Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

EPS Panels in Modern Construction: A Study on Advanced Techniques and Sustainable Acoustic Design

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Abstract - Expanded Polystyrene (EPS) panel technology has emerged as a sustainable and high-performance alternative to conventional masonry and reinforced cement concrete (RCC) construction systems. This study presents a comprehensive evaluation of EPS panel structures with emphasis on structural behavior, thermal efficiency, acoustic performance, and construction efficiency under Indian site conditions. A phased research approach is adopted to examine material characteristics, construction practices, and testing methodologies. The results indicate that EPS panel systems achieve 40–50% faster construction time, as reported by BMTPC (2020), offer approximately 25% improvement in thermal insulation, and contribute to a significant reduction in embodied energy when compared to conventional RCC construction, demonstrating their potential as an efficient and sustainable building system.

Keywords - EPS Panels, Sustainable Construction, Shotcreting, Acoustic Performance, Structural Design, Thermal Efficiency, IS Codes.

I. INTRODUCTION

The construction industry in India is rapidly adopting prefabricated and lightweight building systems to achieve faster delivery, cost efficiency, and sustainability. EPS panel technology, originally developed in Italy in the 1980s, has evolved into a reliable structural system that integrates a polystyrene core with galvanized steel wire mesh and cementitious shotcrete layers.

Despite widespread international adoption and proven structural performance, the application of EPS panel construction in India requires systematic evaluation and contextual adaptation. This research aims to develop a structured framework for the design, testing, and implementation of EPS panel structures suited to Indian construction practices and environmental conditions.

II. LITERATURE REVIEW

Expanded Polystyrene (EPS) panel systems have gained significant attention in modern construction due to their lightweight nature, structural efficiency, and enhanced thermal and acoustic performance. EPS panels typically consist of a low-density polystyrene core sandwiched between welded galvanized steel wire meshes, which are subsequently coated with cementitious shotcrete to form a composite structural element.

Savić and Branković (2018) investigated the flexural and load-bearing behavior of EPS core sandwich panels and reported that the composite action between the EPS core and shotcrete layers provides adequate stiffness and strength for low- to mid-rise buildings. Their study confirmed that EPS panels exhibit ductile failure modes and satisfactory load distribution, making them suitable for seismic applications. Similarly, Murali et al. (2019) studied the mechanical properties of EPS-based lightweight concrete and observed a considerable reduction in self-weight while maintaining acceptable compressive strength, contributing to reduced foundation loads.

Thermal performance is one of the primary advantages of EPS panel construction. Hawileh (2017) evaluated the thermal efficiency of EPS-insulated wall systems and concluded that EPS panels significantly reduce heat transfer compared to conventional masonry walls. Pavlík (2020) further examined the acoustic insulation properties of EPS-based panels and reported sound transmission loss values ranging between 45–55 dB, indicating effective noise reduction in residential and commercial buildings. These properties make EPS panels particularly suitable for urban environments with high thermal and acoustic demands.

Fire performance and safety aspects of EPS panels have also been widely studied. Frangi et al. (2014) analyzed the fire behavior of EPS sandwich panels and found that, when adequately protected with cementitious coatings, EPS panels can achieve fire resistance ratings comparable to traditional wall systems. The study emphasized the importance of proper detailing and fire-resistant finishes to prevent EPS core exposure during fire events.

From a sustainability perspective, Al-Hosni and Al-Maashri (2020) conducted a life-cycle assessment of EPS construction systems and reported a significant reduction in embodied energy and carbon emissions compared to brick masonry and reinforced concrete systems. Ashby (2010) highlighted that lightweight materials such as EPS contribute to sustainable construction by minimizing material consumption and improving energy efficiency over the building lifecycle. UNEP (2019) also emphasized the role of innovative building materials like EPS in achieving global sustainability and green building objectives.

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III. METHODOLOGY

The methodology adopted in this study follows a combined experimental and field-based research approach to evaluate the structural, thermal, acoustic, and sustainability performance of Expanded Polystyrene (EPS) panel construction systems under Indian site conditions. The study framework consists of material characterization, laboratory testing, on-site performance assessment, and comparative analysis with conventional reinforced concrete (RCC) and brick masonry systems. This phase evaluates the mechanical and environmental performance of EPS panels through laboratory and field data comparison.

