of M60 grade [5]. The concrete mix proportion of 1:1.38:1.75 with a water-cement ratio of 0.30 was adopted based on the mix design guidelines of IS 10262:2009. The compressive strength of conventional cement concrete after 28 days of water curing was found to be 72.13

N/mm<sup>2</sup>, whereas the GPC sleeper, cured under ambient conditions for one day, achieved a comparable strength of 73.95 N/mm<sup>2</sup>. Both types of sleepers were prestressed using 18 numbers of 6 mm diameter high-tensile strands with a yield stress of 2942 N/mm<sup>2</sup>, as shown in Figure 14.

The casting process of the geopolymer concrete sleeper is illustrated in Figure 15, while the de-tensioning of the prestressed strands is depicted in Figure 16. The results demonstrate that geopolymer concrete can achieve high early strength under ambient curing, making it a viable and sustainable alternative to conventional concrete for



Fig.14. Prestensioning of strand

Fig.15. Casting of GPC Sleeper

Fig.16. De-Tensioning of strands

prestressed railway sleeper applications.

All sleepers were tested under two-point loading to evaluate their flexural behaviour. Linear Variable Differential Transducers (LVDTs) were positioned at three locations along the soffit of each sleeper—at the centre, and at points 1155 mm to the left and right of the centre—to measure vertical displacements. In addition, dial gauges were installed at the supports and at midspan to monitor deflections during testing. The experimental setup is illustrated in Figure 17. The load–deflection responses of both conventional cement concrete and geopolymer concrete (GPC) sleepers are presented in Figure 18. The M60-grade prestressed GPC sleeper attained an ultimate load of 320 kN, compared to 290 kN for the corresponding prestressed cement concrete sleeper, representing an approximate 10% increase in load-carrying capacity. At the ultimate load level, the GPC sleeper exhibited a 34% higher deflection, indicating improved energy absorption and ductility.

The crack pattern analysis revealed a wider crack distribution and slightly greater crack widths in the GPC sleeper compared to the conventional cement concrete sleeper, suggesting enhanced deformation capacity before failure. Overall, the results confirm that the

prestressed geopolymer concrete sleeper demonstrated superior flexural strength and ductility, establishing its potential as a durable and sustainable alternative for railway applications.

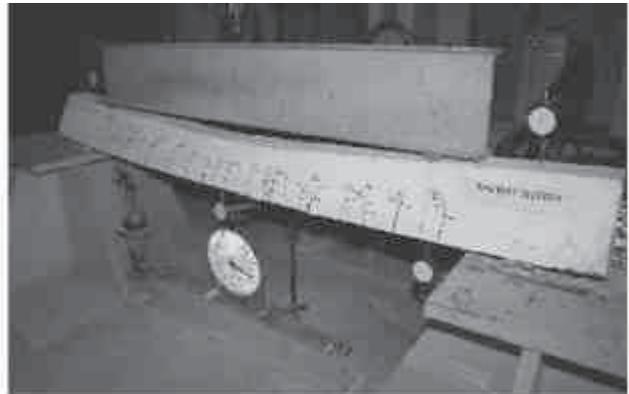


Fig.17. Crack Pattern of GPC Sleeper

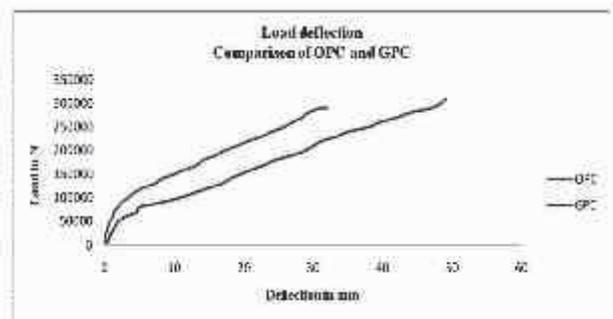


Fig.18. Load - Deflection curve for Cement Concrete and GPC Sleepers

#### d. Ferrocement and Ferrogeopolymer Roof Channel

A ferrocement roof channel is a longitudinal structural element with a curved (often semi-cylindrical) cross-section [5]. In this study, ferrocement channels were cast using cement mortar of mix proportion 1:3 (cement:sand) with a water–cement ratio of 0.45. Each channel specimen measured 3000 mm × 750 mm × 290 mm, including two bottom nibs of 40 mm × 45 mm, and had a uniform thickness of 30 mm. The 28-day compressive strength of the cement mortar was found to be 43.17 N/mm<sup>2</sup> after water curing.

The geopolymer mortar was produced using a binder blend of 50% fly ash and 50% GGBS, combined with three parts of sand and an alkaline activator solution consisting of sodium silicate and sodium hydroxide. Mortar cubes were cast and ambient-cured for 7 days before testing. The compressive strength of the geopolymer mortar with

6 M NaOH concentration after 7 days of curing was 43.94 N/mm<sup>2</sup>, indicating strength comparable to that of conventional cement mortar.

Both ferrocement and ferropolymer roof channels were cast and tested. The reinforcement cage was fabricated using 8 mm and 6 mm diameter steel rods, along with weld mesh and diamond mesh for adequate distribution reinforcement. The geopolymer mortar was applied over the reinforcement to form the ferropolymer channel. While the ferrocement channels were water-cured for 28 days, the ferropolymer channels were ambient-cured for 7 days.

The channels were tested under central point loading, as illustrated in Figure 19, and the tested ferropolymer channel is shown in Figure 20. The load-deflection behaviour of both the ferrocement and ferropolymer roof channels is presented in Figure 21, demonstrating the structural performance and comparative flexural response of the two systems.



Fig.19 Test Setup of Ferropolymer Channel



Fig.20. Ferropolymer Channel After Testing

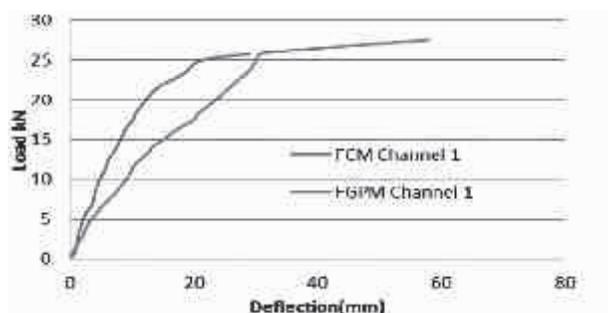


Fig.21. Load - Deflection curve for Ferrocement and Ferropolymer Channels

The ferropolymer channel exhibited a 7.8% increase

in load-carrying capacity compared to the conventional ferrocement channel. Based on the experimental results, it can be concluded that ferropolymer channels demonstrate superior structural performance, owing to their higher strength and comparable stiffness under flexural loading. These findings suggest that ferropolymer channels can serve as a viable and sustainable alternative to conventional ferrocement channels in roofing and lightweight structural applications.

#### 4. Geopolymer Concrete Road

The geopolymer concrete (GPC) pavement consists of two distinct layers – the Dry Lean Concrete (DLC) base layer and the Pavement Quality Concrete (PQC) top layer. The DLC layer was designed using M10 grade geopolymer concrete, with fly ash and GGBS serving as the primary binder components. River sand and locally available coarse aggregates were used as fine and coarse aggregates, respectively. The PQC layer, forming the top surface of the pavement, was laid using M40 grade geopolymer concrete. The mix proportions for both layers were derived following the guidelines of IS 10262:2019, with complete replacement of cement by fly ash and GGBS in the binder system. Pilot-scale GPC road sections were successfully constructed at Ramagundam, Telangana, and Rihand, Uttar Pradesh, India, as illustrated in Figures 22 and 23. The initiative was undertaken by the National Thermal Power Corporation (NTPC), New Delhi, as part of a demonstration project to promote sustainable infrastructure through the utilization of industrial by-products in road construction.



Fig.22. GPC Road @ Ramagundam, Telangana State



Fig.23. GPC Road @ Rihand, Utter Pradesh State

## 5. Conclusions

Based on the detailed experimental investigations carried out on ambient-cured geopolymer concrete (GPC) and its comparison with conventional cement concrete, the following conclusions are drawn:

1. **Feasibility of Manufacture**  
Geopolymer concrete of different grades can be successfully produced under ambient curing conditions using low-calcium fly ash and GGBS as binder components, with varying NaOH molar concentrations to control the rate and extent of geopolymerization.
2. **Superior Mechanical and Durability Performance**  
Ambient-cured geopolymer concrete exhibited superior performance compared to conventional cement concrete in terms of compressive, tensile, and flexural strength, as well as resistance to acid and sulphate attack and lower water absorption, demonstrating its excellent durability characteristics.
3. **Environmentally Sustainable Alternative**  
Geopolymer binders have emerged as a viable and eco-efficient substitute for ordinary Portland cement (OPC), offering high early-age strength, enhanced chemical resistance, and a significant reduction in CO<sub>2</sub> emissions associated with cement production.
4. **Rapid Strength Development and Practical Advantages**  
Geopolymer concrete is a 100% cement-free material that does not require prolonged water curing. Under one day of ambient curing, the desired strength is achieved, making GPC especially suitable for rapid construction and repair applications, such as road pavements and precast elements.

## 5. Technical Requirements and Limitations

The primary limitation in the widespread adoption of geopolymer concrete lies in the requirement for technically trained personnel to accurately determine mix proportions, control activator concentrations, and ensure consistent quality during production and placement.

## 6. Structural Applicability

Experimental studies on beams, sleepers, and ferropolymer elements confirmed that GPC can effectively replace conventional concrete in reinforced and prestressed structural applications, with improved load-carrying capacity, ductility, and crack resistance.

## 7. Potential for Field Implementation

The successful execution of pilot-scale GPC road projects demonstrates its field applicability, cost-effectiveness, and potential for large-scale infrastructure deployment, particularly in regions with abundant availability of industrial by-products such as fly ash and slag.

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# Experimental Investigation on Precast Beam Column Connection with Stiffened Steel Coupler



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## Abstract

The connection between precast beam and column elements plays a crucial role in ensuring the successful implementation of precast construction technology in seismic regions, where lateral stability and structural integrity are of paramount importance. This study presents the development and experimental investigation of one-third scaled precast beam-column connection specimens employing a stiffened steel coupler assembly. Three precast specimens, incorporating one, two, and three wing plates respectively in the beam element, were fabricated and tested under cyclic loading. For comparison, an identical monolithically cast beam-column connection was also tested. Load-displacement responses were recorded to evaluate the hysteretic behaviour, energy dissipation, and stiffness degradation of the specimens. Experimental results revealed that the hysteretic performance of the stiffened steel coupler connection is comparable to that of the monolithic specimen. However, the overall stiffness of the connection requires further improvement. The results also indicated that the performance of the steel coupler assembly is significantly influenced by the number of wing plates incorporated in the precast beam.

## Introduction

The overall performance of precast concrete structures in seismic regions is largely governed by the strength, ductility, and energy dissipation capacity of their connections. Hence, the design and detailing of precast beam-column connections are of paramount importance to ensure the strength, integrity, and reliability of such structures under lateral loading conditions.

Precast concrete construction has gained significant momentum in the modern construction industry due to its advantages such as improved quality control, cost efficiency, and rapid execution. However, one of the major challenges in precast construction is the design of effective beam-column connections, particularly in earthquake-prone areas where the structural demands are severe.

Based on the presence of cast-in-situ concrete, precast beam-column connections are generally classified as wet or dry connections. Wet connections involve the use of fresh concrete to cover the exposed reinforcement in the joint region, thereby emulating the behaviour of monolithic cast-in-situ construction. In contrast, dry connections rely on mechanical devices such as cleat angles, tie rods, post-tensioning strands, threaded rods, and steel plates—joined through bolts or welds—to achieve structural continuity.

Extensive research has been conducted on wet connections, and they are widely adopted in practice due to their emulative behaviour. However, these connections often suffer from drawbacks such as reinforcement congestion within the joint core, the need for extensive formwork, and increased construction time and cost. Comparatively, limited research exists on dry connections, despite their potential to overcome several of these disadvantages. Various types of precast beam-column connections reported in the literature include emulative, pinned, welded, post-tensioned, and bolted systems (Ghayeb et al., 2017).

Although emulative connections exhibit behaviour similar to that of monolithic joints, they still face practical limitations such as formwork complexity, reinforcement congestion, and longer construction durations (Ochs and

Ehsani, 1993; Parastesh et al., 2014; Ertas et al., 2006; Krishnan and Purushothaman, 2019). These limitations have motivated researchers to explore alternative connection systems that can simplify construction while ensuring adequate seismic performance. Despite such efforts, the inelastic behaviour of precast connections under cyclic loading is not yet fully established, and their performance remains a subject of ongoing research (Choi et al., 2013).

To address these challenges, design guidelines have been formulated to emulate the seismic performance of cast-in-place reinforced concrete systems. The American Concrete Institute (ACI) and the American Society of Civil Engineers (ASCE) jointly developed the Guide to Emulating Cast-in-Place Detailing for Seismic Design of Precast Concrete Structures (ACI 550.1R-09) (Xie et al., 2018; ACI 550.1R-09), which provides detailed recommendations for designing precast systems with strength, stiffness, ductility, and energy dissipation comparable to conventional reinforced concrete frames. Similarly, New Zealand, an early adopter of precast technology, issued the Guidelines for the Use of Standard Structural Precast Concrete in Buildings (CAE, 1999), which classified precast frame systems into three types: (i) precast beam units between columns, (ii) precast beam units through columns, and (iii) precast T- or cruciform-shaped units.

In the present study, a novel precast beam-column connection is proposed with the objective of achieving an easily installable and replaceable system, while ensuring adequate structural performance under seismic loading. The key feature of the proposed system is the use of an unbonded stiffened steel coupler, which facilitates ease of replacement following an earthquake and minimizes potential damage to the adjoining structural elements that typically occurs in bonded dissipative components. To maintain overall integrity, the joint region is filled with a suitable high-strength grout, ensuring continuity and providing a surface finish similar to that of a monolithic connection.

The proposed connection employs a stiffened steel coupler assembly (Fig. 1) consisting of predesigned stiffened steel plates with angle sections that serve as the interface between the beam and column elements. The column ends are fitted with steel end plates anchored by threaded rods, enabling quick and precise alignment with the coupler during installation. Similarly, the beam ends are provided with base plates and wing plates containing predrilled holes to facilitate bolted



Fig. 1 View of Stiffened coupler assembly

connection to the coupler assembly. This configuration allows for rapid assembly and disassembly, improving constructability without compromising the structural capacity required for seismic resistance.

The stiffened coupler can be customized to meet the design capacity dictated by the seismic demand of the beam-column connection. In the present experimental investigation, the coupler assembly was designed using four ISA 40 mm × 40 mm × 6 mm angle sections and 4 mm-thick wing plates, proportioned to satisfy the expected moment and shear transfer capacities of the joint under cyclic loading.

## Experimental Investigation

### Material characteristics

The specimens were cast using M35 grade concrete. The measured Young's modulus of the concrete was 27.29 GPa, determined from standard compression tests. The tensile strength of the 10 mm diameter deformed main reinforcement and the 6 mm diameter stirrups were found to be 506 MPa and 516 MPa, respectively, based on tensile testing conducted in accordance with relevant Indian Standard specifications.

### Description of test specimen

To evaluate the seismic performance of the proposed stiffened steel coupler connection, three precast beam-column specimens, designated as PC1, PC2, and PC3, were fabricated and tested. Each specimen consisted of four individual precast elements: the top column, bottom column, beam, and core unit. The longitudinal reinforcement from both the beam and column was welded to end plates provided at their respective faces. The end plate of the column was connected to the steel core element using high-strength bolts, while the beam element was attached to the core through a steel plate connection, also fastened with bolts, as illustrated in Fig.1.

The steel plate at the beam–core interface was designed for a moment capacity of 12 kNm, corresponding to the plastic moment capacity of the monolithically cast reference beam. The three precast specimens differed in the number of wing plates incorporated in the beam—one, two, and three for PC1, PC2, and PC3 respectively. Each wing plate was fabricated from 4 mm thick structural steel conforming to relevant Indian Standards.

All test specimens were constructed with column elements 625 mm in height and beam elements 1500 mm in span, with both members having cross-sectional dimensions of 120 mm × 150 mm, as shown in Fig. 2. The reinforcement detailing for the beams and columns was kept identical to maintain a beam-to-column strength ratio of unity, ensuring uniform flexural response. An identically reinforced monolithic beam–column connection was also cast and tested for comparison. The geometric and reinforcement details of all specimens are presented in Table 1.

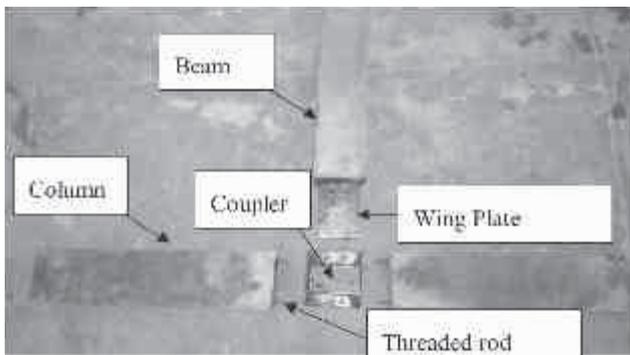


Fig. 2 Components of precast beam and columns with the coupler assembly

Table 1 structural details of RC specimen

Overall depth,	$D$	=	150 mm
Breath,	$b$	=	120 mm
Clear cover,	$c$	=	15 mm
Grade of concrete,	$f_{ck}$	=	35 N/mm <sup>2</sup>
Grade of reinforcement,	$f_{st}$	=	500 N/mm <sup>2</sup>
Area of top reinforcement,	$A_{s,t}$	=	#10x2 mm (157 mm <sup>2</sup> )
Area of bottom reinforcement,	$A_{s,b}$	=	#10x2 mm (157 mm <sup>2</sup> )
Effective depth,	$d$	=	122 mm
Effective cover from top,	$d'$	=	28 mm

### Testing of Specimens

The experimental setup comprised a 50 kN capacity loading frame, within which the test specimens were

securely mounted, and a 30 kN capacity displacement controlled actuator for applying reverse cyclic loading. To simulate the effect of gravity load, an axial load equivalent to 10% of the column's axial capacity was applied at the top of the column using a 500 kN hydraulic jack. Both the top and bottom ends of the column were rigidly fixed to ensure proper boundary conditions during testing.

The test procedure followed the ACI T1.1-01 (2016) standard for displacement-controlled reverse cyclic loading. The cyclic loading history was applied in successive displacement increments, as illustrated in Fig. 3. The lateral displacement at the beam tip was recorded using two Linear Variable Differential Transducers (LVDTs), positioned at the top and bottom surfaces of the beam to ensure accurate measurement of flexural deformations. The applied lateral load was monitored through a tension–compression load cell of 100 kN capacity, installed inline with the actuator.

