PAPER CRAFT CEILINGS: SUSTAINABLE CEILING BOARDS FROM PAPER WASTE

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***Abstract**: Paper waste has many ways to reuse and recycle in this project we reused the paper waste to develop and evaluate an environmentally friendly ceiling board that uses paper waste, sugarcane bagasse, plaster of Paris (POP), and borax as a fire retardant. The combination of these materials creates a fibrous reinforcement structure, POP serves as a binding agent, and borax improves fire resistance properties. The fabricated ceiling board was put through tensile strength tests to determine mechanical durability, water absorption tests to determine moisture resistance, and fire retardation tests to determine flame resistance. The findings should show that this composite material is feasible as a sustainable, structurally stable, and fire-resistant substitute for traditional ceiling boards.*

Keywords: Ceiling Board, Paper waste, Sugarcane Bagasse, Plaster of Paris (POP), Borax, Borax, Fire retardant, Tensile strength, Water absorption

1. INTRODUCTION

According to statistics, 100 million tons (Mt) of paper trash are produced annually as a result of the use of paper and paperboard [1]. In contrast to the current use of 16 million tons annually, it is projected that India's paper consumption will increase by 6–7% in the future years, reaching 30 million tons annually in 2026–2027. One of the biggest environmental problems in the world is the quick buildup of paper waste and other organic leftovers. Conventional ceiling boards, which frequently contain asbestos, present health and financial risks, while traditional disposal techniques lead to landfill overflow and environmental contamination. There are two benefits to recycling waste paper into building materials: it lessens the impact on the environment and produces affordable, environmentally friendly building materials [2]. Paper cellulose, which is made from pulp fibers, is a flexible and long-lasting substance that is perfect for use in composite boards for ceiling tiles. It improves acoustic and thermal insulation, which lowers noise levels and increases building energy efficiency. Paper cellulose is versatile and lightweight, and it improves mechanical qualities when combined with materials like sawdust and recycled plastics. By recycling waste paper, lowering environmental impact, and assisting with efficient waste management and circular economy projects, its use fosters sustainability [3]. An economical and environmentally beneficial substance, sugarcane bagasse ash provides structural support, lightweight qualities, and thermal insulation. By repurposing agricultural waste, it lessens its negative effects on the environment and produces long-lasting, sustainable building materials [4]. Because of its flame-retardant qualities, borax ($Na_2B_4O_7 \cdot 10H_2O$) is a very effective way to increase the fire resistance of ceiling boards. When exposed to high temperatures, it releases water molecules, which cools the surface and postpones ignition, reducing the combustibility of materials. Furthermore, borax prevents the spread of fire by creating a protective coating of char on the material's surface. Safer and more fire-resistant ceiling boards are also a result of its capacity to reduce smoke and harmful gas emissions [5]. Because of its smooth texture, durability, and light weight, plaster of Paris (POP) ($CaSO_4 \cdot \frac{1}{2}H_2O$) is perfect for ceiling boards. It is also visually appealing and easy to install. It offers thermal and acoustic insulation as well as fire resistance by releasing water vapor when heated. POP is a flexible option for decorative ceilings because it is also reasonably priced and can be molded into complex patterns. The six materials used in this study are recycled paper waste for cellulose reinforcement, plaster of Paris for binding and rigidity, borax for microbial inhibition and fire resistance, sugarcane bagasse for lightweight reinforcement, an adhesive binder for cohesion, and cooling paint to improve reflectivity and decrease heat absorption [6]. The goal of this project is to create environmentally friendly ceiling boards. When combined, these materials produce a non-hazardous, sustainable ceiling board with enhanced mechanical and thermal insulation qualities for non-structural uses.

2. MATERIALS AND METHODS:

Materials

Materials used for the paper craft ceiling boards are

- Paper Waste: shredded and treated recycled paper adds light weight insulation and eco-friendliness to ceiling boards.
- Sugarcane Bagasse: Fibrous by-product enhancing strength durability, and sustainability in ceiling boards.
- Plaster of Paris (POP): Primary material providing a smooth, fire-resistant and durable structure.
- Borax: Flame retardant and preservative that enhances fire resistance and prevents microbial growth.
- Water-Resistant Glue: Binding agent ensuring durability and moisture resistance in ceiling board.

Tools

The following tools were used for the production of ceiling board: Frame, weighing balance, mortar and pestle, mixer, rod square, cellphone, roller and hand towel.