Property	EPS Core	Wire Mesh (Galv. Steel)	Shotcrete Layer
Density	15–25 kg/m³	7800 kg/m³	2200 kg/m³
Compressive Strength	0.2–0.4 MPa	—	25–40 MPa
Thermal Conductivity	0.036 -0.48 W/mK	—	1.4 W/mK
Fire Rating	Self-extinguishing (Class E)	—	1 hour (IS 3809)
Sound Transmission Loss	45–55 dB	—	—

Table 1: Typical Material Properties of EPS Panel Components

Parameter	EPS System	RCC Structure
Avg. Construction Speed	10 m²/hr	3 m²/hr
Labor Requirement	40% less	—
Curing Time	3–7 days	14 days
Weight per m²	70 kg	250 kg
Thermal Resistance (R-value)	2.8 m²K/W	0.45 m²K/W

Table 2: Site Performance Comparison (EPS vs RCC)

3.1 Code Compliance and Standardization

- EPS panels comply with Indian building standards to ensure safety, durability, and consistent construction quality.
- Structural design is guided by **IS 456:2000**, covering concrete design and reinforcement detailing.
- Load considerations follow **IS 875 (Part 1–5)** for dead, live, wind, and other loads.
- Seismic design uses **IS 1893**, ensuring stable performance in earthquake-prone regions.
- Materials used (cement, sand, shotcrete) conform to **IS 383**, **IS 2386**, and **IS 516** for strength and testing.
- Fire performance is checked as per **IS 3809 / NBC fire chapter**, ensuring safe occupancy.

Functional Aspect	Relevant IS Code	Adaptation for EPS
Structural Design	IS 456 (2000)	Design equivalent for shotcrete layer
Seismic Design	IS 1893 (2016)	Wall–panel joint detailing for lateral loads
Concrete Mix Design	IS 10262 (2019)	Use of micro-fibers and polymer modifiers
Admixtures	IS 9103 (2021)	Water-reducing agents for shotcrete
Fire Safety	IS 3809 (1979)	Fire-rating test on EPS wall assemblies

Table 3: IS Code Integration

3.2 Thermal Conductivity Test of EPS

The thermal performance of the EPS panels was evaluated using the Heat Flow Meter Method (ASTM C518-21) at a mean temperature of 50 °C. Five samples of varying densities (15, 20, 25 kg/m³) and thicknesses (30, 60, 90 mm) were tested at PSGTECHS COE Indutech Laboratory, Coimbatore, India.

-Test Results

The measured thermal conductivity (λ) values and corresponding thermal resistance (R-values) are summarised in Table 5.

S.No	K Avg (Time)	Sample Description	Mean Temp (Deg C)	Delta Temp (Deg C)	Thermal conductivity W/m-k	Thermal resistance M² *k/w
1.	00.49 Min	15 density - 30mm	50	10.0	0.043193	0.784063
2.	00.48 Min	20 density - 30mm	50	10.0	0.040741	0.794355
3.	00.47 Min	25 density –30mm	50	10.0	0.038344	0.846009
4.	00.58 Min	15 density –60mm	50	10.0	0.045538	1.343111
5.	01.12 HR	15 density –90mm	50	10.0	0.047142	1.955268

Table 5: Thermal Conductivity of EPS Samples (ASTM C518-21)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

-Interpretation of Results

Thermal conductivity decreases as density increases **(15 → 25 kg/m³)**, indicating better insulation at higher densities.

Increasing thickness results in higher R-values, improving thermal resistance as expected.

The measured λ-values fall within the typical performance range for EPS insulating materials **(0.036–0.048 W/m·K)**, confirming suitability for energy-efficient wall systems.

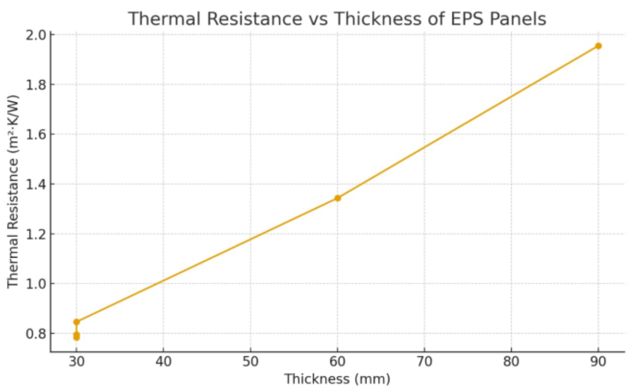

Fig. 1: Relationship between EPS panel thickness and thermal resistance.