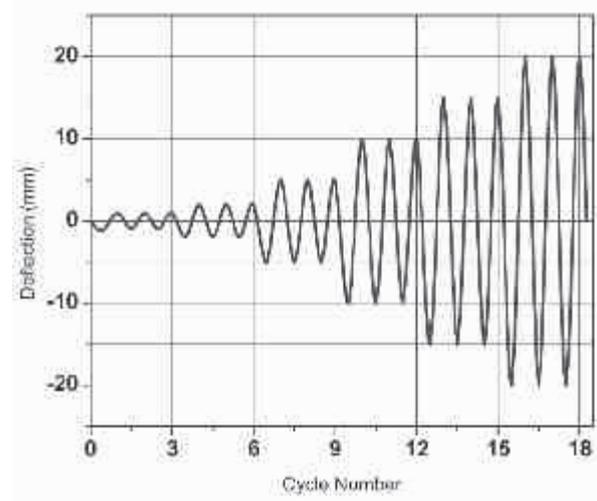
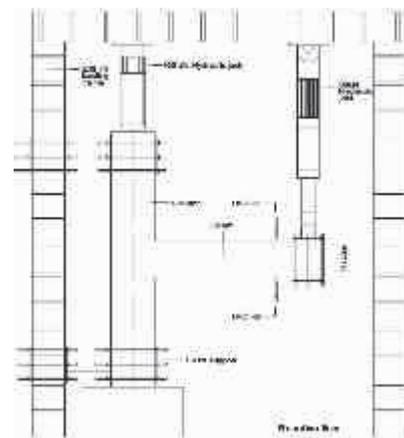


Fig. 3 Loading set up and loading protocol

All sensor outputs, including load and displacement data, were acquired using a data logger connected to a computerized monitoring system. The readings from the LVDTs were continuously monitored, and the corresponding push-pull movement of the actuator was controlled in a displacement-controlled loading mode. The specimens were tested in an upright orientation, with the column positioned vertically and the beam extending horizontally to replicate actual in-situ conditions. The complete experimental setup and cyclic loading protocol are shown in Fig. 3.

## EXPERIMENTAL RESULTS

The experimental responses of the specimens were analyzed and discussed in terms of their load-displacement behaviour, energy dissipation capacity, equivalent viscous damping, and stiffness degradation characteristics. The load-displacement hysteresis loops for all specimens are illustrated in Figures 4–7. The hysteretic response of each beam-column connection exhibited a stable and symmetrical pattern in both loading directions, indicating consistent structural behaviour under cyclic loading. Notably, no pinching effect or slippage was observed in any of the precast connections, demonstrating effective load transfer and integrity of the joint components throughout the testing process. The overall hysteretic behaviour of the precast specimens was found to be comparable to that of the monolithic reference specimen, confirming that the proposed stiffened steel coupler connection can emulate the seismic performance of monolithic beam-column joints.

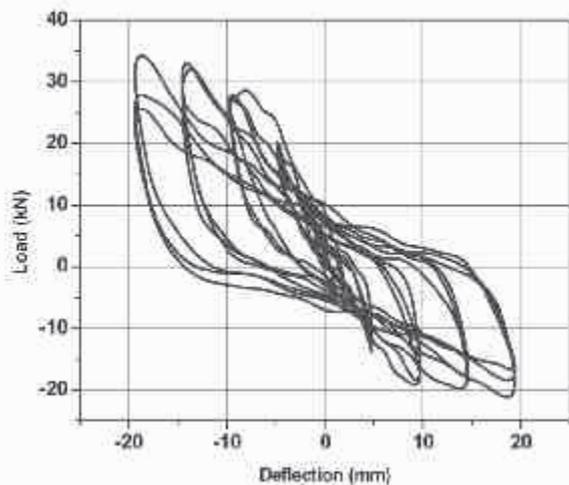


Fig. 4 Load Displacement curve of Monolithic beam column specimen

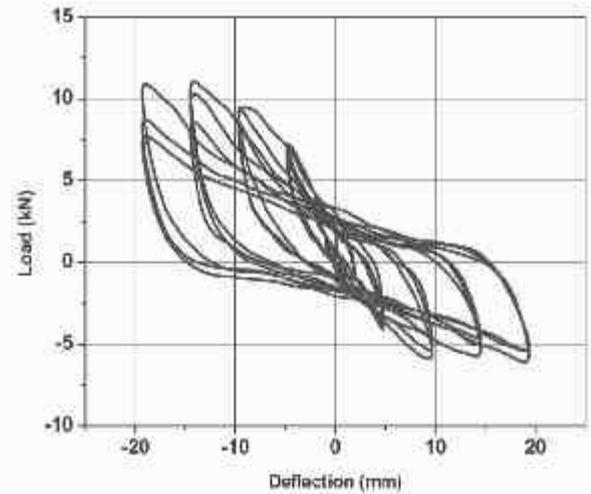


Fig. 5 Load Displacement curve of precast beam column specimen PC1

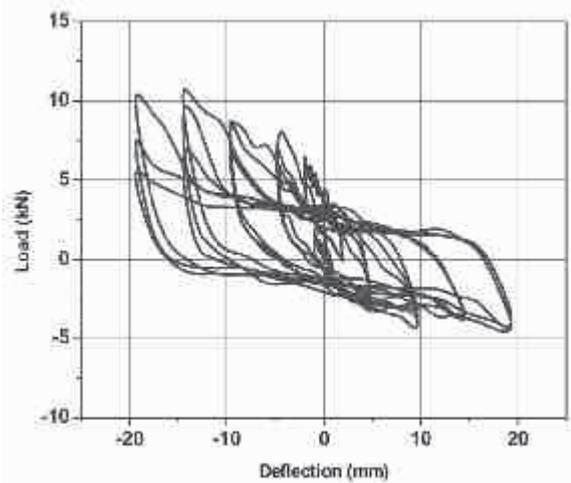


Fig. 6 Load Displacement curve of precast beam column specimen PC2

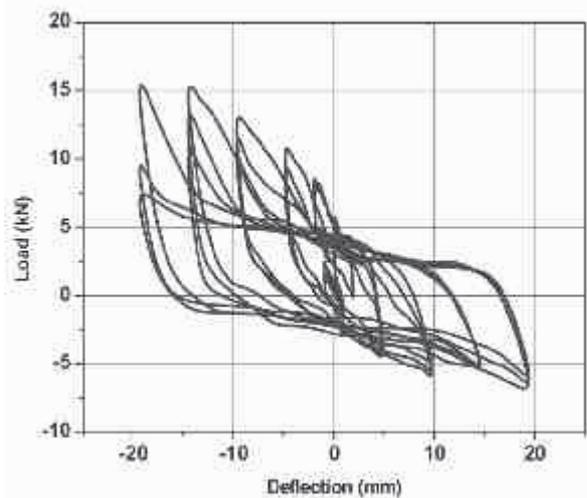


Fig. 7 Load Displacement curve of precast beam column specimen PC3

### Energy Dissipation Ratio

The energy dissipation ratio is a dimensionless parameter that quantifies the proportion of input energy transformed into non-recoverable forms such as heat, friction, or plastic deformation during cyclic loading (Krishnan and Purushothaman, 2010). Its value typically ranges between 0 and 1, with higher values indicating greater energy loss and, consequently, superior energy absorption capability of the structural system.

The cumulative energy dissipation for each specimen was obtained by summing the energy dissipated in all displacement cycles, as illustrated in Figure 8. It was observed that the monolithically cast specimen exhibited slightly lower energy dissipation at smaller displacement levels compared to the precast specimens. This behaviour can be attributed to the presence of the steel core elements in the precast connections, which enhanced localized yielding and frictional damping at the interfaces.

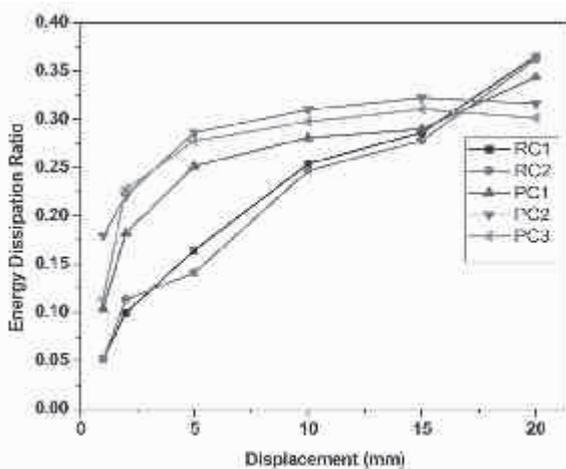


Fig. 8 Energy dissipation capacity of test specimens

At the ultimate displacement level, the maximum energy dissipation ratios for the monolithic specimens (RC1 and RC2) were 0.375, while those for the precast specimens (PC1, PC2, and PC3) were 0.34, 0.33, and 0.32, respectively. This corresponds to an average reduction of approximately 14% in energy dissipation capacity for the precast specimens compared with the monolithic specimen. Despite this marginal reduction, the proposed stiffened coupler connections demonstrated satisfactory energy dissipation performance, confirming their potential suitability for seismic applications.

### Equivalent Viscous Damping

The Equivalent Viscous Damping (EVD) is a parameter used to represent the energy dissipation characteristics of a nonlinear structural system through an equivalent linear viscous model. It is determined by equating the energy dissipated per loading cycle by the actual hysteretic system to that dissipated by an equivalent viscous damper operating over the same deformation range. A higher EVD ratio signifies greater energy dissipation capacity and improved damping performance of the system under cyclic loading.

As illustrated in Figure 9, the EVD values of the precast specimens were found to be consistently higher than those of the monolithically cast specimens over most of the loading cycles, indicating effective energy absorption through the steel coupler assembly. However, at the ultimate displacement stage, the EVD of the precast specimens was observed to be marginally lower than that of the monolithic specimen. This slight reduction is attributed to energy losses associated with excessive cracking in the beam-column regions, which resulted in diminished stiffness and reduced hysteretic area in the final loading cycles.

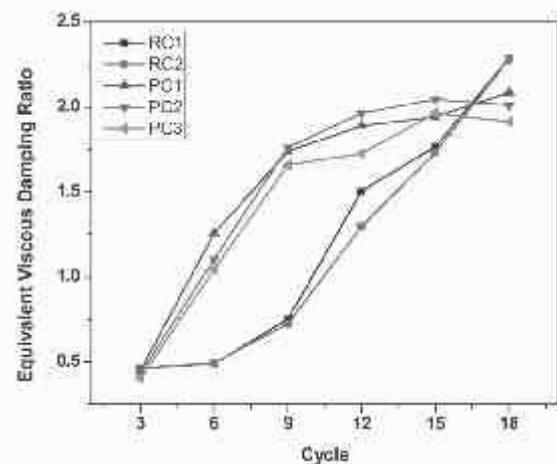


Fig. 9 Equivalent viscous damping of test specimens

### Stiffness Degradation

Stiffness degradation refers to the progressive reduction in the lateral stiffness of a structural system when subjected to repeated cyclic loading. It is a direct manifestation of internal damage, such as cracking, yielding of reinforcement, or bond deterioration, and serves as a critical indicator of a structure's health, ductility, and residual strength. Generally, a higher rate of stiffness degradation corresponds to lower energy

dissipation capacity and reduced ductility, whereas a structure that retains its stiffness over successive loading cycles can sustain greater energy absorption and improved seismic resilience. A rapid stiffness degradation rate often signifies extensive internal damage and may indicate the onset of failure.

As shown in Figure 10, the stiffness of the precast specimens was observed to be lower than that of the monolithically cast specimens throughout the loading cycles. The initial stiffness of the precast beam-column connections was significantly influenced by the number of wing plates integrated into the coupler assembly. Among the tested specimens, PC3, which incorporated three wing plates, exhibited an initial stiffness comparable to that of the monolithic specimen RC2. This demonstrates that the stiffness of the connection can be effectively enhanced by optimizing the number and thickness of the wing plates in the coupler assembly.

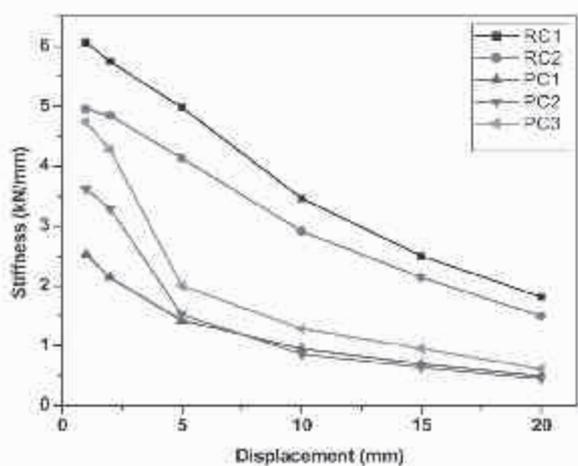


Fig. 10 Stiffness Degradation curve of Test Specimens

However, the rate of stiffness degradation in the proposed precast connections was found to be higher than that of the monolithic reference specimen, indicating the need for further refinement in the coupler design to improve its stiffness retention and cyclic durability under seismic loading.

#### Concluding Remarks

Based on the experimental results and observations made on the precast beam-column connections incorporating stiffened steel couplers, the following conclusions are drawn:

- The hysteretic performance of the precast beam-column connections with stiffened couplers was found to be comparable to that of the monolithically cast specimens. The hysteresis loops exhibited stable behaviour without any evidence of pinching or slippage, indicating effective load transfer and structural integrity.
- The energy dissipation capacity of the precast beam-column connections using the stiffened steel coupler was approximately 14% lower than that of the monolithic reference specimen. Nevertheless, the level of energy dissipation achieved is considered satisfactory for seismic applications.
- The equivalent viscous damping (EVD) values of the precast specimens were consistently higher than those of the monolithic specimens over most loading cycles, confirming the effective damping contribution of the steel coupler assembly.
- The initial stiffness and stiffness retention of the precast beam-column connections were found to be relatively lower than those of the monolithically cast connections. This reduction is attributed to localized flexibility at the coupler interfaces and can be mitigated by optimizing the number and thickness of wing plates in the coupler assembly.

Overall, the study demonstrates that the proposed stiffened steel coupler connection provides satisfactory hysteretic behaviour and energy dissipation characteristics, showing strong potential as an efficient and replaceable precast connection system for seismic regions, with scope for further enhancement in stiffness performance.

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# Welcome to New Members

## A. Individual Life Members

S.No	M.No	Name	Place	Centre	S.No	M.No	Name	Place	Centre
1	15165	Dr Herbert Sinduja J	Chennai	CHEC	30	15195	Dr Naresh Kumar Kalaskar	Hyderabad	HYDC
2	15166	Dr M Muttharam	Chennai	CHEC	31	15196	Er Hitendeo Rajan Panchal	Ahmedabad	AHMC
3	15167	Er Dinesh Babarao Lakade	Wardha	NAGC	32	15197	Er Tarun Kumar Roy	Midnapore	MNRC
4	15168	Er Akhil Abhay Tarpe	Nagpur	NAGC	33	15198	Er Mohit Gothi	Bhopal	BHOC
5	15170	Er Abilash C	Bengaluru	BENC	34	15199	Er Soumya Anand	Alappuzha	KOCC
6	15171	Er Pijush Das	Bengaluru	BENC	35	15200	Er Girish R Tattimani	Bengaluru	BENC
7	15172	Er Kshitij V T	Bengaluru	BENC	36	15201	Er Raghav Girish Tattimani	Bengaluru	BENC
8	15173	Er Vetrivelan R	Bengaluru	BENC	37	15202	Er Vaddi Ramesh	Kakinada	KKNC
9	15174	Er Aravapalli Bulli Rajanaidu	Angara	RJMC	38	15203	Er Balijepalli Satya Venkata Ramana Rao	Rangareddy	KKNC
10	15175	Er U V V Jagannadha Raju	Kakinada	RJMC	39	15204	Er Muniharish Choopa	Navi Mumbai	MUMC
11	15176	Er Salil Bhaskar	Po Thrissur	KOCC	40	15205	Dr KI Radhika	Hyderabad	HYDC
12	15177	Dr Krishna Murari Soni	Delhi	DELC	41	15206	Er Kamal Kumar Mishra	Navi Mumbai	MUMC
13	15178	Er Mohit Chaturvedi	Bengaluru	BENC	42	15207	Dr Naveet Kaur	Faridabad	GGMC
14	15179	Er Mohan R Rayaraddi	Bengaluru	BENC	43	15208	Er Shibashish Prasanta Mukherjee	Mumbai	MUMC
15	15180	Dr Mohammad Afaque	Lucknow	LKNC	44	15209	Er Myana Sai Krishna Hanamkonda	Telangana	WNGC
16	15181	Er Ramendra Bahadur Sinha	Ghaziabad	GHAC	45	15211	Er Muddana Mounika	Nizamabad	HYDC
17	15182	Er Jagadeshwar Adigoppula	Warangal	WNGC	46	15212	Er Manish Sahay	Kolkata	KOLC
18	15183	Er Kodimala Veeraiah	Warangal	WNGC	47	15213	Er Mukoonda Madhab Dutta	Pune	PUNC
19	15184	Er Kudikala Vijay Kalyan	Warangal	WNGC	48	15214	Er Sriram Balasubramanian	Chennai	CHEC
20	15185	Er Sathya Narayanan J	Bengaluru	BENC	49	15215	Er Girisha B	Hassan	BENC
21	15186	Ar Jagan Mohan	Warangal	WNGC	50	15216	Dr Anuradha Parameshwar Iyer	Hyderabad	HYDC
22	15187	Er Rahul Das	Guwahati	GWHC	51	15217	Er Rajeev Singh	Bhopal	BHOC
23	15188	Er Arvind Kachroo	Hyderabad	HYDC	52	15218	Er Krishnanunni M	Suchithra Medchal	HYDC
24	15189	Er A Mohanraj	Chennai	CHEC	53	15219	Er Karunesh Verma	Lucknow	HYDC
25	15190	Er Narasingula Sreenivasa Rao	Hyderabad	HYDC	54	15220	Dr Rakesh Ranjan	Haridwar	UTTC
26	15191	Er Sunil R.K	Bengaluru	BENC	55	15222	Er Agamoni Das	Gurugram	DELC
27	15192	Er Ashish Singh	Varanasi	VARC					
29	15194	Ar Subodh Bapurao Chinchmalatpure	Nagpur	NAGC					

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# Experimental Studies on the Behaviour of Wet Sleeve Column – Beam Joint Under Reverse Cyclic Loading



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## Abstract

*In reinforced cement concrete (RCC) structures, the beam–column joint is a critical zone that must withstand lateral forces induced by seismic actions and gravity loads. Earthquake-induced damages in precast structures are often attributed to inadequate connection detailing between precast elements. The present experimental study investigates a new wet precast beam–column joint configuration incorporating ductile detailing as recommended in IS 13920:2016 for moment-resisting frames. Two precast beam–column joint specimens (designated HCJ-470) and one monolithically cast beam–column joint specimen (MLJ-470), all of identical size and reinforcement details, were prepared. In the HCJ-470 specimens, the column was cast in two segments with a hollow core accommodating the main reinforcement. In both specimen types, the beam reinforcement was anchored into the column in compliance with the development length provisions specified in IS 13920:2016. All specimens were subjected to displacement-controlled reverse cyclic loading. The experimental results demonstrate that the proposed wet precast beam–column joint with a hollow core column exhibited comparable performance to that of the monolithically cast beam–column joint in terms of strength, stiffness, and ductility.*

## Importance of Rcc Beam–column Joint Design

In reinforced cement concrete (RCC) framed structures, the beam–column joint plays a pivotal role in maintaining the overall stability and integrity of the structural system.