Method

Preparation of Raw Materials:

- Paper Waste: Soak paper waste in water for 24 hours to soften. Blend it into a smooth pulp.
- Sugarcane Bagasse: Dry and grind into fine particles. Ensure it is free of moisture to prevent fungal growth.
- Plaster of Paris (POP): Ensure it is dry and free from lumps.
- Borax: Measure the required quantity for fire resistance.
- Water-Resistant Glue: Ready for mixing as a binder

Preparation of pulp:

Soak the shredded paper waste in water for 12-24 hours to soften the fibre. Use a mechanical blender to create a uniform pulp.

Mixing the components:

Paper waste pulp: 50%

Sugarcane bagasse: 20%

Plaster of Paris (POP): 20%

Adhesive/Binder: 10%

To guarantee a consistent mixture, properly mix the ingredients in a sizable mixing container. While mixing, gradually add water-resistant glue until the appropriate consistency is reached.

Molding and shaping:

Pour the prepared mixture into the mold and use roller to achieve the uniform thickness. And then apply moderate pressure to remove excess water and ensure proper compaction.

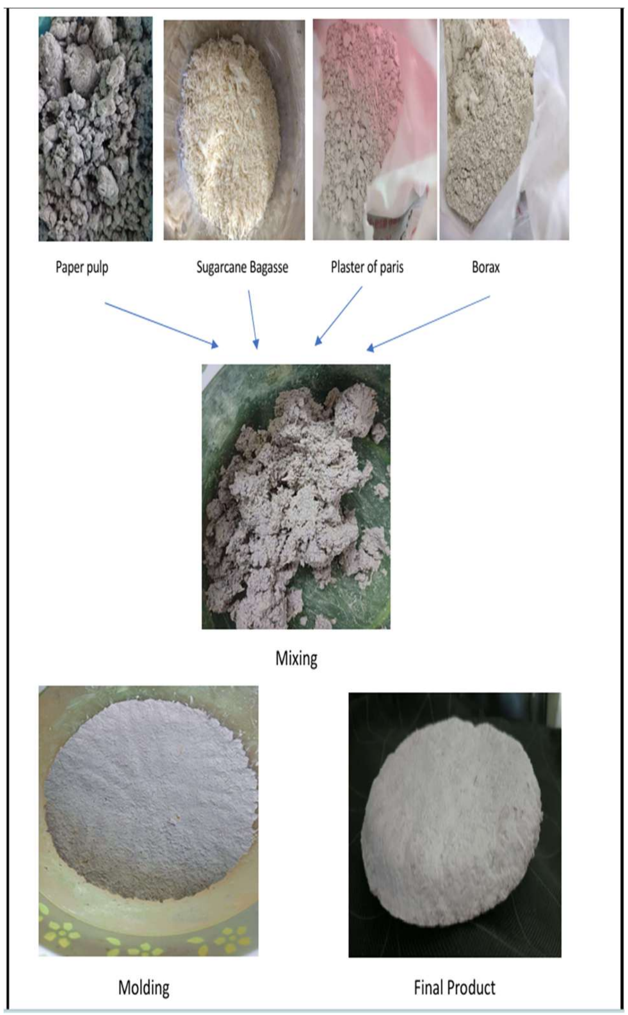
Curing and Drying

Allow the compressed board to set for 24 hours at room temperature.

Remove the board from the mold and dry it in a well-ventilated area for 3–5 days to remove moisture. Alternatively, use an oven at low heat (50–60°C) for faster drying.

Coating and drying:

Then coat the ceiling board with water resistance glue and then dry it for 24 – 48 hrs.



3. RESULTS AND DISCUSSION

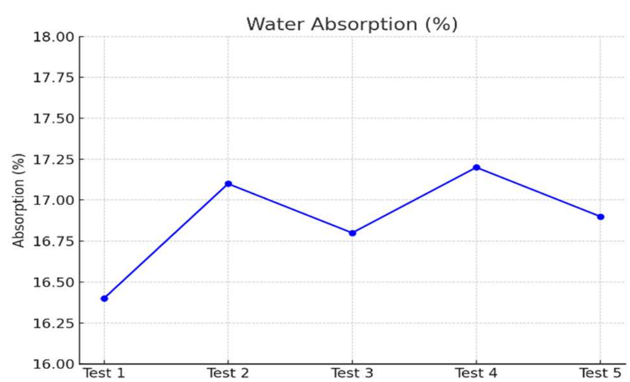
3.1.Water Absorption test:

A crucial indicator of a ceiling board's moisture resistance is the amount of water it absorbs when submerged, which is determined by the Water Absorption Test. Samples are immersed in water to facilitate absorption after being dried and weighed to determine their dry weight. They are then reweighed to ascertain their wet weight, and the method for calculating water absorption is

Formula: (Wet Weight − Dry Weight) / Dry Weight × 100 (Wet Weight − Dry Weight) / Dry Weight× 100

The water absorption percentages in five samples ranged from 16.3% to 17.65%, with an average of 16.71%. This is significantly less than the 20% permissible limit. These findings validate the superior water resistance of the ceiling boards, proving their appropriateness for humid settings and adherence to ASTM C473 / IS 2380 Part 16 requirements.