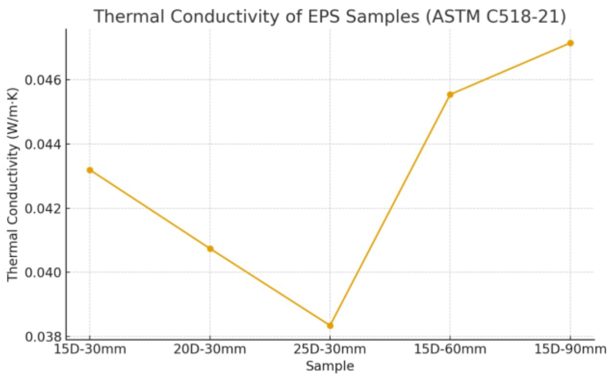

Fig. 2: Thermal conductivity of EPS (ASTM C518-21)

3.3 Tensile Strength Test of GI Wire (2.5 mm Dia)

Detailed tensile strength test report for 2.5 mm GI wire, tested at PSGTECHS COE INDUTECH LABORATORY (Report No. COE/25-26/AUG/15374)

No.	Specimen ID	d_0 mm	F_{max} MPa	dL at break mm
1	GI - WIRE - 1	2.5	865	5.0
2	GI - WIRE - 2	2.5	898	8.1
3	GI - WIRE - 3	2.5	895	6.8
4	GI - WIRE - 4	2.5	862	9.1
5	GI - WIRE - 5	2.5	897	11.6
6	GI - WIRE - 6	2.5	891	9.0

Table 6: Test Result Data

Series n = 6	F_{max} MPa	F_{Break} MPa
$\bar{x}$	885	731
s	16.5	80.7
v	1.87	11.05

Table 7: Statistics

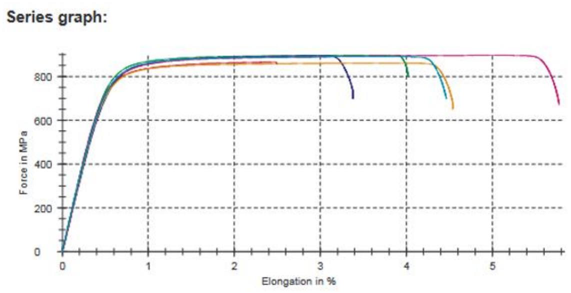

Fig. 3: Series Graph

- Interpretation of Results

The tensile test results show that the 2.5 mm GI wire has high and consistent tensile strength, with Fmax values between 881–898 MPa and a very low variation (1.87%). This indicates uniform material quality. The elongation at break (5.0–11.6 mm) confirms good ductility, meaning the wire can deform safely before failure. Overall, the GI wire is mechanically reliable and suitable for use as reinforcement in EPS panels, providing both strength and flexibility required for construction applications.

3.4 Execution Efficiency and Quality Control Characteristics of EPS Panel Construction

- Systematic Workflow:

EPS panel construction follows a well-organized and sequential workflow due to the use of prefabricated panels with standardized dimensions. This allows clear planning of erection, service integration, shotcreting, and finishing activities, ensuring smooth coordination between different construction stages.

- Ease of Execution:

The lightweight nature of EPS panels enables easy handling, positioning, and alignment with minimal lifting equipment. The simplified installation process improves labor productivity and supports faster construction progress even under limited site constraints.

- Reduced Construction Complexity:

The EPS panel system integrates structural, insulation, and surface finishing functions within a single construction element. This eliminates conventional masonry work, extensive formwork, and repetitive shuttering, resulting in a simplified and efficient construction process.

International Journal of Engineering Research & Technology (IJERT)
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- Quality Control Advantages:

Factory-manufactured panels provide consistent geometry and reinforcement detailing, contributing to uniform structural performance. On-site quality control is enhanced through controlled shotcrete application, ensuring consistent thickness, proper bonding, and improved durability of the composite system.

3.5 Structural Behavior and Load Response Characteristics of EPS Panel Systems.

- Composite Structural Action:

EPS panel systems exhibit effective composite action between the polystyrene core, galvanized steel wire mesh, and shotcrete layers. The interaction of these components results in a monolithic structural element capable of distributing applied loads uniformly across the panel surface.

- Load Transfer Mechanism:

Vertical and lateral loads are efficiently transferred through the shotcrete skins and wire mesh reinforcement, while the EPS core contributes to stability by maintaining spacing and continuity between the structural layers. This mechanism enhances overall load-bearing efficiency.