**Keywords:** Beam-column joint, Ductile detailing, Energy dissipation, Hollow core precast concrete column – sleeve column-beam joint.

It is the region where beams and columns intersect, and where the internal forces such as bending moments, shear forces, and axial loads are transferred effectively from one member to another. The satisfactory performance of a reinforced concrete frame under both gravity and lateral loads primarily depends on the adequate strength and ductility of the beam–column joint region.

## Structural Significance of Beam–Column Joints

The joint region is often subjected to complex stress states due to the interaction of forces from adjoining members. Under normal service conditions, the joint resists gravity-induced bending and shear forces, whereas under seismic loading, it experiences severe stress reversals that can lead to shear failure or bond deterioration if the joint is not appropriately and adequately detailed. As Paulay and Priestley (1992) emphasized, the seismic performance of reinforced concrete moment-resisting frames depends largely on the capacity of beam–column joints to undergo large deformations without a significant loss of strength and stiffness.

During strong ground motions, beam–column joints act as critical energy-dissipating zones. A well-designed joint must be capable of withstanding inelastic deformations through controlled cracking and confinement of the core concrete. Inadequately designed joints, however, can experience brittle shear failure, which is often sudden and catastrophic. Several post-earthquake reconnaissance studies have shown that many partial or complete collapses of RC buildings were attributed to joint failures rather than member failures (Park & Paulay, 1975; Beres et al., 1992).

### *Challenges in Design and Detailing*

The primary design challenge lies in ensuring that the joint possesses adequate shear strength, confinement, and bond between reinforcement and concrete. The joint core is typically confined by transverse reinforcement, which prevents diagonal cracking and spalling of concrete under cyclic loading. The anchorage of beam reinforcement into the column plays a decisive role in maintaining the joint's integrity. If anchorage is inadequate, premature yielding or pullout of bars can occur, leading to degradation of stiffness and load-carrying capacity (Hakuto et al., 2000).

In precast or prefabricated concrete construction, the issue becomes more complex. The discontinuity between elements demands special connection techniques or wet joints to emulate the behavior of monolithic joints. The performance of such joints depends on the bond quality, interface treatment, and connection detailing. Therefore, careful design and experimental validation are essential to ensure that precast beam-column joints achieve monolithic behavior comparable to that of cast-in-situ construction (ACI 352R-02, 2002).

### *Code Provisions and Ductile Detailing*

Recognizing the vulnerability of beam-column joints, modern seismic design codes have incorporated special provisions for ductile detailing. The Indian Standard IS 13920:2016 prescribes requirements for joint shear reinforcement, anchorage length, and confinement reinforcement to ensure ductile performance. Similarly, ACI 352R-02 provides detailed guidelines on joint classification (interior, exterior, and corner joints) and reinforcement detailing for each type. The Eurocode 8 (EN 1998-1:2004) also emphasizes capacity design principles and the need for overstrength in columns to prevent joint shear failure.

These codes collectively underscore that the joint region should be capable of sustaining cyclic inelastic deformations without significant strength loss, thereby ensuring the ductile failure mode of the overall frame structure. The emphasis on ductility, rather than mere strength, is to prevent sudden brittle failures and provide adequate warning before collapse.

### *Research Developments and Performance Evaluation*

Extensive experimental research has been carried out globally to understand and improve the behavior of

beam-column joints under cyclic loading. Studies by Pantazopoulou and Bonacci (1992), Park and Paulay (1975), and more recently, Hakuto et al. (2000), have shown that the joint shear strength and reinforcement detailing significantly affect hysteretic behavior, energy dissipation, and residual strength. Experimental investigations on retrofitted and precast joints have further demonstrated that with appropriate design measures—such as use of confinement reinforcement, high-strength materials, or improved interface bonding agents (e.g., SBR latex)—the performance of precast joints can be made comparable to monolithic ones.

Moreover, analytical and numerical modeling of beam-column joints has become an important area of research to predict the nonlinear behavior and failure mechanisms under seismic actions. These studies support performance-based design approaches, enabling engineers to assess deformation capacity, energy absorption, and joint stiffness degradation.

### *Summary*

In summary, the design and detailing of RCC beam-column joints are of paramount importance for ensuring the overall seismic safety and serviceability of framed structures. The joint must be capable of transferring forces effectively, maintaining structural integrity, and dissipating energy under cyclic loading. Proper detailing as per IS 13920:2016 and related international codes ensures that joints do not become weak links but rather contribute to the ductile and resilient behavior of the structure.

## **Review of Studies on Precast Beam-column Joints**

The development of precast concrete construction has gained momentum over the past few decades due to its advantages in quality control, rapid construction, and reduced on-site labor. However, the performance of precast beam-column joints under seismic and cyclic loading conditions has been a subject of extensive research, as these joints represent the weakest links affecting the overall integrity and ductility of precast frames.

### *Early Investigations*

Early studies on precast beam-column joints primarily focused on understanding the load transfer mechanism and joint behavior under static and cyclic loads. Elliot and Jolly (1993) conducted one of the early investigations on

semi-precast connections, demonstrating that the performance of precast connections strongly depends on the continuity of reinforcement and the interface treatment between precast elements. Similarly, Cheok and Lew (1991) at the National Institute of Standards and Technology (NIST), USA, examined the seismic performance of hybrid precast moment-resisting frames and showed that with proper connection detailing, precast frames could achieve ductility comparable to monolithic systems.

#### *Studies on Connection Detailing and Ductility*

Subsequent research shifted toward improving the ductility and energy dissipation capacity of precast joints. Priestley (1991) and Palmieri et al. (1994) emphasized the role of wet joints—where concrete is cast in situ at the joint region—to ensure better continuity and bond. Englekirk (1995) proposed hybrid precast systems combining mild steel reinforcement and post-tensioning, showing improved hysteretic behavior and self-centering capacity.

More recent studies, such as those by Pampanin, Priestley, and Sritharan (2001), introduced hybrid connections that integrate unbonded post-tensioned tendons with energy-dissipating reinforcement, achieving controlled rocking behavior and superior seismic resilience. These findings influenced the development of the PRESSS (Precast Seismic Structural Systems) program, which established design guidelines for seismic-resistant precast frames.

#### *Experimental and Analytical Research*

Experimental programs by Cheok et al. (1996) and Priestley et al. (1999) demonstrated that precast joints with proper ductile detailing, confinement reinforcement, and grouted sleeve connections can perform as effectively as monolithic joints under cyclic loading. In India, researchers such as Subramanian and Sivaraj (2007) explored the adaptation of IS 13920:1993 ductile detailing provisions to precast connections, showing potential for developing locally viable wet-joint systems.

Analytical and finite element modeling studies (e.g., Pampanin, 2005; Rahman et al., 2012) have further contributed to understanding the nonlinear behavior of precast joints, enabling prediction of joint shear strength, bond-slip mechanisms, and hysteretic response. These models support performance-based design approaches

and facilitate parametric studies for optimizing connection geometry and materials.

#### *Recent Advances*

Recent research has focused on innovative materials and sustainable practices. Use of fiber-reinforced concrete (FRC), engineered cementitious composites (ECC), and high-strength grout in joint regions has been shown to enhance ductility and crack control (Li et al., 2011; Song et al., 2018). The adoption of SBR latex and epoxy bonding agents has improved interface bonding in wet-joint precast systems. Additionally, full-scale shake-table tests conducted in Japan and New Zealand have validated the seismic performance of advanced precast systems developed under the PRESSS framework.

#### *Summary*

In summary, research on precast beam-column joints has evolved from understanding basic force transfer mechanisms to developing high-performance hybrid and wet-joint systems that ensure monolithic-like behavior. The collective outcome of these studies highlights that with proper ductile detailing, connection configuration, and bond enhancement techniques, precast joints can achieve strength, stiffness, and energy dissipation capacities equivalent to, or even superior to, monolithic RCC joints.

### **Experimental Programme**

In this experimental study, concrete of grade M40 was used. Two reference beam-column joint specimens, cast monolithically and designated as ML470, and two hollow-core beam-column joint specimens, designated as HCJ470, were prepared. The numeral 470 denotes the development length of the reinforcement. All specimens were tested four weeks after casting, and the entire testing program was completed within five weeks of casting.

#### *Materials*

Ordinary Portland Cement (OPC) of 43 grade was used in the study. Fine aggregate with a fineness modulus of 2.6 and well-graded coarse aggregate with a maximum size of 10 mm were employed in the concrete mixture. Steel of Fe 415 grade was used in the study. The detailed concrete mixture proportions are presented in Table 1.

Table 1: Concrete Mixture Proportion

Composition (kg/m <sup>3</sup> )					Main composition parameter ratios				Slump (mm)
Cement (C)	Coarse aggregate (CA)	Fine aggregate (FA)	Water (W)	Admixture (SP)	W/C	CA/FA	TA/C	SP/C	
380	1150	750	170	2.5	0.45	1.53	5.00	0.66	75

### Test Specimens

#### Reference specimen

The reference specimen represents the in-situ beam-column joint with ductile reinforcement as stipulated by IS: 13920. The column portion of the beam-column joint specimen had a length of 1600 mm with a cross-section of 200 mm × 200 mm. The beam portion was 900 mm long with a cross-section of 130 mm × 200 mm. The flexural reinforcement in the beam consisted of 2-10 mm diameter bars at the top and 2-10 mm diameter bars at the bottom. Shear reinforcement in the beam comprised 6 mm diameter two-legged stirrups spaced at 125 mm centre-to-centre, placed uniformly throughout the beam length.

The column was reinforced with 4-10 mm diameter longitudinal bars, one placed at each corner within the lateral ties. Lateral ties of 6 mm diameter were provided at a spacing of 125 mm centre-to-centre, including

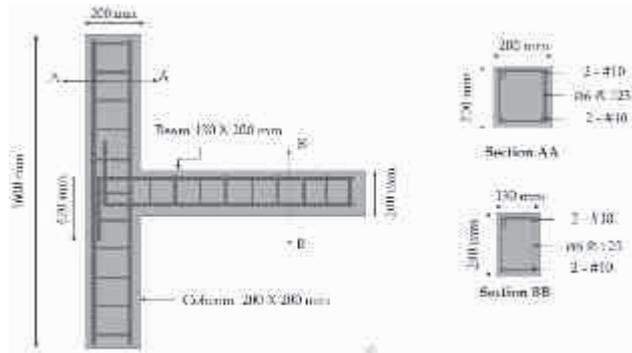


Fig. 1: Structural Details of Monolithic Beam - Column Joint - MLJ 470

additional confinement reinforcement in the beam-column joint region (Fig. 1).

#### Precast Sleeve and Beam Joint

The precast column section had an overall cross-section of 200 mm × 200 mm, with a central hollow core of 120 mm × 120 mm. The main longitudinal reinforcement, consisting of four 10 mm diameter bars, was placed within the hollow core.

Two pieces of sleeve column specimens, each 700 mm in length was cast. To withstand handling and erection stresses, each segment was reinforced with eight 6 mm diameter longitudinal bars, along with 3 mm diameter lateral ties spaced at 150 mm centre-to-centre. The cross-section of sleeve column is presented in Fig. 2. The precast sleeve column is shown in Fig. 3.

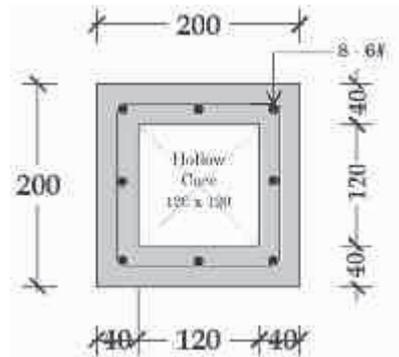


Fig. 2: Structural Details of Column Sleeve



Fig. 3: Sleeve Column, 700mm long

A solid precast beam of dimensions 130 mm × 200 mm and 900 mm in length was cast with the same flexural and shear reinforcement details as the corresponding monolithic beam specimen. Appropriate development lengths for both top and bottom longitudinal reinforcements were provided in the form of projecting dowel bars during casting. Fig. 4 elucidates the integration of the joint with sleeve column. A coat of SBR-

modified cement slurry was applied to the inner surface of the sleeve immediately before casting the in-situ concrete at the joint region, to ensure effective bonding between the precast and in-situ portions.

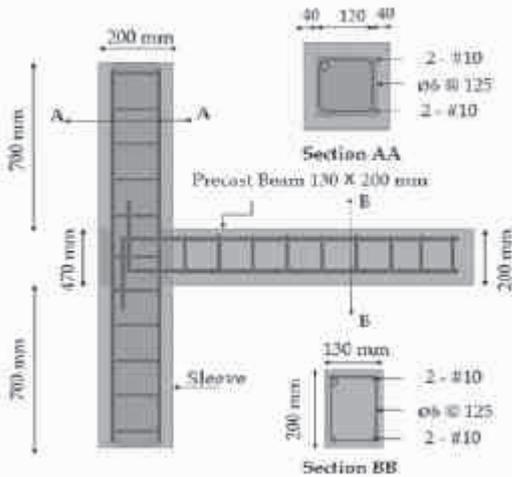


Fig. 4: Precast Beam-(Sleeved) Column Joint (HCJ 470)

frame with a capacity of 100 kN. Hydraulic jack was mounted on the top of the column to apply the gravity load. Reverse cyclic loading was introduced through an actuator of 50 kN capacity and 50 mm displacement range. The actuator applied displacement-controlled cyclic loading at the free end of the beam.

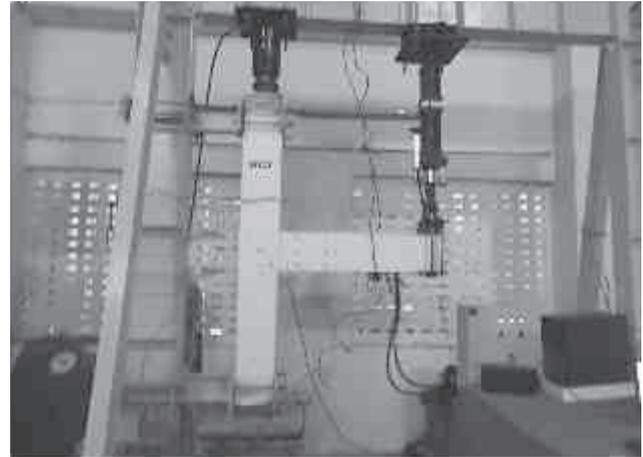


Fig. 5: Testing Arrangement

## Experimental Study

### Testing Arrangement

The experimental test setup is shown in Fig. 5. The column specimen was positioned vertically with both ends rigidly clamped. The test was conducted in a loading

frame with a capacity of 100 kN. Hydraulic jack was mounted on the top of the column to apply the gravity load. Reverse cyclic loading was introduced through an actuator of 50 kN capacity and 50 mm displacement range. The actuator applied displacement-controlled cyclic loading at the free end of the beam. To monitor joint rotation, two LVDTs were placed on the loading frame, while an additional LVDT was positioned at the free end of the beam to record vertical displacement. Two electrical resistance strain gauges were attached on the top and bottom faces of the beam to measure strain responses. At each displacement increment, three push-pull loading cycles were applied.

Table 2: Load vs Displacement

Displacement, mm	Drift ratio	Load, kN			
		MLJ470		HCJ470	
		Forward Cycle	Reverse Cycle	Forward Cycle	Reverse Cycle
±2	0.22	13.0	-13.2	17.19*	-15.90
±3	0.33	13.7	-13.7	17.72	-17.00
±4	0.44	13.6	-13.6	18.15	-17.90
±6	0.67	12.9	-15.5*	18.33	-18.90
±7	0.78	14.0	-15.4	18.65	-18.30
±9	1.00	14.5	-16.4	18.88	-18.90
±12	1.33	15.7	-17.4	19.94	-20.00
±16	1.78	17.5	-17.4	20.10	-20.00
±20	2.22	18.4	-18.4	19.95	-20.00
±23	2.56	18.4	-18.4	19.95	-20.00
±30	3.33	18.4	-18.4	19.97	-20.00
±35	3.89	18.4	-18.4	20.10	-20.00
±42	4.67	18.2	-17.2	19.86	-16.70
±45	5.00	14.5	-15.0	19.97	-15.50

\*First crack formed

Initially, a constant axial load of 15kN was applied. This load intensity was approximately the 10% of the estimated ultimate axial load carrying capacity of the column. The reverse cyclic loading sequence is presented in Table 2. The test results represent the average of two test specimens in each joint type.

### Performance of Reference Joint

In the reference joint specimen (MLJ 470), the first flexural crack was observed on the beam during the 6 mm displacement cycle, located about 170 mm from the beam-column junction, at a load of 15.5 kN. The crack first appeared as a hairline crack at the soffit of the beam and propagated upward to approximately mid-depth. With further displacement cycles, additional flexural cracks developed at various locations along the beam, accompanied by widening of the initial crack.

At the 9 mm displacement cycle, a hairline crack appeared at the beam-column interface. During the 12 mm displacement cycle, at a load of 17.4 kN, all existing hairline cracks widened and propagated further. With continued increase in displacement cycles, additional cracks formed at the beam-column interface, leading ultimately to failure of the reference joint at a load of 18.4 kN, which occurred at 35mm displacement cycle.

The crack pattern at 30mm displacement cycle and at the ultimate stage are presented in Figs. 6 & 7.

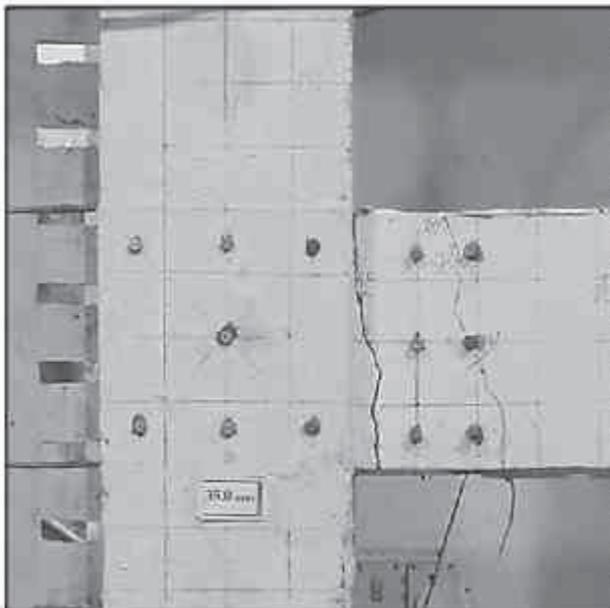


Fig. 6: Crack Pattern MLJ 470 at 30 mm displacement

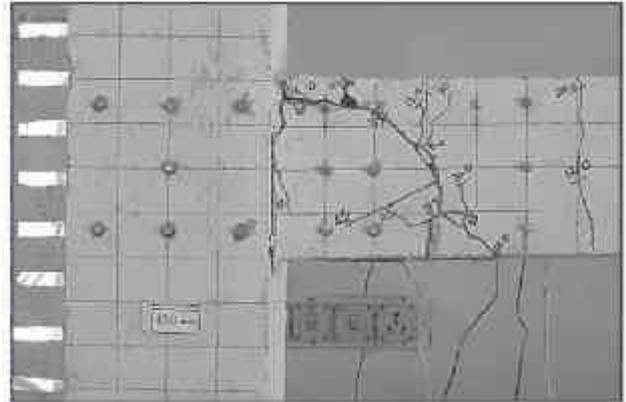


Fig. 7: Crack Pattern MLJ 470 at Ultimate load

### Performance of Hollow Core Column Joint

The hollow core joint column (HCJ 470) exhibited a structural response similar to that of the reference joint (MLJ 470), with a slight enhancement in its load-carrying capacity. The first flexural crack was observed during the 2 mm displacement cycle, approximately 230 mm away from the beam-column junction. This crack gradually widened and propagated upward in the subsequent displacement cycles.

