PFS Panel [Perlite Filled System Panel]

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Abstract - Scholarly articles exploring Perlite Filled System (PFS) panels, also known as Perlite-based insulation panels, focus on their thermal performance, mechanical properties, and applications in building construction. They investigate the use of perlite, a naturally occurring volcanic rock, as a lightweight aggregate in concrete or other composite materials to create insulation panels with good thermal resistance.

This paper investigates the development of geopolymer foam boards using perlite wastes as raw material. The combination of geopolymerization technology with the foaming process creates a new type of lightweight material. Our results show that the increase in hydrogen peroxide concentration leads to improved thermal insulation properties. The developed perlite-based thermal insulation panels exhibit low density, high thermal resistance, and potential for use in energy-efficient buildings. This study demonstrates the feasibility of utilizing perlite wastes in the production of sustainable building materials.

This project draws inspiration from the concept of circular economy — turning waste into resources — and aims to create a sustainable solution by developing a composite insulation panel using: OPC Cement as the primary binder,
Fly ash as a pozzolanic and eco-friendly filler,
Perlite ore for its excellent thermal insulating properties,
Shredded printed receipts to repurpose hazardous, non-recyclable waste,And jute fibers for reinforcement and improved structural integrity.The resulting PFS Panel not only offers competitive thermal insulation, fire resistance, and soundproofing, but also helps to significantly reduce environmental burden. It is a promising step toward green building materials that are cost-effective, durable, and eco-conscious. This project focuses on experimental validation of the panel's strength, fire performance, thermal efficiency, and overall viability as a replacement for synthetic insulation products

Key Words:PFS Panel [Perlite Filled System Panel] geopolymer,geopolymerization

1.Introduction

In recent years, the construction industry has faced increasing pressure to shift toward sustainable, environmentally friendly, and low-carbon building materials. Traditional insulation panels, such as PUF (Polyurethane Foam) panels, although effective in thermal insulation, are derived from petroleum-based chemicals and are known to emit toxic gases when burned, contributing significantly to environmental pollution and health risks. Additionally, these panels are relatively expensive and non-biodegradable, raising concerns about their long-term impact on ecosystems.

Simultaneously, the world is witnessing an ever-growing crisis of non-recyclable waste, particularly thermal printed receipts. These receipts are coated with chemicals like BPA or BPS, making them unsuitable for conventional recycling and extremely harmful when disposed of in landfills or incinerated. This not only contributes to waste accumulation but also releases harmful toxins into the environment. This project draws inspiration from the concept of circular economy — turning waste into resources — and aims to create a sustainable solution by developing a composite insulation panel using:
OPC Cement as the primary binder, Fly ash as a pozzolanic and eco-friendly filler, Perlite ore for its excellent thermal insulating properties, Shredded printed receipts to repurpose hazardous, non-recyclable waste, And jute fibers for reinforcement and improved structural integrity.The resulting PFS Panel not only offers competitive thermal insulation, fire resistance, and soundproofing, but also helps to significantly reduce environmental burden. It is a promising step toward green building materials that are cost-effective, durable, and eco-conscious. This project focuses on experimental validation of the panel's strength, fire performance, thermal efficiency, and overall viability as a replacement for synthetic insulation products.

2.Methodology

For this dissertation work it is proposed to carry out the work in the following phases.
Phase I : Detection of Non- recyclable material.
Phase II : Check for material usage in other fields.
Phase III: Find out the product in which the non- recyclable material can be used.
Phase IV: Find the other materials to use in mixture.
Phase V : Comparison of the product with traditional product.
Phase VI: Market survey of material availability, rates and costing and proportioning of materials.

Phase VII: Making model.
Phase VIII: Conducting tests on the product and making final product .

Benefits of PFS Panel:

1)Eco-Friendly & Sustainable: Made from natural and waste materials like fly ash and shredded receipts, reducing landfill load and pollution.

2)Excellent Fire Resistance: Can withstand temperatures up to ~600°C, far higher than conventional panels.

3)Cost-Effective: Uses low-cost and locally available materials, making it affordable for large-scale use.

4)Waste Utilization: Provides a practical use for non-recyclable thermal paper, fly ash, and other industrial waste.

5)Good Flexural Strength: Reinforced with jute fibers, the panel resists cracking and maintains structural integrity.

6)Moderate Sound & Moisture Insulation: Offers basic insulation benefits due to perlite and fiber content.

7)Supports Circular Economy: Promotes the reuse of waste into functional construction products.

4.Limitations of PFS Panel

1)No BIS/ASTM Standards Yet: Being a new concept, it lacks formal approval under standard building codes.

2)Limited Long-Term Testing: Still under development; durability over decades is not fully proven.

3)Moisture Sensitivity: May absorb water if not coated/sealed properly, affecting strength over time.

4)Heavier than Foam Panels: Due to cement and fly ash content, it’s less lightweight than PUF or EPS panels.