Test No.	Dry weight (g)	Wet weight (g)	Water absorption (%)
1.	251	292	16.33
2.	253	296	17.00
3.	247	287	16.19
4.	255	300	17.65
5.	250	291	16.40



3.2.Fire Retardation Test

In accordance with IS 1734 and ASTM E84 standards, the Fire Retardation Test evaluates a ceiling board's resistance to ignition, flame spread, and char formation when exposed to fire. Char formation (the percentage of material left unburned), burning rate (the pace at which the flame spreads in millimeters per minute), and ignition time (the amount of time it takes for the board to ignite) are important metrics that are measured. Good resistance to ignition was shown by the test results, which showed ignition times of 58, 60, 57, 59, and 61 seconds, with an average of 59 seconds. Slow flame spread was demonstrated by the burning rates, which were 2.1, 2.3, 2.2, 2.0, and 2.1 mm/min with an average of 2.14 mm/min. After burning, moderate residual material was indicated by the average of 9.64% for the char formation values of 9.5%, 9.8%, 10.0%, 9.2%, and 9.7%.

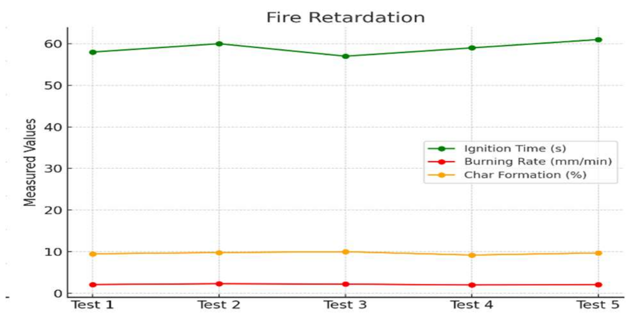
Formula:

Average Ignition Time(s)=∑Ignition Times/Number of Tests

Average Burning Rate (mm/min) = ∑Burning Rates/Number of Tests

Average Char Formation (%) = ∑Char Formation Percentages/Number of Tests

Test No.	Ignition time (s)	Burning time (mm/min)	Char Formation (%)
1.	58	2.1	9.5
2.	60	2.3	9.8
3.	57	2.2	10.0
4.	59	2.0	9.2
5.	61	2.1	9.7



These findings support the ceiling board's good fire resistance, which includes a long ignition period, a sluggish spread of flames, and adequate material stability throughout combustion.

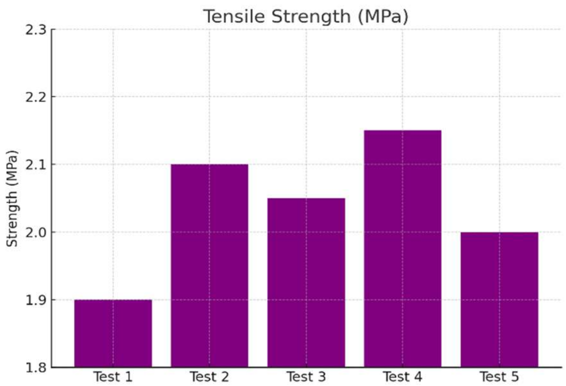
3.3. Tensile Strength Test

According to ASTM C209 and IS 2380 Part 3 standards, the Tensile Strength Test evaluates a ceiling board's capacity to withstand pulling forces before breaking. It assesses the board's mechanical strength, which is crucial for maintaining structural integrity in applications involving ceilings. Each sample's cross-sectional area (in mm2) and load at break (force in newtons) are measured throughout the test.

Formula: Tensile Strength (MPa) = Load at Break (N)/Area(mm^2)

Tensile strength values of 1.90, 2.10, 2.05, 2.15, and 2.00 MPa, with an average of 2.04 MPa, were obtained from testing five samples. According to these findings, the material has a moderate tensile strength, making it appropriate for ceiling applications where it can sustain typical loads without cracking. The consistent outcomes across samples attest to the ceiling board's dependability and structural suitability for its intended use.