At the beam-column junction, a crack that had formed earlier was observed to widen significantly during the 20 mm displacement cycle and to propagate further upward. With continued increase in displacement cycles, additional cracks developed along the beam-column interface. The specimen attained an ultimate load of 20.1 kN at a 35 mm displacement cycle.

The crack pattern at 20mm displacement cycle and at the ultimate stage are presented in Figs. 8 & 9.

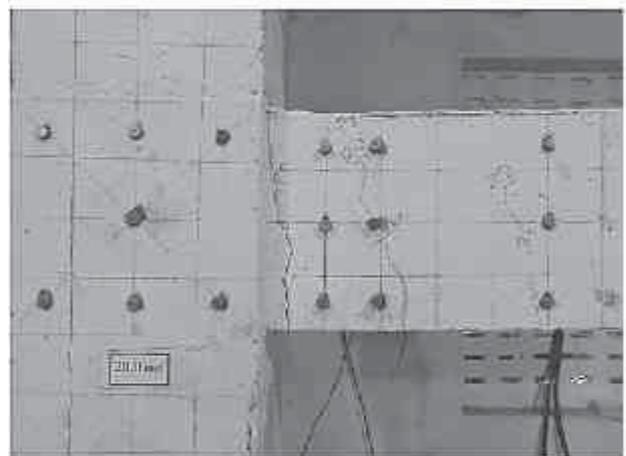


Fig. 8: Crack Pattern HCJ 470 at 20 mm displacement cycle

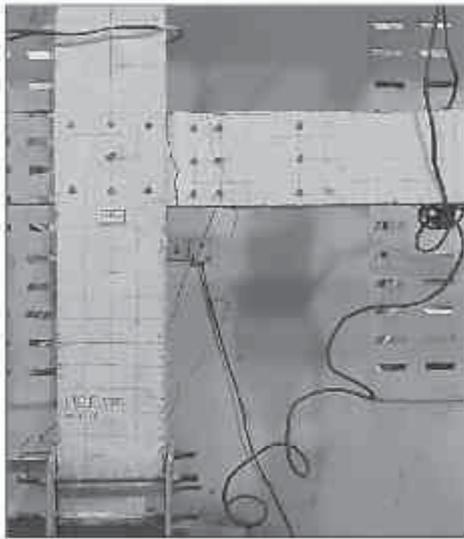


Fig. 9: Crack Pattern HCJ 470 at Ultimate Load

### Load Vs Displacement

The load–displacement response of both the reference joint (MLJ) and the hollow core joint (HCJ) specimens is presented in Fig. 10. Both specimens exhibited a similar overall behavior. However, the HCJ specimen showed a yielding load of 17.5 kN, which is approximately 13% higher than that of the MLJ specimen (15.6 kN). This marginal enhancement can be attributed to the additional confinement provided by the sleeve reinforcement. Furthermore, the HCJ exhibited about a 9% increase in load capacity at the ultimate load level compared to the reference specimen.

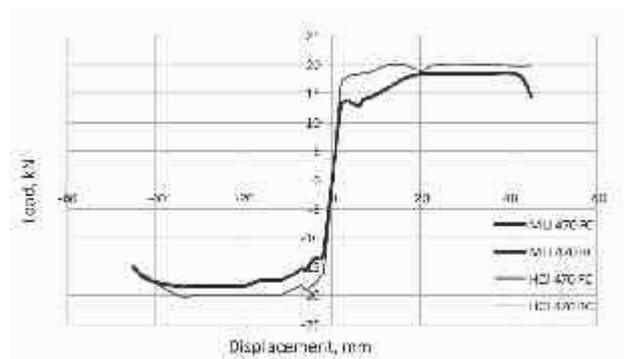


Fig. 10: Superimposed Curve of Load Vs Deflection

### Stiffness Degradation

The reference specimen exhibited a rapid deterioration in stiffness up to the formation of the initial crack, which occurred at a drift ratio of 0.67. Thereafter, the rate of stiffness degradation became moderate up to a drift ratio

of 1.78, corresponding to the stage just before the formation of the plastic hinge at the beam–column interface. Beyond this point, up to the maximum drift ratio of 5.0, the stiffness degradation progressed gradually.

In the case of the HCJ specimen, a reduction in stiffness was observed up to the initiation of cracking at a drift ratio of 0.22, followed by a moderate degradation until the formation of the plastic hinge. For both specimens, the stiffness degradation remained gradual after the plastic hinge developed at a drift ratio of 1.78.

Table 3 presents the degradation of stiffness with increasing drift, and the corresponding results are illustrated in Fig. 11. It is evident that the HCJ specimen demonstrated a slightly improved stiffness performance compared to the MLJ specimen, which may be attributed to the additional confinement provided by the sleeve reinforcement.

Table 3 Stiffness degradation with increased drift ratio

Specimen	Yield Displacement, mm	Ultimate Load, kN		Ultimate Disp. mm		Ductility Factor
		FC	RC	FC	RC	
MLJ 470	2.0	18.40	18.40	45	45	22.5
HCJ 470	2.0	20.10	20.10	45	45	22.5

FC- Forward cycle

RC- Reverse cycle

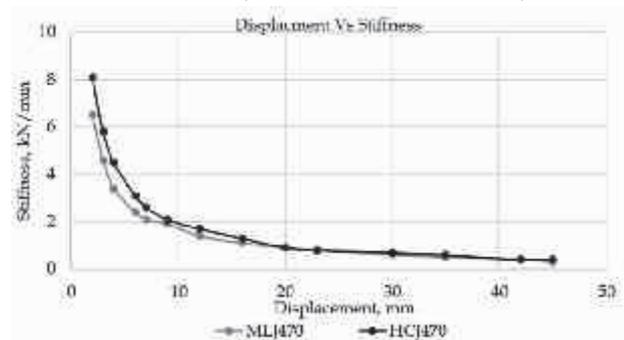


Fig. 11: Displacement vs Stiffness degradation

### Ductility Factor

The displacement ductility factor is defined as the ratio of the maximum displacement to the yielding displacement. The load–displacement envelope was employed to determine the yield and ultimate displacements. The ultimate displacement, corresponding to 80% of the peak load on the descending branch of the curve, was considered for identifying the first yield displacement. The calculated ductility factors for the reference and

Table 4: Ductility Factor

Drift ratio	Displacement, mm	MLJ470			HCJ470		
		Load, kN	Stiffness, kN/mm	Stiffness Reduction, %	Load, kN	Stiffness, kN/mm	Stiffness Reduction, %
0.22	2	13.10	6.5	--	16.19	8.1	--
0.33	3	13.70	4.6	29.23	17.36	5.8	28.40
0.44	4	13.60	3.4	26.09	18.03	4.5	22.41
0.67	6	14.20	2.4	29.41	18.62	3.1	31.11
0.78	7	14.70	2.1	12.50	18.48	2.6	16.13
1.00	9	16.95	1.9	09.52	18.90	2.1	19.23
1.33	12	16.60	1.4	26.32	19.97	1.7	19.05
1.78	16	17.45	1.1	21.43	20.05	1.3	23.53
2.22	20	18.40	0.9	18.18	19.50	0.9	30.77
2.56	23	18.40	0.8	11.11	19.98	0.8	11.11
3.33	30	18.40	0.6	25.00	19.98	0.7	12.50
3.89	35	18.40	0.5	16.67	20.05	0.6	14.29
4.67	42	17.70	0.4	20.00	18.28	0.4	33.33
5.00	45	14.75	0.3	25.00	17.74	0.4	0.00

hollow-core beam-column joints are presented in Table 4. Both joints exhibited identical performance, with a ductility factor of 22.5.

**Energy Dissipation Capacity**

The load-displacement hysteresis loops for specimens MLJ470 and HCJ470 are shown in Figs. 12 and 13. The

energy absorption capacity corresponds to the area enclosed by the hysteresis loop on the load-deflection envelope. Due to instrumentation limitations, energy dissipation could be recorded only at higher displacement levels, i.e., from 6 mm displacement onwards. The energy dissipated at various displacement cycles is presented in Table 5. It is observed that the energy dissipation per cycle for both specimens varied by

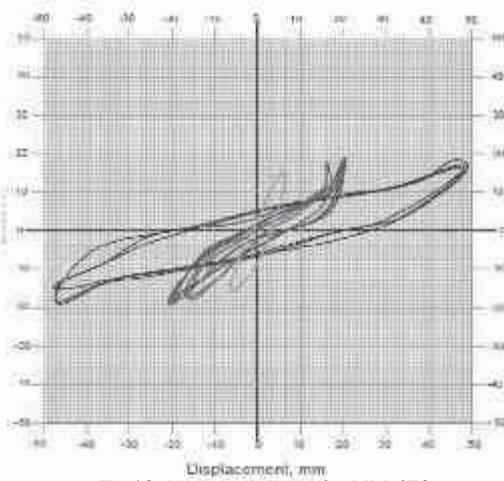


Fig 12: Hysteresis Loop for MLJ 470

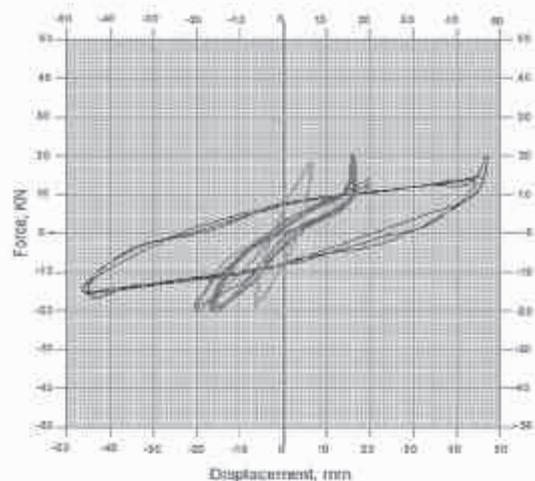


Fig 13: Hysteresis Loop for HCJ 470

Table 5: Energy Dissipation capacity

SPECIMEN	ENERGY DISSIPATION – kN-mm							
	6 mm cycle		16 mm cycle		20 mm cycle		45 mm cycle	
	FC	RC	FC	RC	FC	RC	FC	RC
MLJ 470	52.87	60.32	113.09	71.81	108.39	104.40	388.56	463.71
HCJ 470	63.95	71.25	122.01	64.61	115.63	101.64	516.28	513.06

approximately 10% up to the formation of the plastic hinge. The maximum energy dissipated in the HCJ specimen was about 11% higher than that of the MLJ specimen, which may be attributed to the additional confinement effect provided by the sleeve.

## Conclusion

Based on the limited experimental investigation, the following conclusions are drawn:

- The present study demonstrates the feasibility of constructing precast beam-column joints suitable for use in moment-resisting frames as per the provisions of IS 13920.
- The proposed precast technique, integrating a hollow-core column with a beam joint, is simple in concept and practical for implementation in the construction field.
- The key structural performance parameters—ultimate load, ductility factor, stiffness degradation, and energy dissipation—of the precast beam-column joint are comparable to those of a monolithically cast joint.
- The observed marginal enhancement (about 10%) in the overall structural performance of the hollow-core joint may be attributed to the nominal additional reinforcement provided within the sleeve.
- The SBR-cement slurry coating applied at the interface ensured effective structural bonding between the precast concrete sleeves and the in-situ concrete during reverse cyclic loading.
- An overall lesson learnt from this study is that when the beam reinforcement is adequately confined with the column the joint exhibits ideal elasto-plastic behaviour which is a perfect characteristic of ductile structural performance.
- Further investigations involving a greater number of specimens and a wider range of test parameters would provide a more comprehensive and reliable basis for the practical adoption of the proposed technique in real-world construction applications.

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# The Need for Convention in Non-conventionality in Sustainable Concretes

## Establishing Conventions in Non-Conventional Approaches to Sustainable Concrete



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### Abstract

*The construction industry is a major contributor to global CO<sub>2</sub> emissions, largely due to cement production. Enhancing the sustainability of concrete is, therefore, imperative for advancing environmentally responsible construction and resilient infrastructure. Recent innovations in materials, mix design, and technology have demonstrated significant potential to reduce the environmental impact of concrete. However, the adoption of non-conventional materials and alternative production methods presents several challenges related to performance consistency, durability, and regulatory acceptance. This paper examines these challenges and emphasizes the urgent need for standardization and the establishment of conventions to ensure the reliable and widespread implementation of sustainable or “green” concretes.*

### Introduction

Since 1950, the global consumption of natural resources has increased nearly eightfold across all major sectors. Presently, resource utilization has reached approximately 60 billion tons per year. Among these sectors, the construction industry remains the largest consumer of raw materials, exerting immense pressure on finite natural resources. For every 900 million tons of usable materials produced, an estimated 6,000 million tons of waste are generated—contributing substantially to environmental pollution and posing a growing threat to ecological balance and human well-being.

A comprehensive United Nations study examining the interdependence of population growth, food production,

**Key words:** Concrete, Sustainability, Materials, Methods and standards

industrial pollution, and the depletion of non-renewable resources concluded that, if current exploitation trends persist through the 21st century, the planet's carrying capacity could be exceeded—potentially leading to severe ecological and societal crises. Since 1930, more than 100,000 chemical compounds have been synthesized, yet the health and environmental impacts of nearly 95% of these remain inadequately understood.

In this context, sustainability in concrete construction has gained global prominence. International frameworks such as the Paris Agreement (United Nations, 2015; Schleussner et al., 2016) and the United Nations Sustainable Development Goals (SDGs) (Colglazier, 2015) emphasize urgent action to mitigate climate change and promote sustainable development. Achieving carbon neutrality by 2050 requires collective effort across all sectors, as highlighted by the American Cement Association. Advancing toward this goal demands intensified research and innovation in sustainable materials, alternative binders, and energy-efficient technologies. Engineers, architects, and construction professionals must take active responsibility by adopting the “Go Green” philosophy and integrating sustainability principles into every phase of design, construction, and material development.

### Why Traditional Concrete is not a Green Material

Concrete, in various forms, has been used for more than two millennia, with origins tracing back to ancient Roman construction. Today, it remains the most widely utilized material on Earth after water, forming the backbone of modern infrastructure and urban development. However, its ubiquity has made concrete a victim of its own success. Once criticized primarily for its aesthetic and urban heat impacts, attention has increasingly turned

toward its significant environmental footprint (University of Built Environment, 2024).

The environmental burden of conventional concrete is both substantial and multifaceted, posing major challenges to the realization of sustainable construction. The most critical issue is its high carbon footprint. Cement—the key binding component of concrete—alone accounts for approximately 8% of global CO<sub>2</sub> emissions. Cement production involves the calcination of limestone at elevated temperatures, a process that is both energy-intensive and dependent on fossil fuels, resulting in extensive greenhouse gas emissions and contributing to global climate change and air pollution.

In addition to carbon emissions, traditional concrete production and use have several ecological and resource-related drawbacks. The large-scale extraction of raw materials such as sand, gravel, and limestone often causes habitat destruction, soil erosion, groundwater depletion, and loss of biodiversity. The escalating demand for these materials exerts tremendous pressure on local ecosystems and communities, frequently resulting in land degradation and conflicts over resource allocation.

Furthermore, conventional concrete exhibits a limited service life and generates substantial quantities of construction and demolition waste, which are often non-recyclable. These wastes accumulate in landfills, undermining efforts toward a circular economy and sustainable material management within the construction sector.

Given its high carbon intensity, resource depletion, and waste generation, it is evident that traditional concrete cannot be classified as a green or sustainable construction material. Future progress in the field must therefore focus on developing low-carbon alternatives, enhancing recycling technologies, and adopting innovative mix designs that reduce dependency on Portland cement while maintaining structural performance.

### **Making Traditional Concrete Green for Sustainable Construction**

With rising environmental challenges, the World Business Council for Sustainable Development (WBCSD) has prioritized the reduction of greenhouse gas (GHG) emissions through its Emissions Reduction Accelerator

(ERA) initiative. This program assists member organizations in minimizing emissions across their value chains, focusing particularly on promoting green concrete as a key pathway toward sustainable construction.

The WBCSD advances several global strategies to achieve this goal:

**Concrete Zero:** A collaboration with the Climate Group and the World Green Building Council (World GBC) to ensure that all concrete used globally achieves net-zero emissions by 2050.

**Cement CO<sub>2</sub> Protocol:** Developed under the Cement Sustainability Initiative (CSI), this protocol standardizes the measurement and reporting of CO<sub>2</sub> emissions from cement production in accordance with international GHG frameworks.

**Alternative Fuels and Materials:** Promoting the use of low-carbon fuels in place of traditional fossil fuels, and encouraging clinker substitutes such as calcined clay, fly ash, and recycled concrete aggregates.

**Energy Efficiency:** Optimizing energy consumption at every stage of cement and concrete production to minimize emissions and operational costs.

**Carbon Capture, Utilization, and Storage (CCUS):** Supporting the development and deployment of CCUS technologies to capture process-related CO<sub>2</sub>, despite current economic constraints.

**Waste Heat Recovery (WHR):** Implementing WHR systems to reuse heat generated during production, thereby improving overall energy efficiency.

The transition to green concrete represents a crucial opportunity to drive sustainability in the construction industry. As global concerns over climate change, resource depletion, and rapid urbanization intensify, green concrete offers a practical solution that balances durability, strength, and environmental responsibility. By integrating recycled materials, efficient technologies, and circular economy principles, the construction sector can significantly reduce its carbon footprint and pave the way for a more resilient and sustainable built environment for future generations.

## Challenges in Adopting Non-conventional Materials and Methods in Sustainable Concrete

The transition toward sustainable or green concretes requires the integration of non-conventional materials and innovative methods. While such approaches offer substantial environmental and performance benefits, they also pose several challenges that must be addressed to ensure large-scale adoption. The benefits and challenges (Nilimaa, 2023) associated with non-conventional concretes are summarized below:

The successful adoption of non-traditional materials and techniques in sustainable concrete production depends on addressing several critical issues:

- **Material Quality Variability:** The performance of recycled aggregates and supplementary cementitious materials (SCMs) varies significantly with source and processing, impacting consistency and reliability.
- **Higher Initial Costs:** Although long-term economic and environmental benefits are evident, the upfront investment for green technologies and materials remains a deterrent.
- **Lack of Awareness and Training:** Limited understanding among engineers, contractors, and policymakers about the performance and advantages of green concretes slows implementation.