5)Handling of Thermal Paper Waste: If not processed correctly, BPA/BPS in receipts may pose health/environmental concerns.

6)Scaling Challenges: Industrial production methods for this panel are not yet standardized

5.Properties of PFS Panel

Material	Purpose in the Panel
OPC Cement	Acts as the primary binder, provides strength, and holds the entire mix together.
Fly Ash	Enhances workability, reduces cement usage, improves durability, and supports sustainability.
Perlite Ore	Provides excellent thermal insulation and makes the panel lightweight.
Shredded Printed Receipts	Reuses non-recyclable thermal paper waste, contributes to fire resistance and bulk.
Jute Fiber	Acts as natural reinforcement, prevents cracks, and improves flexural strength.
Water	Required for hydration and proper bonding of all components.

6.Results

a)Flexural Strength Test:

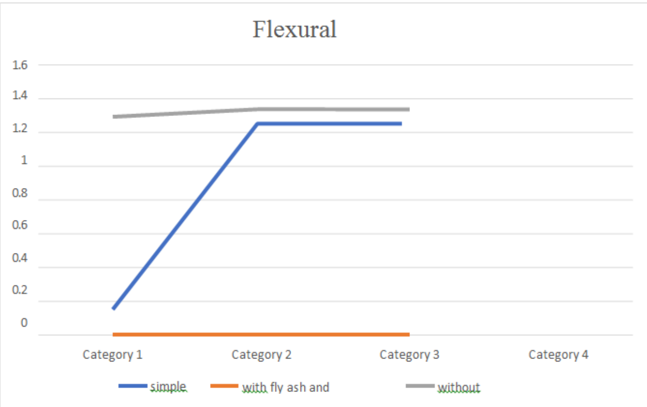

Fig a.Results of Flexural Strength Test

The result of the flexural strength tests differ due to changes of materials in the product made as following:

i)Color variation defines the material changes as following:

Blue color indicates that product contains OPC Cement, Perlite, Jute Fiber, Printed Receipts etc.

Orange color indicates the product also contains fly ash and hardener.

Gray color indicates that the product is without hardener and ony contains OPC Cement, Perlite, Jute Fiber, Printed Receipts and Fly Ash etc.

ii)The above color variations shows the results as follows:

Samples in the Blue color line give the average results of 0.899 N/mm2.

Samples in the Orange color line failed gaining strength due to usage of hardener it broke even in 3 days of curing.

Samples in the Gray color line gave the best average results of

1.32 N/mm2.

iii)The categories in the chart say the sample calculation as follows:Samples casted with the materials indicated in the color wise categories in the chart has 3 samples each.

b)Fire Spread test by perlite quantity variation:

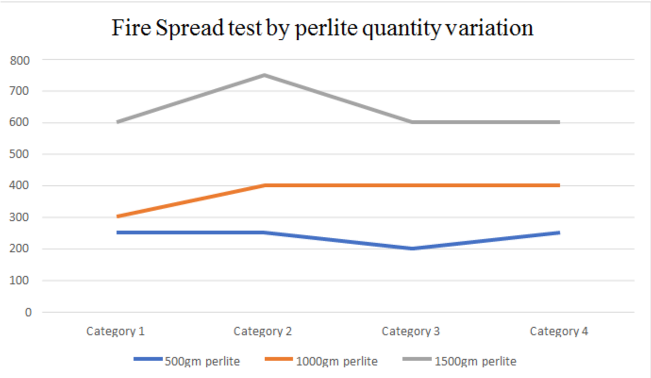

Fig b.Results of Fire Spread Test

The result of the Fire Spread tests differ due to changes of materials in the product made as following:

i)Color variation defines the material changes as following:
Blue color indicates that product contains 500 gm Perlite ore.
Orange color indicates the product contains 1000 gm Perlite ore.
Gray color indicates that the product contains 1500 gm Perlite ore.

ii)The above color variations shows the results as follows:
Samples in the **Blue color** line give the average results of 237.50 C.
Samples in the **Orange color** line 3750 C.
Samples in the **Gray color** line gave the best average results of 637.50 C.

iii)The categories in the chart say the sample calculation as follows:
Samples casted with the materials indicated in the color wise categories in the chart has 4 samples each.

7.Cost Efficiency of both Panels [i.e. PUF and PFS Panels]

a)Material Costing of PUF Panel [Polyurethane Foam Panel]

Material	Rate (INR/kg)	For 1 sq.ft. (approx. in kg & INR)	For 1 sq.m. (approx. in kg & INR)
Polyol + Isocyanate	190	0.6 kg / □114	6.5 kg / □1235
Adhesive/Bonding Agent	150	0.02 kg / □3	0.25 kg / □38
Fire Retarders	250	0.01 kg / □3	0.1 kg / □25
Blowing Agents (e.g., Pentane)	80	0.01 kg / □1	0.1 kg / □8
Total	-	Rs. 121	Rs. 1306

Material Costing of PUF Panel [Polyurethane Foam Panel]

b)Material Costing of PFS Panel (Perlite Filled System Panel)