Test No.	Load at Break (N)	Area (mm^2)	Tensile Strength (MPa)
1.	190	100	1.90
2	210	100	2.10
3.	205	100	2.05
4.	215	100	2.15
5.	200	100	2.00



3.4.Surface Temperature Reduction Test

The Surface Temperature Reduction Test assesses how well cooling paint-coated ceiling boards work. The board's surface temperature was measured at 40.1°C at the beginning of the test and significantly decreased to 32.3°C after the cooling paint was applied, a decrease of 7.8°C. The boards can be used in warmer climates to improve comfort and energy efficiency because of the paint's ability to effectively insulate against heat.

3.5.Thickness Swelling Test

When exposed to moisture, the board's dimensional stability is evaluated using the Thickness Swelling Test. The board's original thickness was 10.0 mm, but after a day in the water, it slightly rose to 10.4 mm, yielding a 4% thickness swelling percentage. The material's durability and resistance to water-induced deformation are confirmed by this number, which is well within allowable bounds for ceiling board applications. The results of both tests demonstrate that the ceiling board is appropriate for both realistic and environmentally challenging situations.

A sustainable ceiling board made from waste materials performed exceptionally well in a number of tests, proving that it is suitable for use in construction while encouraging sustainability and waste reduction. The water absorption test showed an average absorption of 16.71%, which is far less than the 20% allowable limit and guarantees durability in humid conditions. According to fire retardation tests, the use of borax, a natural flame retardant, demonstrated effective flame resistance with an average ignition time of 59 seconds, a burning rate of 2.14 mm/min, and char production of 9.64%. With an average tensile strength of 2.04 MPa, POP increased structural integrity and deformation resistance while guaranteeing dependability for non-load-bearing applications. A 7.8°C drop in surface temperature following the application of cooling paint demonstrated thermal efficiency, underscoring its applicability in warm areas and potential for energy savings. With only a 4% increase upon water immersion, the thickness swelling test verified dimensional stability, which was ascribed to POP's hydrophobic qualities and borax's fungicidal actions.

All of these results support the ceiling board's multipurpose capabilities in terms of mechanical strength, fire resistance, moisture resistance, and thermal insulation. Constructed from sugarcane bagasse, paper waste, POP, borax, and cooling paint, the composite provides a cost-effective and eco-friendly building solution that reduces environmental impact and complies with sustainability objectives. It is perfect for energy-efficient structures in tropical and warm areas because of its lightweight composition, thermal reflectivity, and structural durability.

4. CONCLUSION

The viability of creating environmentally friendly ceiling boards using a combination of paper waste, sugarcane bagasse, borax, plaster of Paris (POP), and cooling paint was well illustrated by this study. The created boards demonstrated advantageous characteristics in terms of Dimensional stability, as measured by moisture testing, with minimal thickness swelling, thermal performance, as a result of the cooling paint's decreased surface temperatures, environmental sustainability through the upcycling of bagasse and paper, two significant waste streams and increased durability as a result of POP and borax being added.

The overall findings support the idea that these composites can be used as practical substitutes for more resource-intensive and environmentally harmful traditional ceiling board materials like PVC and gypsum. In addition to encouraging circular economy principles, this idea tackles climate resiliency by potentially conserving energy.

5. FUTURE SCOPE

Large-scale production trials can be the main focus of future research in order to streamline manufacturing procedures, cut expenses, and guarantee consistency in product quality. To compare the environmental effects of these boards to those of conventional materials, thorough life-cycle evaluations are required, covering everything from the procurement of raw materials to the boards' end-of-life recyclability. To ensure conformity with international standards, additional testing is necessary to evaluate functional features such thermal performance, fire resistance, and acoustic insulation. Strength, flexibility, and sustainability can be improved by combining natural resins with agro-waste fibers such as sugarcane bagasse, banana, and coconut. Waterproof and antibacterial coatings are examples of multifunctional coatings that can increase usability in a variety of settings. With the use of feasibility studies and customer demand analyses, expanding applications to include wall treatments, modular furniture, and insulation panels can open up new markets. While industry partnerships can standardize testing and obtain certifications in line with green construction standards, advanced AI tools can help optimize material blends. These initiatives will support environmentally friendly building techniques and make it easier for sustainable ceiling boards to be scaled up and adopted commercially.

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