- Ductile Response Behaviour:

EPS panel structures demonstrate a ductile load response characterized by gradual deformation under increasing load. The presence of steel wire mesh reinforcement supports energy dissipation and controlled deformation, contributing to structural reliability under service and extreme loading conditions.

- Crack Development Characteristics:

Under load, micro-cracks tend to develop in a distributed and progressive manner within the shotcrete layer. This controlled crack pattern indicates effective stress redistribution and composite behaviour, preventing sudden or localized distress.

- Energy Absorption Capacity:

The EPS core, in combination with reinforced shotcrete skins, enhances the energy absorption capability of the panel system. This characteristic is particularly beneficial in resisting dynamic and lateral loading, contributing to improved structural resilience.

- Joint and Connection Performance:

Properly detailed panel-to-panel and panel-to-slab connections ensure structural continuity and integrity. These connections facilitate effective load sharing and maintain overall stability of the EPS panel structural system.

- Serviceability Performance:

EPS panel structures demonstrate satisfactory serviceability characteristics, including controlled deflections and stable performance under normal occupancy loads. The composite configuration supports long-term structural functionality and comfort.

3.6 Performance Considerations for Effective Implementation of EPS Panel Systems.

- Design Integration:

Effective performance of EPS panel systems is achieved through proper integration of architectural and structural design. Early coordination ensures optimal panel layout, accurate opening placement, and efficient load transfer across structural elements.

- Connection Detailing:

Attention to panel-to-panel and panel-to-structural element connections enhances continuity and composite action. Well-detailed joints contribute to uniform load distribution and overall structural stability.

- Shotcrete Application Quality:

Uniform and controlled application of shotcrete on both faces of EPS panels ensures consistent thickness, proper encapsulation of wire mesh reinforcement, and improved surface integrity. This practice supports long-term strength and durability of the system.

- Curing and Surface Protection:

Adequate curing of the shotcrete layer enhances material performance and durability. Appropriate surface finishes and protective coatings further contribute to environmental resistance and long-term serviceability.

- Construction Coordination:

Coordinated execution among structural, mechanical, and electrical works enables seamless integration of services within the EPS panel system. This approach reduces rework and enhances construction efficiency.

- Workmanship and Execution Practices:

Skilled handling, accurate alignment, and systematic installation of panels promote consistent construction quality. Adherence to recommended execution practices supports reliable structural and functional performance.

- Long-Term Performance Assurance:

The composite configuration of EPS panels, combined with proper detailing and execution, contributes to stable long-term performance, making the system suitable for sustainable and modern construction applications.

Fig. 4: Panel Erection

Fig. 5: Shotcreting

Fig. 6: Finishing

IV. Results and Discussion

The integrated study confirms that EPS panel systems can achieve structural, thermal, and acoustic performance suitable for Indian climatic and seismic zones. Their high energy efficiency, lower embodied carbon, and rapid construction process support their adoption in affordable and sustainable building programs. Laboratory testing and field performance evaluation demonstrate the technical feasibility and performance advantages of EPS panel construction systems when compared with conventional RCC and brick masonry structures. The results highlight improvements in construction efficiency, thermal performance, structural reliability, and overall sustainability.

V. CONCLUSION

EPS panel construction demonstrates strong potential as a next-generation building system for India. It ensures speed, strength, safety, and sustainability. Field validation and experimental results justify its structural reliability and long-term durability.

VI. FUTURE SCOPE

- Long-term durability and weathering studies under Indian climatic variations.
- Development of seismic performance equations specific to EPS walls.
- Fire-resistant EPS formulations using halogen-free additives.
- Integration with BIM and digital twin tools for lifecycle monitoring

ACKNOWLEDGMENT

I would like to express my sincere gratitude to **Mr. Sinic K. S., MD of Hikae Equs**, for providing the opportunity, resources, and constant support that enabled me to carry out this research work. His encouragement and leadership have been instrumental throughout this study.

I am deeply thankful to **Dr. Alein J. S., Structural Engineer (Ph.D.)**, for her expert guidance, valuable insights, and continuous support. Her technical understanding of EPS panel behavior and advanced structural design significantly enriched the quality of this research.

I also extend my appreciation to **Ms. Anila A, Civil Engineer (M.Tech Renewable Energy)** for her practical inputs, on-site assistance, and valuable contributions during data collection and analysis.

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