- **Regulatory and Certification Gaps:** The absence of unified standards and certification protocols for alternative materials creates uncertainty in design and approval processes.
- **Performance and Durability Concerns:** Skepticism persists regarding the long-term mechanical and durability performance of green concretes compared to traditional OPC systems.
- **Need for Technical Expertise:** The use of innovative binders and materials demands specialized skills, which may not be widely available in the current workforce.
- **Market Resistance:** Conventional construction practices and industry conservatism continue to impede the transition to sustainable alternatives.
- **Resource Availability:** The uneven geographic distribution of recyclable and industrial by-products poses logistical and supply chain challenges.

Addressing these barriers calls for standardization, capacity building, and policy support to integrate sustainable practices into mainstream construction. Collaborative efforts among researchers, industry stakeholders, and regulatory bodies are essential to accelerate the acceptance of green concrete as a viable and enduring solution for the future of sustainable construction.

Aspect	Benefits of Non-Conventionality	Challenges for Broader Adoption
<b>Sustainability</b>	Reduces carbon emissions through lower cement usage and higher incorporation of industrial by-products; conserves natural resources by utilizing recycled materials.	Dependence on the consistent availability and quality of industrial by-products.
<b>Performance</b>	Offers superior strength, ductility, and resistance to chemical attack, freeze-thaw cycles, and cracking.	Performance variability demands rigorous quality control, advanced testing, and long-term validation.
<b>Durability</b>	Improved service life due to reduced permeability and potential self-healing characteristics.	Repair and maintenance of specialized concretes may be complex and costly.
<b>Economics</b>	Reduces lifecycle costs by reusing waste products and improving longevity.	Higher initial material, testing, and training costs for new technologies and equipment.
<b>Industry Adoption</b>	Encourages innovation and supports circular economy models.	Lack of established standards, limited awareness, and insufficiently trained workforce hinder acceptance.

Conventional Concrete	Non-Conventionality (Alternative Materials and Methods)	Convention in Non-Conventionality (Standardized Integration)
Primarily composed of Portland cement (OPC), natural aggregates (sand and gravel), and water.	Utilizes supplementary cementitious materials (SCMs) such as fly ash, ground granulated blast furnace slag (GGBS), rice husk ash, and calcined clays.	The widespread use of formerly non-conventional SCMs like fly ash and GGBS has become routine, with their incorporation now regulated through established standards.
Environmental impact: High energy consumption and <small>significant CO<sub>2</sub> emissions from</small> clinker production.	Waste utilization: Incorporates industrial byproducts and waste-derived materials, conserving natural resources and reducing landfill burden.	Ongoing research aims to develop standardized test procedures and specifications for emerging SCMs to ensure consistent performance and reliability.
Properties: Well-established benchmarks for strength, durability, and workability, but limitations include susceptibility to cracking, shrinkage, and chemical attack.	Advanced properties: Enables high-performance concrete (HPC), ultra-high-performance concrete (UHPC), and self-compacting concrete (SCC) for specialized structural applications.	New design standards and codes increasingly integrate previously non-conventional components, such as graded recycled aggregates, into approved mix design practices.
Cost and availability: Materials are widely available, economical, and suitable for mass-scale construction.	Alternative binders: Employs binders such as geopolymers that use alkaline activation instead of OPC hydration.	Alternative binders are progressing toward codification and certification within green building frameworks (e.g., LEED, BREEAM), supporting their adoption in mainstream construction.

### The “Convention in Non-Conventionality” of Concrete Materials

The concept of “convention in non-conventionality” in concrete materials captures the growing movement toward formalizing and standardizing the use of sustainable, non-traditional constituents. This evolution reflects global efforts to lower the environmental footprint of conventional concrete by integrating waste-derived materials, alternative binders, and innovative manufacturing techniques into accepted construction practice. As these non-conventional materials gain scientific validation, regulatory acceptance, and industry confidence, they gradually transition from experimental options to established, codified solutions—creating a new convention rooted in sustainability.

### How to Transform Non-Conventionality into Convention in Sustainable Concretes

The transition from non-traditional concrete materials to standardized, widely accepted practice is driven by environmental necessity, evolving standards, technological advancements, and global industry collaboration.

#### *Necessity for Low-Carbon Alternatives*

With the cement sector being one of the largest emitters of global CO<sub>2</sub>, the urgent demand for low-carbon construction materials is pushing innovative, previously experimental solutions into mainstream practice. This environmental imperative is accelerating the adoption of sustainable binders, recycled aggregates, and waste-derived constituents.

#### *Standardization to Ensure Reliability*

For non-conventional materials to achieve widespread acceptance, they must meet stringent requirements for performance, safety, and durability. Standards bodies such as ASTM, ISO, BIS, and EN are actively developing and refining test protocols, classifications, and specifications for new materials. These efforts build confidence among engineers and regulators, enabling predictable and repeatable performance.

#### *Performance and Cost Efficiency*

Although some alternative concretes may involve higher initial costs, many deliver superior durability, reduced

permeability, and longer service life, thereby lowering long-term maintenance expenditure. The use of industrial by-products (fly ash, GGBS, silica fume) and other waste materials also provides an economical resource base, driving continued research to optimize both performance and cost.

### *Industry-Wide Collaboration*

Global collaboration is central to scaling sustainable concrete technologies. Organizations such as the Global Cement and Concrete Association (GCCA), representing a major share of worldwide production, have committed to achieving carbon-neutral concrete by 2050. Progress toward this goal requires harmonized standards, coordinated research, and large-scale implementation of low-carbon technologies across the construction sector.

### *Enabling Technologies*

Emerging digital tools, including AI, machine learning, and automated testing systems, are transforming the way concrete is designed and validated. These technologies enable accurate prediction of performance, rapid optimization of complex mix proportions, and greater consistency in materials derived from variable waste streams.

In this evolving landscape, the “convention in non-conventionality” reflects the institutionalization of sustainable, high-performance, and environmentally responsible materials. The industry is steadily moving beyond its reliance on OPC, natural sand, and gravel, embracing standardized alternatives that meet contemporary engineering challenges while addressing urgent environmental demands

## **Approaches to Establishing the Convention of Non-conventionality in Sustainable Concretes**

### *1. Supplementary Cementitious Materials (SCMs)*

Although ordinary Portland cement (OPC) has traditionally served as the primary binder in concrete, sustainable practice increasingly involves partial replacement with industrial by-products possessing pozzolanic or latent hydraulic properties (Jones et al., 2010; Mehta & Monteiro, 2014; Siddiqui et al., 2025).

- Fly Ash: A coal-combustion by-product that improves workability, long-term strength, and durability. Its use reduces clinker consumption

and diverts significant quantities of waste from landfills.

- Ground Granulated Blast-Furnace Slag (GGBS): A steel industry by-product capable of replacing up to 50% of OPC. It enhances chemical resistance, lowers permeability, and substantially reduces the embodied carbon of concrete.
- Silica Fume: An ultra-fine material from silicon and ferrosilicon production. Its high reactivity refines pore structure, increases strength, and boosts corrosion resistance.
- Calcined Clays: Heat-activated clays (e.g., metakaolin) that provide high pozzolanic activity. Their abundance in many regions makes them an effective low-carbon option for large-scale construction.

### *2. Geopolymer Concrete*

Geopolymer concrete represents a fully non-conventional alternative by eliminating OPC altogether. It utilizes aluminosilicate-rich industrial by-products (e.g., fly ash, GGBS) activated with alkaline solutions to form a robust, cementitious binder through geopolymerization.

- Binders: Strength derives from the formation of aluminosilicate gels rather than OPC hydration products.
- Benefits: Geopolymer concrete can reduce CO<sub>2</sub> emissions by up to 80% and offers superior resistance to chemical attack, heat, and fire—making it suitable for aggressive and high-performance environments.

### *3. Novel and Recycled Aggregates*

Dependence on natural river sand and gravel is increasingly unsustainable. Alternative aggregates help conserve natural resources and support circular-economy objectives.

- Recycled Concrete Aggregate (RCA): Produced from demolished structures, RCA reduces waste, conserves natural aggregate, and supports sustainable demolition practices.
- Plastic and Glass Aggregates: Shredded plastics and ground waste glass act as partial replacements for fine or coarse aggregates. They reduce landfill burden and can impart lightweight or decorative attributes.

- Crumb Rubber: Derived from scrap tires, crumb rubber improves impact resistance and ductility when used in partial replacement of coarse aggregates.
- Other Waste-Derived Materials: Industrial wastes (e.g., steel dust) and agricultural residues (e.g., rice husk ash, bagasse ash) are being extensively studied as potential aggregate or binder components.

#### 4. High-Performance and Smart Concretes

Modern concrete research is evolving beyond traditional strength-based formulations to materials that offer enhanced functionality, durability, and resilience (National Institutes of Health, 2024).

- Self-Healing Concrete: Employs bacteria or encapsulated healing agents that precipitate minerals to autonomously seal microcracks, prolonging service life and reducing maintenance.
- Ultra-High-Performance Concrete (UHPC): A dense, fiber-reinforced material providing exceptional compressive and tensile capacity, enabling slender, durable, and long-span structural elements.
- Light-Transmitting and Light-Emitting Concretes: Incorporating optical fibers or photoluminescent additives, these concretes deliver functional benefits such as ambient illumination and enhanced road safety, alongside aesthetic applications.

#### Concluding Remarks

- The adoption of green concrete represents a critical pathway toward enhancing sustainability in the construction industry and mitigating environmental degradation. As the world grapples with the escalating challenges of climate change, resource depletion, and rapid urbanization, green concrete offers a viable and forward-looking solution that minimizes environmental impact while maintaining structural performance and durability. By incorporating recycled materials, alternative binders, and innovative manufacturing technologies, the industry can significantly reduce carbon emissions and strengthen the circular economy, ultimately contributing to healthier and more resilient communities.

- However, existing building codes, regulatory frameworks, and design standards often lag behind technological advancements in sustainable concrete. This misalignment can create procedural barriers, slow approvals, or restrict the wider adoption of innovative materials and construction practices.
- Achieving meaningful progress requires coordinated efforts among architects, engineers, material scientists, contractors, policymakers, and standard-setting bodies. By promoting best practices, improving awareness, and prioritizing sustainability in design and regulation, the construction sector can redefine its benchmarks and transition toward more environmentally responsible materials.
- Moving forward, the widespread acceptance of green concrete will not only transform construction practices but also reflect a collective commitment to safeguarding the planet for future generations. Establishing a “Convention in Non-Conventionality”—that is, standardizing and institutionalizing sustainable concrete technologies—will be a decisive step in this transition and an essential milestone on the path to a greener, more sustainable future.

#### *Declaration of competing interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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86	15253	Er Neeraj Mathur	Barmer	JAIC					
87	15254	Er Prateek Suthar	Udaipur	JAIC					

# 3D Printing of Buildings – A Technological Perspective



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## Abstract

Globally, the construction industry is under significant pressure to improve sustainability and operational efficiency, driven by the high resource demand and persistent material waste inherent in conventional, formwork-dependent construction methods. Additive manufacturing (3D printing) has emerged as a disruptive technology, enabling automated, layer-wise fabrication directly from digital models, and minimizing resource use, labour, and carbon impact. This paper reviews the historical development, technical foundations, and modern implementation of 3D printed construction, with a focus on materials innovations such as printable cementitious systems and geopolymers, process automation, and reinforcement strategies. Case studies from global leaders—including projects in the USA, India, and Europe—demonstrate milestones in affordability, speed, and material efficiency, while highlighting technical advancements in process control, instrumentation, and structural optimization. Key engineering challenges such as rheology, interlayer bonding, dimensional accuracy, curing, and standardization are examined in detail. The research concludes with life-cycle sustainability assessments and outlines how the integration of robotics, digital design, and innovative materials positions 3D printing as a transformative solution for rapid, sustainable, and affordable housing worldwide.

**Keywords :** 3D Printing; Additive Manufacturing; Construction Technology; Geopolymer Concrete; Rheology; Automated Fabrication; Structural Engineering; Sustainable Construction.

## 1. Introduction

The construction industry has historically depended on labour-intensive, formwork-based practices that restrict design flexibility, efficiency, and sustainability. These conventional methods, though well established, are increasingly being scrutinized for their inefficiency and excessive resource consumption. The sector currently accounts for approximately 100 billion tons of raw material usage each year, with significant material waste generation that positions it among the most resource-intensive global industries (amfg.ai, 2025). According to the World Bank (2012), urban centers worldwide generate about 1.3 billion tons of solid waste annually, a figure projected to reach 2.2 billion tons by 2025. Building materials alone contribute to nearly half of the total solid waste volume produced globally (Transparency Market Research, 2024). This persistent waste generation underscores the urgent need for sustainable and automated construction methodologies to reduce the industry's environmental footprint.

Additive manufacturing, or three-dimensional (3D) printing, has emerged as a transformative solution to these long-standing challenges. Defined as the process of fabricating structures layer by layer directly from a digital model, 3D printing eliminates the need for formwork and extensive manual operations while ensuring high precision and design adaptability (Buswell et al., 2007). Early research into large-scale additive fabrication was pioneered by the University of Southern California through the concept of “Contour Crafting,”

which demonstrated the feasibility of automated construction processes (Tay et al., 2017). Since then, commercial systems developed by COBOD, ICON, and Apis Cor have advanced the technology from laboratory prototypes to full-scale implementation, enabling applications from affordable housing to complex architectural elements. These developments mark a significant shift towards the Industry 4.0 framework, integrating robotics, digital design, and intelligent materials for automated and sustainable building delivery.

The evolution of 3D printing from a rapid prototyping tool into a full-fledged construction technology has been supported by its unique advantages in precision, waste reduction, and structural optimization. Additive manufacturing minimizes material waste by up to 60%, reduces human error, and allows geometries that are unattainable through traditional formative or subtractive methods (Ngo et al., 2018; JK Cement, 2025; Sinterit.com, 2025). Moreover, recent innovations in material science have further enhanced its environmental potential. For instance, 3D-printed concrete systems incorporating bone-inspired internal geometries and silica-rich biominerals such as diatomaceous earth exhibit the ability to absorb carbon dioxide rather than emit it. Such systems can reduce cement consumption by approximately 70% and enable structures to sequester up to 142% more CO<sub>2</sub> than conventional concrete (Jacobs, 2025). These advancements illustrate a convergence between automation, material engineering, and environmental sustainability.

The global 3D printing in construction market is projected to expand from an estimated USD 2.4 billion in 2025 to about USD 256.7 billion by 2035, reflecting its disruptive potential across both developed and emerging economies (futuremarketinsights.com, 2025). The technology significantly enhances safety and operational efficiency by minimizing on-site labour requirements—allowing projects to be executed with as few as two or three supervisors per site (amfg.ai, 2025). Demonstrative projects, such as India's first fully 3D-printed villa in Pune, highlight its capacity to leverage locally available materials, streamline construction timelines, and reduce overall project costs (Indian Express, 2025). The fusion of digital fabrication, sustainable materials, and intelligent automation positions 3D printing as a key enabler of a more resource-efficient and environmentally responsive construction paradigm.

## 2. Historical Context and Evolution of 3D Printing

Long before the advent of computer-aided design and automated fabrication systems, Indian craftsmanship embodied the essence of additive principles in everyday practices. A familiar example lies in the preparation of the traditional festive snack “murukku.” The process involves pressing rice flour dough through patterned moulds to form spiral geometries built up layer by layer. Each precise, repeated motion of the press forms the complete pattern from base to top, effectively demonstrating the fundamental concept of material extrusion. This culturally rooted analogy subtly parallels the principle of modern 3D printing—where material is deposited in a controlled, layered manner to build complex geometries.

The scientific foundation of modern additive manufacturing (AM) emerged in the early 1980s with Chuck Hull's invention of stereolithography, a process that used ultraviolet light to selectively solidify liquid resin in successive layers (Hull, 1986). During the 1990s and early 2000s, 3D printing technologies expanded rapidly across industrial sectors, primarily for prototyping and product development. Key innovations during this period included selective laser sintering (SLS), fused deposition modeling (FDM), and laminated object manufacturing (LOM), which collectively advanced the precision and scalability of additive fabrication (Ngo et al., 2018; Sinterit, 2025). These developments established the foundation for the wide adoption of AM techniques in manufacturing, medicine, aerospace, and eventually, construction.

## 3. Technical Background

### 3.1. 3D Concrete Printing: From Digital Model to Physical Structure

3D printing for buildings is fundamentally a digital-to-physical process, wherein a detailed 3D CAD or BIM model is sliced into horizontal layers. Each layer is then translated to instructions for automated robotic systems that deposit material precisely as per design (Vajiram & Ravi, 2025).

A typical 3D construction printing setup comprises three main subsystems:

- A. **Printing Hardware:**  
Large-scale gantry or multi-axis robotic arm systems enable controlled movements in

three directions (X, Y, Z). These systems can address projects ranging from entire building shells to complex forms and special components (TechSci Research, 2025).

- B. **Material Delivery System:**  
Automated pump-and-hose assemblies feed printable concrete, mortars, or innovative composites. Next-generation systems incorporate real-time control and automated batching for mix quality and process stability (AMS India, 2025).
- C. **Control Software:**  
Advanced software converts digital geometry into optimized toolpaths and dynamically adjusts parameters like speed, extrusion rate, and nozzle position for accuracy, quality, and efficiency in execution (Vajiram & Ravi, 2025).

### 3.2 Materials for 3D Printing

#### a) Printable Cementitious Systems

Conventional concrete mixtures are unsuitable for extrusion-based printing, as large aggregates and long setting times cause flow and stability issues. Instead, custom-designed mixes use:

- Fine aggregates (<4mm),
- Low water-to-binder ratios (0.30–0.38),
- Superplasticisers, viscosity modifiers, and accelerators to achieve rapid set and flowability (Tay et al., 2017; TechSci Research, 2025).

Pioneering Indian projects—such as those by IIT Madras and L&T—have developed printable mixes with compressive strengths between 25–50 MPa and rapid set times tailored for diverse climatic conditions (AMS India, 2025).

#### b) Geopolymers and Eco-Friendly Alternatives

To reduce environmental impact, many researchers focus on geopolymers—binder systems based on industrial by-products such as fly ash or GGBS, activated by alkaline solutions. These alternatives can deliver up to 60% lower CO<sub>2</sub> emissions and offer equivalent or even superior strength to traditional cement-based concrete (Mechtcherine et al., 2021; RSC Publishing, 2025). Cutting-edge research in India explores bio-composites

and printable metals for specialized defense and infrastructure use (RSC Publishing, 2025).

#### c) Rheological Optimization

Robust 3D printing depends on precise control of material rheology:

- Yield stress of 300–600 Pa,
- Plastic viscosity of 50–150 Pas are typical targets to guarantee pumpability and buildability (Zhang et al., 2020). Sensor integration and AI-driven feedback loops are now substantially reducing print variability and material waste (ACTS International, 2024).