Material	Rate (INR/kg)	For 1 sq.ft. (approx. in kg & INR)	For 1 sq.m. (approx. in kg & INR)
OPC Cement	7	1.0kg/ □7.00	10.75 kg/ □75.32
Fly Ash	0.83	0.5 kg/ □0.415	3.85 kg/ □3.20
Perlite Ore	20	1.5 kg/ □30	5.39 kg/ □107.6
Printed Receipts (shredded)	0	0.05/ □0.00	0.18 kg/ □0.00
Jute Fiber	80	0.05 kg/ □4	0.54 kg/ □43.2
Total	-	□41.415~ 42	□229.32~ 230

Material Costing of PFS Panel [Perlite Filled System Panel]

8.Future Scope of the Panel:

With the growing emphasis on sustainability and eco-conscious construction practices, the PFS Panel holds great promise for expansion and innovation. Its ability to convert non-recyclable and industrial waste into a functional, fire-resistant insulation product opens up numerous possibilities for future development. The following points highlight the broader scope and potential applications of this concept:

1)Industrial-Scale Production: Scaling up from lab prototype to mass production for commercial buildings, warehouses, and prefabricated structures.

2)Standardization & Certifications: Getting certified under BIS, ASTM, or ISO standards for thermal insulation, fire resistance, and mechanical strength.

3)Integration with Green Building Programs: Can be2 promoted under LEED, GRIHA, or IGBC ratings for eco-friendly construction.

4)Replacement for PUF Panels: With improved fire resistance and sustainability, it can serve as a non-toxic alternative to traditional polyurethane foam panels.

5)Material Research & Development: Further R&D can explore other non-recyclable wastes (like X-ray films, multilayer food wraps) to improve properties.

8 .Conclusion-

The PFS Panel project successfully demonstrates a sustainable, low-cost, and eco- friendly alternative to conventional PUF panels. By innovatively utilizing non-recyclable waste materials like printed thermal receipts, fly ash, perlite ore, and jute fibers, this panel not only addresses environmental challenges but also delivers enhanced fire resistance, better flexural strength, moisture resistance, and soundproofing qualities. With its potential to reduce landfill waste and carbon footprint while promoting green construction practices, the PFS Panel holds significant promise for future applications in residential, industrial, and commercial insulation solutions. This project stands as a step forward in the journey toward circular economy and sustainable building materials.

9. Referance

1)IS 3812 (Part 1): 2003 – Fly Ash for Use in Cement and Concrete: This standard defines the chemical and physical requirements for fly ash used as a pozzolanic material. It supports the use of fly ash in reducing cement content while improving strength, durability, and workability of concrete — a core component of the PFS panel.

2)IS 12436:1988 – Rigid Polyurethane Foam for Thermal Insulation – Specification: Establishes performance characteristics for PUF insulation panels, which serve as a benchmark to compare the thermal conductivity, fire behavior, and density of the PFS panel as an alternative.

3)ScienceDirect – Topic: Perlite: Research articles on ScienceDirect detail perlite's performance as a thermal insulator. Expanded perlite is shown to resist temperatures >850°C and is widely used in fireproof plasters and insulation boards, making it ideal for PFS panel integration.

4)Construction and Building Materials Journal (Elsevier): Multiple studies highlight the effectiveness of incorporating waste materials and industrial byproducts (such as paper pulp, agricultural fibers, and fly ash) into cementitious composites to improve sustainability and reduce construction costs.

5)NTPC Fly Ash Utilization Report (National Thermal Power Corporation): Demonstrates the large-scale generation and potential utilization of fly ash in construction products. Promotes the use of fly ash in bricks, panels, and precast elements to minimize landfill dependency and CO_2 emissions.

6)Environmental Protection Agency (EPA) – Hazard Assessment of BPA in Thermal Papers: Identifies printed receipts as a source of BPA, a hazardous compound. While unsafe in open disposal, encapsulating thermal paper in cementitious material (like in the PFS panel) can prevent leaching and environmental contamination.

7)BMTPC (Building Materials and Technology Promotion Council) Reports: Promotes alternative building technologies using lightweight aggregates, natural fibers, and waste materials. Encourages pilot projects that demonstrate fire resistance and energy efficiency — key targets of the PFS panel.

8)IS 3346:1980 – Method for Thermal Conductivity of Thermal Insulation Materials: Standard testing procedure to measure and compare thermal conductivity. Helps benchmark the insulation value of the PFS panel versus conventional systems like PUF and EPS.

9)IS 15498:2004 – Specification for Precast Concrete Wall Panels: Provides general guidelines for design, performance, and testing of precast wall panels, which can serve as a foundation for future standardization of the PFS panel.

10)Journal of Hazardous Materials – Utilization of Non-Recyclable Paper Waste in Cement: Confirms that embedding chemically coated papers in cement matrices stabilizes them and minimizes toxic release, aligning with the PFS panel's use of thermal receipts.