### 3.3 End-to-End Process Workflow

The 3D concrete printing workflow follows these fundamental steps:

- Design and Slicing:** CAD/BIM models are sliced into horizontal layers (typically 5–20 mm thick). AI enhances path optimization for complex or material-efficient geometries (Vajiram & Ravi, 2025).
- Material Preparation and Delivery:** Automated batching, admixture dosing, and pumping ensure consistent mix quality tailored to environmental and design requirements.
- Robotic Extrusion (Printing):** Controlled extrusion along generated toolpaths enables precise layer stacking. Robotic and gantry-based printers can now also deposit insulating or functional materials in addition to concrete (AMS India, 2025).
- Reinforcement Placement:** Structural reinforcement is either inserted manually between print pauses or integrated using automated and hybrid approaches for enhanced load-bearing capacity (AMS India, 2025).
- Curing and Finishing:** Surface finishing and controlled curing (chemical and environmental) follow printing to ensure structural integrity and durability.

### 3.4 Reinforcement Placement Strategies and Structural Integration

A distinctive challenge in 3D printed construction is efficient reinforcement integration through an automated process. Contemporary strategies include:

- Pause-and-place insertion of steel bars: Practiced in pilot projects for resuming printing after reinforcement placement (RILEM TC 276-DFC, 2021; AMS India, 2025).
- Continuous fiber reinforcement: Integration of steel or polymer fibers into the printable mix boosts tensile and flexural strength (ScienceDirect, 2025).
- Hybrid precast-printed connections: Prefabricated modules containing reinforcement are joined by printed elements for hybrid load-sharing.
- Topology optimization: Software-based digital modeling tailors geometry for stress distribution, maximizing structural efficiency while cutting material usage (Mechtcherine et al., 2021; Wiley Online Library, 2025).

Recent research explores robotic placement of rebar and welded mesh during printing and even the development of printable reinforcement materials (Wiley Online Library, 2025). India and international code committees are now working toward new standards for load transfer and reinforcement in automated construction (AMFG, 2025).

## 4. Study on Modern 3D Printed Structures

### 4.1 Affordable Housing Projects: ICON, Texas, USA

ICON's work in Texas represents a breakthrough in the use of robotic 3D concrete printing to deliver scalable, affordable housing. Their Vulcan system prints Lavacrete—a durable, insulated, cement-based composite—layer by layer to form structural walls and foundations, with the core printed in less than 24 hours, 3 weeks for walls printing, and total house completion still requiring several months considering finishing (Fig. 1).



Fig. 1 Affordable Housing Project in Texas  
(Image Credits: Madeleine P., 2021, <https://www.3dnatives.com/>)

### 4.1.1 Instrumentation and Process Automation

ICON's Vulcan printer employs an integrated sensor suite for real-time control of extrusion rate, layer thickness, and nozzle position, with feedback loops enabling adaptive printing to compensate for environmental variation (ICON, 2025). The system is monitored via visual cameras, LiDAR, and embedded moisture/fluid sensors, ensuring every wall segment achieves required dimensional tolerances.

### 4.1.2. Material Strength and Performance

The proprietary Lavacrete mix is formulated to reach compressive strengths between 34–46 MPa in 28 days, exceeding conventional American residential minimums (ArchDaily, 2024). Quality control data indicate printed structures typically display enhanced interlayer adhesion, yielding robust walls with improved impact resistance and low thermal conductivity.

### 4.1.3. Efficiency and Timing

Construction time for the basic shell is under 24 hours, and a completed home is delivered in 7–8 days, from print start to roof capping. ICON's method achieves up to 70% reduction in workforce requirements, with reported material waste reductions exceeding 60% due to precise deposition and limited offcut generation (New Atlas, 2025; CNBC, 2025).

### 4.2. ISRO–Tvasta 3D-Printed House (IIT Madras, India)

In India, indigenous technology pioneered by Tvasta and ISRO at IIT Madras led to the nation's first on-site printed single-storey house (Fig. 2) using locally developed quick-



Fig. 2 Single Storey House  
(Image Credits: Tvasta)

setting concrete (ISRO–Tvasta, 2021). In this project, a 600 sq.ft. house was built in less than five days with 30–40% lower cost compared to traditional construction (DesignDekko, 2021), and the workflow paired digital slicing, adaptive robotic extrusion, and tailored mix design to accommodate local climate and resource availability (IIT Madras, 2021; Gadgets360, 2021).

#### 4.2.1. Instrumentation and Automation

Tvasta's custom printer includes digital control of pump rate, layer deposition, and environmental sensors for humidity and temperature, paired with real-time data feeds into BIM integration for construction monitoring (ISRO–Tvasta, 2021; DesignDekko, 2021).

#### 4.2.2. Material Strength and Performance

Locally developed quick-setting concrete for Indian climate achieves compressive strengths of 25–30 MPa at 7 days and 35–40 MPa at 28 days, suitable for residential standards. Micro-reinforcement and mineral admixtures ensure uniform bonding and reduced shrinkage.

#### 4.2.3. Efficiency and Construction Time

The project's complete workflow—site preparation, printing, curing, and internal fitout—was completed in under five days. Automated mix design and rapid print cycles cut labour requirements by more than half and

reduced material wastage by up to 80% compared to regional alternatives (IIT Madras, 2021; Gadgets360, 2021).

## 5. Technical Challenges

Before large-scale 3D printing can fully realize its transformative potential in the construction industry, a number of technical challenges must be overcome. These challenges span material science, process control, construction quality, and regulatory frameworks, each presenting unique engineering hurdles. The following table summarizes the principal challenges grouped by aspect, defines each challenge, and highlights the key engineering implications. This structured view supports targeted research, development, and policy actions essential for advancing 3D concrete printing from pioneering demonstrations to reliable, routine practice in the built environment.

## 6. Sustainability and Environmental Considerations

3D printed construction offers compelling environmental and economic advantages over traditional building techniques. Foremost among these is the elimination of temporary formwork, which substantially lowers both the volume and complexity of construction and demolition waste, resulting in significant cost savings and a reduced environmental footprint (Kruger et al., 2019). The precision of digital fabrication ensures that only the required volume of material is deposited, leading to a

Aspect	Challenge	Engineering Implication
Material Rheology	Balancing pumpability and buildability	Requires real-time rheological monitoring and adaptive control
Interlayer Bonding	Weak interfaces, anisotropic strength	Critical to optimize surface moisture and deposition timing; may need activation methods for improved bonding
Dimensional Accuracy	Geometric deviations (nozzle drift, calibration)	Necessitates closed-loop robotic control and continuous sensor feedback
Curing and Shrinkage	Non-uniform drying causes shrinkage/cracking	Automated environmental and moisture control systems recommended
Code Standardization	Lack of universally accepted structural codes	Active development by RILEM/ISO; requires regulatory and industry engagement

30–40% reduction in raw material consumption as compared to conventional methods (Mechtcherine et al., 2021; RSC Publishing, 2025). This reduction is achievable because structures are engineered and printed to their exact geometric and load-bearing requirements, thus minimizing excess.

Advanced binders—including geopolymers and supplementary cementitious materials (SCMs) such as fly ash, GGBS, and metakaolin—further decrease embodied carbon relative to ordinary Portland cement. Life-cycle assessment studies have shown that geopolymer-based 3D printed structures can achieve up to 60% lower CO<sub>2</sub> emissions across the building's life span while maintaining comparable mechanical performance and durability (Kruger et al., 2019; RSC Publishing, 2025). Robotic automation brings additional efficiencies by shortening construction cycles and nearly eliminating rework, as ongoing digital error checking and automated QA/QC curb the need for costly corrections. This leads to reduced machinery operation times, lower site energy demand, and diminished transportation-related emissions.

The robust integration of recycled aggregates and locally sourced materials supports circular economy objectives, especially important in regions with limited raw material availability (Mechtcherine et al., 2021; AMS India, 2025). Numerous recent projects incorporate passive solar features, superior thermal insulation, and digitally customized elements, advancing overall energy efficiency for residential and commercial occupants.

## 7. Concluding Remarks

- The convergence of digital fabrication, robotics, and materials innovation is reshaping the way architectural and civil engineering projects are conceived and executed.
- 3D printing enables sustainable, efficient, and affordable construction by utilizing cementitious and geopolymer systems engineered for pumpability, extrudability, and buildability—key requirements for dependable automated construction.
- Current research frontiers focus on:
  - Improving interlayer bonding and rheological optimization.
  - Developing reinforcement strategies, including fibre reinforcement, pre-embedded mesh, and automated cable placement.

- Advancing smart process control systems such as real-time instrumentation, digital twins, and AI-based error correction.
- Establishing design codes, quality assurance frameworks, and standardized testing protocols.
- Progress in material chemistry, process automation, and policy support is accelerating the adoption of 3D printing for affordable, sustainable, and rapid delivery of housing and infrastructure—particularly in developing economies such as India.
- The technology's proven capability to deliver resource-efficient, low-carbon construction while improving overall performance positions 3D printing as a pivotal enabler of sustainable development and a key contributor to post-pandemic infrastructure resilience.

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# News From Head Quarters

## 1. ICI-GC Meeting:

The 158<sup>th</sup> GC Meeting was held on 8<sup>th</sup> December 2025 at Hyderabad.

ACF President met the GC members and requested for the active participation of ICI in ACF activities.



## 2. ICI Annual Awards Function :

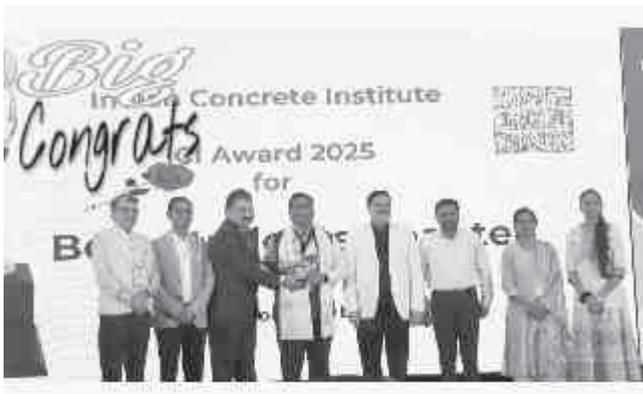
This year, the ICI-Annual Awards Function was celebrated on 9<sup>th</sup> December 2025 during ACECON 2025 at Hotel Taj Deccan, Hyderabad. The award winners were honoured

with prestigious trophies and personalized citations, recognizing their remarkable contributions to the construction industry. The details of the Awardees are as under.

Category of the Award	Awardee(s)
Outstanding Concrete Technologist	Dr.Keshav Chandrakant Tayade
Lifetime Achievement	Er.Parthasarathi Sengupta
Lifetime Achievement	Er.Samir Surlaker
Lifetime Achievement	Dr.Prem Krishna
Lifetime Achievement	Er.V.Suresh
Outstanding Concrete Structure	RAPP-7&8 Project, Chittorgarh
Jury Appreciation Award	Siesta Tower
Outstanding Prestressed Concrete Structure	Prestressing Innovation in U-Girder Casting –DMRC Phase-IV (DC-02)
Jury Appreciation Award	330 Meters Span Cantilever & Prestressed Concrete Box Girder Type Bridge at Baghchhal

Dr.A.Ramakrishna Award for Best Project with Precast Concrete in India	Wilo Warehouse, Pune
Sustainability in Concrete Construction	Navi Mumbai International Airport
Innovative Applications of Special Concretes	Construction Of Permanent Campus Phase-Afor IIT Tirupati
The Best Paper Published in ICI Journal	“Analysis of the Palau Bridge Failure: Role of Creep and Shrinkage ” by <u>Ms.Mary Williams &amp;Prof.Devdas Menon</u>
The Best Paper on Construction Techniques Published in ICI Journal	“White Topping Overlay: Insights from an Experimental Stretch” by <u>Dr.Vishal Ramesh Thombarc</u>
Best Ph.D. Thesis in Concrete	“Behaviour of RC exterior beam - Column joint with alternative Ductile detailing under reverse Cyclic loading ” by <u>Dr.Bilkis Banu</u>
Young Scientist	Dr.Bijily Balakrishanan
Best Centre	ICI-Nagpur Centre
Best Students Chapter	K.D.K. College of Engineering, Nagpur
Emerging Students Chapter	Poornima College of Engineering,

### PHOTO GALLERY





**2. “ACECON 2025” - ICI International Conference – 6<sup>th</sup> Asian Conference on 'Ecstasy in Concrete'**

The Indian Concrete Institute organized the 6<sup>th</sup> Asian Conference on 'Ecstasy in Concrete' (ACECON 2025) which was held from 8<sup>th</sup> to 10<sup>th</sup> December 2025 at Hotel Taj Deccan, Hyderabad. ICI-Hyderabad Centre hosted this Quinquennial Conference.

Earlier five consecutive ACECONs were held at Bengaluru (2000), Mumbai (2005), Chennai (2010), Kolkata (2015), and Delhi (2022). Each edition brought together leading global experts, researchers, designers, and industry professionals to exchange advancements in concrete science and construction technologies. Continuing this legacy, ACECON 2025 was centered on the theme “Concrete Innovations: Exploring Tomorrow's Frontiers”.

ACECON was recognized as one of Asia's most prestigious International Events in the field of Concrete Technology, Structural Engineering, and Sustainable Construction Practices. ACECON 2025 was supported by several prestigious Educational and Institutional partners, fostering collaboration and knowledge sharing across academia and Industry.

ACECON 2025 brought together over 500+ delegates and 21 distinguished plenary and keynote speakers from India, U.S.A., Canada, China, Italy and Australia. Also, there were 11 Invited Lectures from Industry Experts across the globe. Talks highlighted both global innovations and Indian-specific challenges, fostering discussions on latest research, technology and practical implementation. Altogether, a total number of 125

technical papers were presented in ACECON 2025 in various parallel sessions (18 sessions).

Overall, ACECON 2025 served as an excellent platform for knowledge dissemination, professional networking, and showcasing innovations in concrete technology. The conference significantly contributed to advancing discussions on sustainable and resilient construction practices aligned with future infrastructure needs.





# News From Centres

## ICI - Ahmedabad Centre

### Lecture on 'Engineering Excellence behind the World's Tallest Temple – 24,000+ m<sup>3</sup> Raft Casting'

On the eve of 29/11/2025, there was an inspiring lecture at GICEA on the planning and execution of the massive 24,000+ m<sup>3</sup> raft concreting, a 54-hour continuous operation recognized in the Golden Book of World Records.

Organized by GICEA with the support from ICI and Ambuja Cement, the session highlighted the visionary leadership of Shri.P.S.Patel, Managing Director & Chairman, PSP Projects Ltd., and the meticulous planning and teamwork behind this milestone.

Key Highlights of the project execution was :

- \* More than three months of planning and daily one-on-one discussions
- \* Robust strategies for logistics, temperature control, and uninterrupted concrete flow
- \* Flawless 54-hour execution

The session had a full house with more than 225 professionals attending, many standing, showing the enthusiasm and engagement of the engineering community.



## ICI - Bengaluru Centre

### 1.ICI-Bengaluru Centre – Ultratech Awards 2025

ICI-Bengaluru Centre – Ultratech Awards 2025 was held on Saturday the 27<sup>th</sup> of September 2025 at Sheraton Grand Bangalore Hotel at Brigade Gateway. Over 300 plus professionals from Construction Industry, Builders, Consulting Engineers, Architects, Academicians, Researchers, members of ICI and students attended this mega event. 'Dr. C. S. Viswanatha Memorial Lecture' 2025 on "Topic: 'Crafting landmarks where technology meets construction excellence'", was delivered by Er. M. V. Satish, which was very well received by the audience.

Er.H.R.Girish, Chairman ICI-Bengaluru Centre welcomed the gathering. President, ICI, Dr.V.Ramachandra, Presided over the function.





The following awards were presented :

1. Outstanding Concrete Engineer :  
Prof. J. M. Chandra Kishen
2. Emerging Concrete Engineer :  
Er.Vishwanath K Dalawai
3. Outstanding Concrete Dissertation :  
Er.Dany Devanesan D



Apart from this, Concrete Structures under various categories were presented including the Infrastructure Category for the Project Thin White Topping (TWT) of selected roads in Bengaluru city.



Vote of thanks was given by Dr.G.Narayana, Treasurer, ICI-Bengaluru Centre. He thanked all the ICI members and the Guest Speaker, Jury Members, Senior Members of ICI, Ultratech & team and coordinators of ICI-Bengaluru Centre, for conducting the program successfully.

## 2. One-Day Seminar on “Construction Chemicals / Admixtures for Durable Structures – Building Stronger, Smarter, Greener” :

ICI-Bengaluru Centre organized a One-Day Seminar on “Construction Chemicals / Admixtures for Durable Structures – Building Stronger, Smarter, Greener” on 24<sup>th</sup> October 2025

The Eminent Speakers and the topics were as follows :



Er.Mahesh Ashok Banda  
Topic: Curing Compounds:  
Smarter Alternative to Water curing



Er.Vinodh Kumar G  
Topic: Admixtures for Sustainable  
Construction



Er.V.R.Kowshika  
Topic: Contribution of Chemical admixtures and additives to Concrete industry



Er.R.K.Jaigopal  
Topic: Importance of Mineral Admixtures in Manufacture of Ultra High-Performance Fiber Reinforced Concrete.



Er.N.Venkates  
Topic: Practical aspects of use of Chemical and Mineral Admixture in RMC



Er.H.R.Girish  
Topic: Techno-legal Dimension to Construction Chemicals and Admixtures - Avoiding legal fall-outs.

Master of Ceremony Dr.Santhosh B.S., Hon. Secretary welcomed the dignitaries on the dais.

The essential aspects of “Construction Chemicals / Admixtures for Durable Structures – Building Stronger, Smarter, Greener” was highlighted by the Hon. Chairman Er.H.R.Girish.

The importance of Construction Chemicals / admixtures in various applications across Built Environment ranging from Buildings which include bathrooms, kitchens, balconies, decks, water tanks, swimming pools and to even green roofs to Infrastructure projects were deliberated in the seminar.





Dr.G.Narayana, Hon. Treasurer, thanked all the participants, Dignitaries, Speakers, Sponsors, Delegates, E.C. Members and Coordinators of ICI-Bengaluru Centre, for conducting the program successfully. The seminar witnessed 150 enthusiastic participants and the session was interactive. The program concluded with the National Anthem.

## ICI - Bhopal Centre

### ICI Awards

ICI-Bhopal Centre celebrated ICI awards in association with M/s.Ultratech on 29<sup>th</sup> November 2025. A Lecture on '2D and 3D Precast' was delivered by industry expert, Er.S.J.Vijay.



## ICI - Chennai Centre

### 1. Brainstorming Workshop on "Forensic Engineering: Investigating the Unseen – Building Bridges and other Infrastructures"

ICI-Chennai Centre conducted Two days' Brainstorming Workshop on "Forensic Engineering: Investigating the Unseen – Building Bridges and other Infrastructures" at ICI HQ Technology Centre on 26<sup>th</sup> and 27<sup>th</sup> September 2025. Dr.A.R.Santhakumar, Dr.Prof.Muttharam Mr.G.Sivakumar, Dr.V.Rajendran, Dr.Radhakrishna G Pillai, Dr.K.Muthumani, Er.C.Kalyanasundaram, and Er.Ravi Shankkar Subramaniam J., delivered lectures.



## 2.Signed MOU with VIT University :

An MoU was signed by the ICI-Chennai Centre on 16<sup>th</sup> October 2025 with VIT University.

The objectives of the MoU are to jointly organise corporate and field training programmes for construction personnel ; organizing National level competitions related to the field of concrete at the VIT Campus and facilitating industrial consultancy through the industry network of ICI.



## 3.ICI-RDC National Cube Test Competition Season 3 Culminates with Felicitation at SRMIST, Kattankulathur :

A grand felicitation ceremony celebrating the winners of the ICI-RDC National Cube Test Competition – Season 3 was held at Dr. T. P. Ganesan Auditorium, SRM Institute of Science and Technology (SRMIST), Kattankulathur on 1<sup>st</sup> November 2025.

Er.T.Archunan, Director (Projects), Chennai Metro Rail Limited (CMRL), graced the occasion as the Chief Guest and honoured the winners. Prof.C.Muthamizhchelvan, Vice-Chancellor, SRMIST, delivered an inspiring address to the participants and guests. The event also witnessed the presence of eminent concrete experts including Dr.V.Ramachandra, President, ICI; Er.Anil Banchor, Managing Director, RDC Concrete India Ltd; Er.R.Radhakrishnan, Secretary General, Indian Concrete Institute, Er.Vinay Gupta, Past President ICI and Er. Manoj Kawalkar, President (Elect) ICI, Er.Muralidharan N G, Chairman, ICI-Chennai Centre, Dr.Venkateswara Rao, Chairman, ICI-Hyderabad Centre along with other senior professionals and industry leaders.

In the Student Category, the team from Prasad V Potturi Siddharatha Institute of Technology emerged as the winner and received a cash award of 1,00,000, presented by Er. Archunan. The Professional Category was won by Chryso India Pvt Ltd, while Elan Concrete Private Limited bagged the top position in the Expert Category, each receiving a cash prize of ₹50,000. SRMIST Kattankulathur candidates participated in the event and also won runner up positions in both Students and Professional Category.

Er. Archunan, in his address highlighted the massive and ongoing infrastructure development across the country and urged aspiring civil engineers to remain grounded in the fundamentals of their discipline to ensure long-term career success. Further he appreciated the award ceremony focussing on recognising engineering professionals for their contribution in developing quality concrete products.

Prof.Muthamizhchelvan, Vice Chancellor, SRMIST urged industry partners, such as RDC, to provide continuous support by organizing similar competitions and events

across academic institutions, fostering practical exposure and collaborative learning opportunities for students.

Dr.V.Ramachandra, President, Indian Concrete Institute highlighted the growth of the institute with 50 centres across country with 400 student chapters, emphasised students to become members in ICI and gain the benefits.

Er.Vinay Gupta, Former President, ICI mentioned about high-performance concrete and students to be prepared in designing M150 Concrete and above.

Er.Radhakrishna, Secretary General, ICI highlighted the ways ICI Chennai Centre collaborate with industry partners along with academic institutions for the benefit of all stakeholders in concrete industry.

Er. Manoj Kawalkar, President Elect, ICI expressed ICI's keenness to collaborate between industry and institutions and Dr. Venkateswara Rao, Chairman, ICI Hyderabad Centre, invited the gathering to join forthcoming International ACECON 2025 to be held at Hyderabad during December 2025

Er. Anil Banchor, CEO & MD of RDC Concrete mentioned about the evolution of this competition over 3 years and appreciated ICI Chennai Centre for being the torch bearer in organising such intellectual competition motivating students.

Earlier, Er. Muralidharan N G, Chairman ICI Chennai Centre formally welcomed the gathering and expressed enthusiasm in making this as the 100<sup>th</sup> event of the centre by the existing executive committee.

Dr.PT Ravichadran, Head, Department of Civil Engineering, SRMIST proposed formal vote of thanks.

## ICI - Ghaziabad Centre

### 1. Annual General Meeting

The ICI-Ghaziabad Centre successfully organized its Annual General Body Meeting followed by Concrete Day 2025 Celebrations on 13<sup>th</sup> September 2025. The event witnessed around 170 enthusiastic participation from members, industry

leaders, technocrats, academicians, and professionals from the construction sector.

The AGM commenced with a welcome address by Er.Rahul Goel, Chairman, ICI-Ghaziabad Centre.

- Er.Vineet Bajaj, Hon. Secretary, presented the Annual Report highlighting the achievements, activities, and initiatives undertaken by the Centre during the past year.
- Er.J.K.Goel, Treasurer, presented the audited accounts of the Centre.
- Dr.Rajeev Goel, Ex-Vice President (North), ICI, addressed the gathering with insightful thoughts and guidance for future growth. The AGM concluded with a Vote of Thanks by Er.Arun Kumar, Vice Chairman.

### 2. Concrete Day 2025 Celebrations

The Concrete Day programme began with the welcome of dignitaries on the dais followed by presentation of plants to the Chief Guests, Keynote Speaker, and senior members of ICI-Ghaziabad Centre.

#### Keynote Session

The highlight of the evening was the Technical Talk delivered by Er.S.J.Vijay on "Ready Manufactured Buildings". He shared valuable insights on emerging trends, technical feasibility, sustainability aspects, and the future potential of prefab and modular buildings in India.

### 3. Awards & Felicitations

The event also featured the Annual Awards Ceremony to recognize outstanding contributions in the field of concrete technology in Western Uttar Pradesh.

**Award Recipients:**

Lifetime Outstanding Concrete Technologist – 2025 (Western UP):

- o Er.G.K.Sahu
- o Er.Manoj Mittal

Outstanding Concrete Technologist – 2025 (Western UP):

- o Er.Sushil Rajak

Outstanding Young Concrete Technologist – 2025 (Western UP):

- o Er.Vishal Kumar Yadav

**Outstanding Concrete Structure Awards – 2025**

The following projects were recognized under the Outstanding Concrete Structures category:

**Infrastructure Category:**

- Meerut Hapur Ganga Expressway

**Building Category:**

- Skycrest Tower, Sector 62, Noida

**4. Executive Committee Announcement**

The new Executive Committee for the term 2025–2027 was announced by Dr.Rajeev Goel, Ex VP (North), ICI, serving as the Returning Officer.

The formal programme concluded with a Vote of Thanks by Dr.Vineet Bajaj, Secretary, ICI-Ghaziabad Centre

**Networking & Fellowship**

The evening concluded with a fellowship dinner, which provided members and dignitaries an excellent opportunity to network, share experiences, and strengthen professional ties.



**ICI - Gurugram Centre**

**1. Concrete Day Celebrations:**

ICI-Gurugram Centre celebrated Concrete Day in association with M/s.UltraTech on 3<sup>rd</sup> October 2025 at Hotel Sunday, Gurugram. Keynote address was delivered by Er Vijay SJ (MRICS) on 'Manufactured RCC Buildings as a Product (BaaP)'

The following Awards were presented:

1. Lifetime Achievement
2. Outstanding Concrete Technologist
3. Best Institutional / Infrastructure / Industrial Concrete Structure
4. Innovative Residential Concrete Structure
5. Sustainable Homes (Cluster-wise)

Er.Subhas Balakumar, Director (Projects), Engineers India Ltd & Er.Sanjay Varshney, Executive Director, Signature Global were given Special Recognition.

**INDIAN CONCRETE INSTITUTE  
WISHES ALL ITS MEMBERS  
A HAPPY & PROSPEROUS NEW YEAR  
2026**

## ICI - Hubballi Dharwad Centre

### 1. ICI -UltraTech Awards 2025

ICI-Hubballi Dharwad Centre organised ICI-UltraTech Awards 2025 function on 29.10.2025 at Kalaburgi in association with UltraTech Cements Ltd. Dr.Siddaramappa S.Awati, Former Principal, PDA College of Engineering/Professor of Civil Engineering SDU Kalaburagi was the Chief Guest of the function.

Dr.V.Ramachandra, President, Indian Concrete Institute presided over the function. In his address, he highlighted the activities of the ICI and the importance of the event.

The Best Concrete Teacher for North Karnataka Award was presented to Dr.Suresh G.Patil. Prof.Shaik Md.Azam was given the Outstanding Engineer of North Karnataka Award. The Award for Outstanding Concrete Building was given to Mr.Mallek Bagwan for residential building category and Sharanara Ashirwad was given for Public building category.

Er.Suresh Kiresur, Vice-President of ICI-HUDC welcomed the gathering. Er.Shrihari K.H. proposed vote of thanks. More than 400 participants were present during the award function that included Engineers, Architects, Builders Owners, ICI Members and other dignitaries.



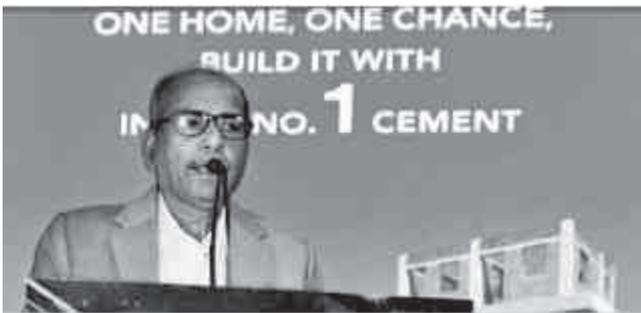
Felicitation to award winners.



Address by the Chief Guest Dr.Siddaramappa S.Awati

### 2. Site Visit

Civil Engineering students visited the UltraTech Cement (UTCL) Ginigera Grinding Plant on 21<sup>st</sup> November 2025, gaining valuable exposure to cement manufacturing processes, quality control systems, and sustainable material practices. The visit was coordinated by subject experts Dr.Veeresh Karikatti and Mr.Rajat Khodanpur, and was organized under the aegis of the ICI Hubballi-Dharwad Chapter, following the initiative taken under the UTCL-KLEIT Centre of Excellence.



Welcome Address by Er.Suresh Kiresur



Presidential address by Dr.V.Ramachandra



## ICI - Kakinada Centre

### 1. One Week Workshop on “Structural Designing Using ETABS” :

ICI-Kakinada Centre organized a “One Week Workshop on “Structural Designing using ETABS” between 6<sup>th</sup> and 11<sup>th</sup> October 2025 at Aditya University, Surampalem in collaboration with ACCE(I) Kakinada Centre & Aditya University. The Resource Person was Mr. Buri Dali Naidu, Technical Trainer, APSSDC. 46 Students participated in the Workshop which focussed on practical understanding of structural modeling and analysis using ETABS. Students gained hands-on exposure to real-time structural design workflow. Participants enhanced their structural analysis skills and developed confidence in using professional software tools.



### 2. Workshop on “Analysis of Structures using ETABS”

Workshop on “Analysis of Structures using ETABS” was conducted between 10<sup>th</sup> and 11<sup>th</sup> of October 2025 at Aditya University, Surampalem by ICI-Kakinada Centre in collaboration with ACCE (I) Kakinada Centre and Aditya University. Mr. Mohan Balaga, Structural Engineer, Genesis Planners Pvt. Ltd was the Speaker. Around 80 Students participated. This was a focussed training session introducing structural behaviour interpretation and result verification techniques using ETABS.

This session improved conceptual clarity on structural behaviour and system response interpretation.

### 3. Technical Webinar on 'Empowering Construction Stakeholders through Digital Construction Using BIM'

A Technical Webinar on 'Empowering Construction Stakeholders through Digital Construction Using BIM' was held on 26<sup>th</sup> October 2025 through Google Meet. Dr. Sunil Nandipati, Assistant Professor, Department of Civil Engineering, GITAM School of Technology, Visakhapatnam was the Resource Person. Around 74 participants- ICI Members, Engineers & Students were benefitted. The webinar highlighted the importance of digital workflows, collaborative modeling and BIM adoption in modern project execution. Participants understood BIM applications in project planning, coordination, and lifecycle documentation.



#### 4. Webinar on 'Design Principles of Formwork for Civil Structures' :

Prof.Dr.Badam Sundar Rao, from ICI-Kakinada Centre, delivered an insightful webinar on Design Principles of Formwork for Civil Structures on 16<sup>th</sup> November 2025. The session focused on the fundamental concepts, design requirements, and practical considerations involved in formwork systems used in modern construction.

During the webinar, he explained the functional role of formwork, types of materials commonly used, and the criteria for selecting appropriate formwork based on structural, safety, and economic factors.

The speaker also highlighted best practices for efficient formwork design, common challenges encountered at construction sites, and methods to ensure quality, durability, and safety.

Key topics included load considerations, pressure exerted by fresh concrete, stability requirements, and the importance of proper alignment and support systems.

Real-time case examples and field experiences shared by Prof. Dr. Sundar Rao provided participants with practical clarity on the subject.

The webinar was informative and enhanced the participants' understanding of formwork design methodology and its significance in achieving safe and efficient construction practices.

36 participants attended the programme.



#### 5. Training Programme on Artificial Intelligence (AI) in Civil Engineering :

A physical training program on AI Tools Related to Civil and Structural Engineering was organized by ICI-Kakinada Centre at Aditya University, Surampalem on 22<sup>nd</sup> November 2025. The session was delivered by Dr.T.Suman Kumar, Ph.D., and was aimed at practicing consulting civil engineers seeking to integrate modern digital tools into their professional practice.

The program provided an overview of the growing role of Artificial Intelligence in the civil engineering sector. Dr. Suman Kumar introduced participants to various AI-driven applications that support design optimization, structural analysis, project planning, material prediction, risk assessment, and quality monitoring.

Key highlights of the session included:

- ❑ Introduction to AI, Machine Learning, and Data-Driven Decision Making
- ❑ Use of AI tools for structural design, load prediction, and performance evaluation
- ❑ Case studies demonstrating improved accuracy, safety, and efficiency using AI-based systems

21 participants attended the programme.



## 6. Physical Training Program on AI Tools Related to Civil and Structural Engineering

On 29<sup>th</sup> November 2025, as a continuation of the previous session, ICI-Kakinada Centre organized another physical training program on AI Tools Related to Civil and Structural Engineering at Aditya University, Surampalem. This session was conducted by Dr.Yashwanth K. K., Ph.D., and was aimed at practicing consulting civil engineers interested in adopting advanced digital technologies in their professional work. Dr.Yashwanth provided an in-depth insight of artificial intelligence applications specifically tailored to structural analysis, design automation, and construction engineering. The session highlighted how emerging AI tools can support engineers in improving accuracy, productivity, and decision-making.

Key topics covered in the program included:

- Overview of AI frameworks used in civil and structural engineering
- AI-assisted structural modelling, load behaviour prediction, and optimization
- Applications of AI in failure detection, safety evaluation, and structural health monitoring
- Integration of AI tools with existing engineering software platforms



## 7. Training Programme on 'Building Information Modelling'

A Training on 'Building Information Modelling' by ICI-Kakinada Centre in association with ACCE (I) Kakinada Centre & Aditya University was conducted on 6<sup>th</sup> December 2025. The Resource Person was Dr.N.Sunil, Ph.D. Asst Professor, Civil Department, GITAM University and the venue was Computer Lab-8, Bill Gates Bhavan, Aditya University, Surampalem, Kakinada

21 Trainees participated in the programme.





## ICI - Kolkata Centre

### 1. Concrete Talk :

Concrete Talk was organized by ICI-Kolkata Centre in association with Adani Cement on 4<sup>th</sup> November 2025. 150 participants including Engineers, Architects, consultants, Chief & Superintending Engineers, attended the Concrete Talk. Er.Santanu Adhikari, Chairman, ICI-Kolkata Centre spoke on ICI activities and its contributions, followed by Vice-President (East) Er.Kaushik Bandyopadhyay on relevance of such events. Dr.Subhajit Saraswati presented on “Few Issues related to concrete Technology & Construction” and Dr.Anirban De, Professor, Manhattan University, New York presented on “Performance of Floodwalls during hurricane Katrina”. Participants had an excellent interaction during Q & A session.



### 2. Training Programme :

ICI-Kolkata Centre & Adani Cement organised Training of newly joined Junior Engineers who are posted at different Blocks, Panchayats of West Bengal at PRDA (Panchayat & Rural Development Agency) Training Centre, Kalyani. Dr.Dipesh Mazumdar, Professor of Jadavpur University also took session on concrete.



### 3. Lecture



Er.Shantanu Adhikari, Chairman, ICI-Kolkata Centre delivered lecture at the 8<sup>th</sup> Cementing India of Indian Chamber of Commerce, Kolkata on 02.12.25.

## ICI - Lucknow Centre

### Concrete Day Celebration :

ICI-Lucknow Centre celebrated Concrete Day on 13<sup>th</sup> September 2025. The Chief Guest was Er.Jitendra Kumar Banga, Retd. En C (HOD) and Advisor, Planning Department, Government of Uttar Pradesh and the Guest of Honour was Er.Vijay Kanaujia, Engineer-in-Chief (Project & Planning), UPPWD.

A Technical Session on the topic “High Rise-Tall Building Constructions” was delivered by Ar.Reza Kabul who has an extensive expertise with 37years in high-rise architecture. This session brought together over 130 technocrats from Lucknow.

This event was organized in collaboration with MP Birla Cement Group as the title sponsor, marking a significant milestone in the centre's commitment to advancing concrete technology and construction practices in the Northern India region.

The technical presentation comprehensively addressed the complexities and challenges associated with high-rise construction in the Indian subcontinent, with particular emphasis on:

- A. Environmental and Geographical Considerations
- B. Structural Engineering Aspects
- C. Building Systems and Services
- D. Sustainable Construction Practices
- E. Regulatory Compliance
- F. Design Integration



Address by Chief Guest Er.Jitendra Kumar Banga



Guest of Honour Er.Vijay Kanaujia



Inaugural address by Er.A.K.Singh



Lamp lighting by distinguished dignitaries

## ICI - Madurai Centre

### Technical Event on "Cold Formed Steel Building Systems: Opportunities and Challenges"

On 29/09/2025, Dr.M.Nithyadaran, Associate Professor, Department of Civil Engineering, IIT, Tirupati, gave a presentation on "Cold Formed Steel Building Systems: Opportunities and Challenges"

A brief introduction on cold formed sections covering manufacturing process, available shapes, etc., was presented.

The advantages of CFS building systems such as its light weight, ease of construction at site with low skill labourers, eco-friendly construction, etc., were highlighted.

The 3 types of framing viz., platform framing, platform framing with truss arrangement and ledge framing were explained. The floor system options, framing in floors and walls around openings, etc., were elucidated. Thumb rules usually adopted for spacing of studs, etc., were shared. Construction styles and load path in gravity and lateral load cases were presented. Alternatives available for sheathing and insulation were also discussed.

The technical presentation was followed by lively interaction.

## ICI - Nagpur Centre

### 1. Concrete Talk on "Low Carbon High Performance Concrete - Overcoming the Challenges in High Rise Infra Projects"

The Indian Concrete Institute-Nagpur Centre in association with Adani Cement, organized a Concrete Talk on "Low Carbon High Performance Concrete - Overcoming the Challenges in High Rise Infra Projects" on 26<sup>th</sup> November 2025. The program was well-attended by industry professionals, Government officials and members. The hall was brimmed with participants.



### 2. Workshop on 'Prestressed Concrete'

ICI-Nagpur Centre successfully hosted a One-Day Workshop on 'Prestressed Concrete' on 29<sup>th</sup> November 2025, with 105 participants.

The Chief Guest, Er.Sambhaji Shivaji Mane, Chief Engineer, PWD Nagpur Region and Guest of Honour, Er.Vinay Gupta, graced the occasion.

The workshop featured presentations by :

1. Er.T.V.Rudramoorthy
2. Er.Ramkumar S. L.
3. Er.Pushpam Kumar
4. Er.Seelam Prasad
5. Er.A.Sivaraman

The Executive Engineer, PWD, commended the workshop, providing positive feedback and requested ICI-Nagpur Centre to organize similar workshops on relevant topics.



lectures and was attended by over 100 participants, including students, faculty, and industry professionals. The event's success was greatly facilitated by the support of prominent institutional dignitaries and six industry sponsors.

The event was honoured by the presence of the Chief Guest Er.S.K.Mishra, IRSE, Retired Principal Chief Engineer from Indian Railways, Prayagraj.

Presiding Dignitaries were Prof.V.K.Srivastava, Officiating Director, MNNIT Allahabad and Prof.R.M.Singh, Head of the Civil Engineering Department, MNNIT Allahabad.

Following the Welcome Address by the Chairman and Secretary of the ICI-Prayagraj Centre, Prof.Srivastava and Prof.Singh addressed the gathering, emphasizing the importance of concrete technology in nation-building and academic research. The Chief Guest, Er.S.K.Mishra, then delivered his address, sharing insights from his long and distinguished career in the Indian Railways.

The event was structured around two highly informative technical sessions delivered by renowned experts, providing valuable knowledge to the attendees:

Technical Session I was by Prof.L.K.Mishra, Professor, Department of Civil Engineering, MNNIT Allahabad on the topic "Sustainable Concrete Practices" which covered advancements in materials and methodologies to achieve greater environmental responsibility in construction.

Technical Session II was by Er.Ghanshyam Dwivedi, Retired Chief Engineer, U.P. Jal Nigam on the topic "Retrofitting and Crack Repair in Structures."

Both sessions were extremely well-received. Following the presentations, an interactive doubt-clearing session was conducted, allowing participants to directly engage with the experts and clarify their queries, ensuring maximum knowledge takeaway.

The event concluded with a formal vote of thanks to the Chief Guest, all speakers, participating dignitaries, sponsors, and the enthusiastic participants for making the Annual Concrete Day 2025 a resounding success.

## ICI - Prayagraj Centre

### Concrete Day 2025 :

The Annual Concrete Day 2025 was successfully organized by the ICI-Prayagraj Centre at the Motilal Nehru National Institute of Technology (MNNIT Allahabad) on September 28, 2025. The event commenced at 6 p.m. in the Institute Seminar Hall and focussed on crucial contemporary topics in Civil Engineering. The program featured two expert keynote



## ICI - Puducherry Centre

### 1. Installation of New team of office bearers' :

New team of office bearers' were installed by Shri.R.Radhakrishnan, Secretary General, ICI-HQ. Chief Guest: Shri.V.P.Ramalingam, MLA ; and Dr.S.Kothandaraman, Professor and former Principal, Pondicherry Engineering College was the Guest of Honour. Around 450 guests attended the function.

Er.N.J.L.Ramesh @ Ashhirwaad Ramesh took over the charge as Chairman for 2025–2027 along with his team of office bearers.



## 2.Mason Training Programme

Mason Training Programme was conducted at Motilal Nehru Government Polytechnic College along with Adani Cements on 14<sup>th</sup> August 2025. Around 50 masons and 20 students participated in the event. Theory and practical classes were conducted. Certificates of participation were issued to all the participants.



## ICI - Salem Centre

### 1.Workshop on "Building A Sustainable Future with Cement and Concrete: Best Practices

ICI-Salem Centre in association with UltraTech RMC organized a Workshop on "Building a Sustainable Future with Cement and Concrete: Best Practices" on 08.10.2025 at Department of Civil Engineering, Mahendra Engineering College, Namakkal. 55 participants, including civil engineering students and professionals were present. Er.M.A.Joseph, AGM Marketing, UltraTech RMC, North TN, was the Chief Guest and Resource Person. Er.K.Kumaraguruparan, Chairman, ICI-Salem Centre was the Guest of Honour.

Workshop focussed on :

- Understanding the behaviour of concrete under different environmental and load conditions
- Discussing common challenges faced during concreting in real-time construction projects
- Best practices for mixing, placing, compacting, and curing concrete to ensure high-quality, durable results
- Importance of safety measures and quality control during concreting operations

Emphasis on sustainability and eco-friendly practices in the use of cement and concrete



## 2.Site Visit to RMC Plant in Salem

ICI-Salem Centre in association with UltraTech RMC undertook a Site Visit to RMC Plant in Salem on 08.10.2025.



The site visit to the RMC plant provided participants with an opportunity to observe the practical application of the best practices discussed in the workshop.

A technical expert from UltraTech RMC conducted the session, explaining the RMC production process, quality control measures, and the role of technology in ensuring efficient and sustainable concrete production.

Participants about 55 in number were able to see firsthand how concrete is manufactured, tested and transported for large-scale construction projects.

## 3.Technical Seminar on “Influence of AI in the Construction Industry” :

ICI-Salem Centre in association with Perumal Manimekalai College of Engineering organized a Technical Seminar on “Influence of AI in the Construction Industry” on 24.10.2025 Chief Guest and Resource Person was Dr.V.Balaji Subbramanian, Vice-Chairman, ICI-Salem Centre.

The Seminar focused on :

- Exploring the rapidly growing influence of Artificial Intelligence (AI) on the construction industry.
- Discussing how AI is transforming key aspects of construction from project design to execution and management
- AI's role in enhancing productivity, reducing costs, improving safety and optimizing decision-making in construction projects and
- Analyzing the integration of AI technologies in automation, smart construction sites, and predictive maintenance



Key Topics covered were :

- AI in project design and planning, including the use of generative design tools.
- AI's role in project management, such as predictive analytics for cost and schedule optimization.
- The growing use of robots, drones, and autonomous vehicles in construction for site monitoring and automation.
- How AI enhances safety through real-time monitoring, risk prediction, and quality control.
- Sustainability in construction driven by AI's ability to optimize material use and energy efficiency

The target audience was the Civil engineering students and faculty members.

## ICI - Warangal Centre

### National Conclave on 'SPACE-2025' (Sustainable Practices and Advances in Civil Engineering) :

The National Conclave on SPACE-2025 (Sustainable Practices and Advances in Civil Engineering) was successfully held on 26<sup>th</sup> & 27<sup>th</sup> September 2025 at Sri Sathya Sai Convention Centre, Warangal. The event was jointly organised with the Association of Consulting Civil Engineers (India) – ACCE(I), Warangal Centre.

The conclave aimed to bring together engineers, architects, builders, academicians, industry experts, researchers, and students to explore the latest advancements, sustainable solutions, and emerging technologies shaping the future of civil engineering.

The conclave was inaugurated by the Chief Guest Dr.V.Suresh, Chairman, National Building Code (NBC) of India, an eminent leader known for his contributions to sustainable and safe built environments.

Keynote Speakers & Expert Resource Persons were :

- Dr.V.Suresh, Chairman NBC, New Delhi.
- Dr.R.Siva Chidambaram, Scientist, CSIR-CBRI, Roorkee.
- Dr.Suriya Prakash, Professor of Civil Engineering, IIT Hyderabad

- Dr.P.Rathish Kumar, Professor of Civil Engineering, NIT Warangal
- Dr.C.V.Shiva Ram Prasad, CEO, Global Research Academy
- Er.C.A.Prasad, Director, Metry Engineering Consultancy
- Smt.Deepika Vaishnav, Founder, Expert RERA Services
- Dr.Debasish Sanyal, Professor of Architecture, NIT Raipur

These experts delivered technical lectures on material innovation, structural resilience, digital construction, RERA compliance, research advancements, and sustainable engineering methodologies.



The Conclave was a remarkable success, achieving its objective of providing a comprehensive platform for learning, collaboration, and professional development. The combined efforts of ACCE(I) and ICI Warangal Centres, along with the support of national office bearers,

industry partners, and academic institutions, made the event impactful and memorable.

The conclave set a strong foundation for future initiatives in sustainable engineering, research advancement, and industry-academia synergy.

# News From Student Chapters

## Jadavpur University

### Lecture Session

Under the initiative by ICI-Students Chapter of Jadavpur University, a lecture session was organized on 23.11.2025 by Dr.Anubhav Roy, Stanford University, the Resource Person. Prof.Debashis Bandopadhyay, Prof.Kaushik Bandopadhyay and Prof.Subhajit Saraswati were also present.



### 2. Construction Site Visit at Jewel by Samurai

A construction site visit was organized for the 3rd-year students to provide practical exposure to real-world construction activities. The visit took place on 29<sup>th</sup> September 2025 to a 2B+G+18 storeys Residential Tower under construction. The site is located in the Nirman Nagar area of Jaipur.

The objective was to identify and recall key construction materials, equipments, and safety protocols observed on-site ; to explain the functions of various construction elements, site layouts, the roles of professionals involved

## Poornima College of Engineering, Jaipur

### 1.Value-Added Course on SketchUp Software

Value-Added Course on SketchUp Software was organized by the Department of Civil Engineering, Poornima College of Engineering, Jaipur in association with Indian Concrete Institute (ICI) during 22<sup>nd</sup> September 2025 – 26<sup>th</sup> September 2025.

in the project ; to Demonstrate the ability to assess site safety measures relate theoretical knowledge to real-world construction processes and to evaluate construction methodologies, project management strategies, and career opportunities through interaction with site personnel.

The site visit to Jewel by Samurai provided valuable hands-on experience and helped students to connect their academic learning with field applications. The exposure to various construction phases enhanced their technical understanding, problem-solving skills, and professional awareness. Such visits play a crucial role in shaping future civil engineers by offering practical insights into the industry.

Dr.Vishal Singhal was the Co-Ordinator.



### 3. Construction Site Visit to Altitude, Hare Krishna Marg, Jagatpura, Jaipur :

Construction Site Visit to Altitude, Hare Krishna Marg, Jagatpura, Jaipur was organised on Tuesday, the 30<sup>th</sup> September, 2025. Mr.Mohit Kumar Tiwari was the Faculty Coordinator.

The objective of the visit was to provide students with practical exposure to on-site construction practices and techniques. It aimed to bridge the gap between theoretical knowledge and real-world applications by observing structural components, construction methodologies, materials used, and safety measures. The visit also intended to enhance understanding of project management, quality control, and the role of engineers in executing civil engineering works.

The interaction with site professionals enhanced understanding of practical problem-solving, teamwork, and site management techniques essential for a civil engineer.



## Swami Keshvanand Institute of Technology, Management & Gramothan (skit), Jaipur

### 1.ICI FEST 2025

The Indian Concrete Institute (ICI) Student Chapter of Swami Keshvanand Institute of Technology, Management & Gramothan (SKIT), Jaipur successfully organized the ICI Fest 2025 from 26<sup>th</sup> to 28<sup>th</sup> September 2025 in collaboration with the Bureau of Indian Standards (BIS). The FEST witnessed overwhelming enthusiasm and emerged as one of the largest student-driven civil engineering festivals in India, attracting a record participation of 5010 students from more than 10 engineering colleges across Rajasthan and neighbouring States. The event was envisioned as a platform to nurture innovation, creativity, and industry-academia interaction while reinforcing the importance of quality and sustainability in civil engineering practice.



The FEST commenced on 26<sup>th</sup> September 2025 with a grand inaugural ceremony that set a highly motivating tone for the three-day celebration. The Chief Guest and Keynote Speaker, Mr.Anoop Bartariya, renowned Architect and Urban Planner, delivered an inspiring address on the significance of design innovation and sustainable planning in shaping modern cities. The Guests of Honour included Mr.Manoj Kawalkar, President Elect, Indian Concrete Institute; Mr.Surjaram Meel, Chairman, SKIT; and Mr.Jaipal Meel, Director, SKIT, whose words of encouragement inspired students to excel in their professional and technical pursuits.



The first day also featured several captivating events such as Joist Kwik – Bridge Making, Brick-o-Brick – Masonry Challenge, Tower Craft – Structural Stability Competition and CAD Mania, testing students' conceptual knowledge, creativity, and analytical skills. The highlight of the day was the Panel Discussion titled “Nirmaan Mein Navachaar”, featuring Mr.P.D.Goel, Managing Director, Goel Constructions, Mr.Sunil Jain, Managing Director, Akshat Apartments, Mr.Anand Wardhan Agarwal, Director, Meluha Newinfra Pvt. Ltd. (MNPL) and Mr.Manoj Kawalkar, President Elect, Indian Concrete Institute. The

discussion emphasized the emerging trends in construction technology, digital design, and entrepreneurship opportunities for civil engineers. These hands-on competitions allowed participants to translate classroom learning into practical structural solutions.

The second day, 27<sup>th</sup> September 2025 was dedicated to the BIS Standards Carnival and Industry Conclave, organized in collaboration with the Bureau of Indian Standards (BIS). This segment aimed to promote quality awareness, standardization, and adherence to BIS Codes in construction. The day began with a formal inauguration by Mr.V.K.Singh, Senior IPS Officer and Additional Director General, SOG & SIT, as Chief Guest. The event was further adorned by the presence of Mr.D.R.Meghwani, Secretary, Public Works Department, Government of Rajasthan; Ms.Shuchi Sharma, Ex-IAS Officer; and Ms.Kanika Kalia, Director and Head, BIS Rajasthan. Each of them shared valuable insights on the role of innovation, integrity, and quality assurance in modern infrastructure development.



The carnival witnessed participation from 44 leading industries that showcased construction materials, technologies, and sustainable practices through exhibitions and live demonstrations. In addition to the carnival, students enthusiastically participated in Quiz

Competitions, Debate, Essay Writing, and the Best out of Waste Challenge, each encouraging critical thinking, communication, and creative reuse of materials. The Drone Workshop added a modern dimension to the event, familiarizing students with aerial surveying and mapping techniques relevant to the industry.



The third day, 28<sup>th</sup> September 2025, marked the culmination of the festival with the Valedictory Ceremony and the much celebrated "Run for Quality" Walkathon, which drew participation from over 1000 students and professionals. The Walkathon, organized in association with BIS, was aimed at promoting public awareness about the importance of quality and safety in construction. The morning witnessed a spirited environment as students carried banners and messages advocating sustainable development and responsible engineering. Another major highlight of the day was the 24-hour Hackathon "InnovIClon", a flagship event of ICI FEST, where student teams worked relentlessly to develop innovative solutions to real-world engineering challenges. The Hackathon encouraged multidisciplinary collaboration and creative problem-solving aligned with the Smart Infrastructure and Sustainable Construction themes. In addition, Scavenger Hunt and Model United Nations (MUN) added a refreshing cultural and strategic aspect, demonstrating teamwork and leadership among the participants.



The Valedictory Ceremony honoured winners of various competitions, recognized exceptional performers, and extended gratitude to all stakeholders for their immense contribution to the success of the event. Certificates and prizes were distributed to winners and organizing teams. Dignitaries and invited guests appreciated the collective efforts of the ICI Student Chapter and the SKIT faculty for successfully hosting such a grand event. The fest also received widespread media coverage across multiple newspapers, highlighting its scale and student-led execution.



In conclusion, ICI FEST 2025 proved to be a landmark event that strengthened the bond between academia and industry while inspiring future engineers to embrace innovation, sustainability, and quality as guiding principles. The event not only reflected the academic and technical excellence of SKIT Jaipur but also reinforced the institute's commitment to promoting experiential learning and leadership among students. The organizing committee acknowledges the support of Indian Concrete Institute Headquarters, Bureau of Indian Standards, SKIT Management, and all participating institutions and industries for making the event a resounding success.

## 2. Rethinking Roads 2025

The Department of Civil Engineering and Centre of Excellence in Transportation Engineering at Swami Keshvanand Institute of Technology, Management & Gramothan (SKIT), Jaipur, successfully organized a two-day Conclave & Conference on "Rethinking Roads 2025" in collaboration with Muskaan NGO, ICI and IGBC.

The event was inaugurated by Padma Shri Maya Tandon, in the presence of eminent guests Mr.V.K.Singh (ADGP, Law & Order, Rajasthan), Mr.Manoj Bhatt, Chairman, Muskaan Foundation & former DGP, Rajasthan, Mr.Ramashankar Pandey, Chairman, FICCI Road Safety Committee and Dr.Vishal Thombare, Dy. Chief Engineer, BMC, Mumbai.

Experts from JDA, PWD, RSRDC, World Bank, RTO, academia, and industry shared valuable insights on enhancing road safety and sustainability.

Key takeaways included the importance of early road safety education, behavioral change, robust pre-hospital care, use of sustainable materials in road construction, and the development of advanced driver training centres.

Gratitude to all speakers, partners, and participants for contributing to this initiative towards safer and smarter roads for the future.



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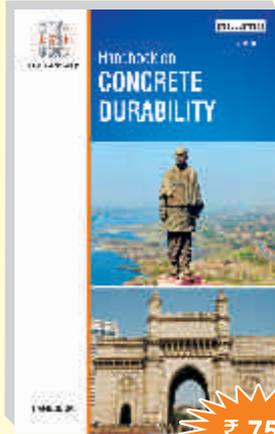


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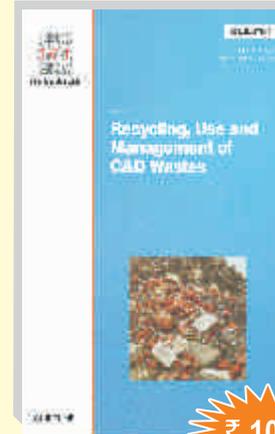
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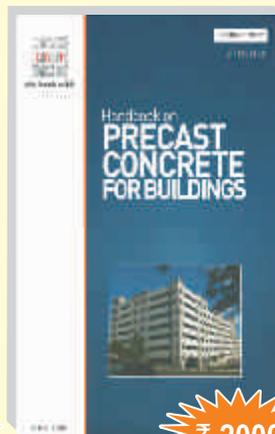
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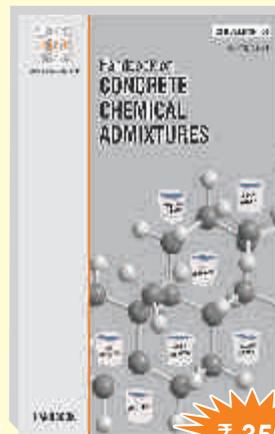
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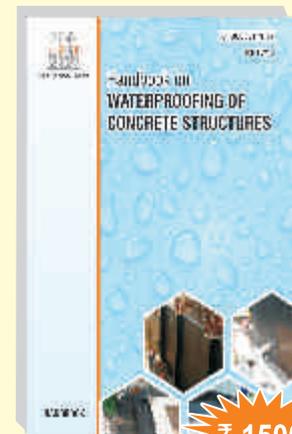
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