# DEVELOPMENT OF BIODEGRADABLE COMPOSITE MATERIAL FROM RICE STUBBLE USING NATURAL BINDER

**Ishaan Kauhaad**

*Learning Paths School*

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**Abstract -** *Rice-stubble burning is a major environmental concern contributing significantly to release of particulate matter in the air and greenhouse gas emissions. Despite policy interventions, waste management remains a challenge due to limited economically feasible alternatives. The study presents development of biodegradable composite material from rice stubble using low-cost easily available natural binders. Multiple ways and binder systems were experimentally evaluated including hot water treatment, acid and alkali pretreatments and various natural binders. Early formulations suffered from many problems such as brittleness, uneven drying and poor reproducibility. Through systematic improvements a composition comprising alkali-treated finely ground rice stubble combined with tamarind powder (imli powder) as a natural binder and chalk powder as a hardening agent was developed. The developed material demonstrated mutability in its uncured state, enabling fabrication into different shapes. Following curing the composite hardened into a rigid structure with improved surface finish and mechanical stability.*

***Key Words***: **rice-stubble, agro-waste utilization, natural binders, biodegradable composite, sustainable material**

## 1. INTRODUCTION

Rice cultivation substantial quantities of post-harvest residue commonly known as rice stubble. In many regions particularly in northern India this residue is burned frequently to rapidly clear fields for subsequent cropping cycles. Crop residue burning releases large amounts of PM-2.5 and PM-10 particulate matter and greenhouse gases, resulting in severe seasonal air pollution and adverse health and environmental impacts [1].

Transforming agricultural waste into value added materials represents a promising approach to mitigating residue burning while simultaneously supporting sustainable material development. Natural fibre-waste composites derived from agro-waste such as bagasse, bamboo and hemp have been extensively studied [8],[9]. However rice stubble remains unutilized due to its high silica content, lignin-rich structure and processing challenges [3].

This research aims to develop a low-cost, biodegradable composite material using rice stubble and naturally derived binders. The study focuses on enhancing fiber pretreatment, binder selection, and curing behavior to achieve acceptable mechanical integrity and reproducibility while maintaining sustainability.

## 2. MATERIALS AND METHOD

### 2.1 Raw Material Preparation

Rice stubble was collected from local agricultural sources. This stubble was manually cut into small segments to facilitate chemical treatment and grinding.

### 2.2 Preliminary Processing and Early Formulations

Initial trials involved soaking in hot boiling water for at least 12 hours in order to soften the fibres, followed by mechanical grinding to form a fibrous paste. Wheat flour and cornstarch were added as binding agents and water was used to attain a semi-solid structure. The mixture was manually compressed using a mechanical compressor into a flat surface and sun-dried for approximately 24 hours.

### 2.3 Chemical Pretreatment Trials

To enhance the softening of fibres, chemical pretreatment was also considered. Initially dilute hydrochloric acid was employed; however, reaction with starch binders(cornstarch) caused paste solubility and low compressibility. Later sodium hydroxide (NaOH) was employed because of its ability to decompose lignin and enhance fibre compatibility [4], [5]. The cut rice stubble was treated with NaOH solution for at least 12 hours and then washed with water to remove alkalinity.

### 2.4 Binder and Hardener Optimization

To enhance sustainability and strength, food based binders (wheat flour) were replaced. Calcium Carbonate ($CaCO3$) commonly known as chalk powder was added as a hardening agent and cornstarch was kept as a temporary binder. Although this formulation produced harder samples, surface cracking and inconsistent reproducibility was observed across batches.

### 2.5 Final Composite Formulation

Cornstarch was replaced by tamarind (imli) powder because of its hygroscopic nature and controlled solubility

[7]. Alkali-treated rice stubble was ground with a limited amount of water to prepare a semi-solid pulp. The pulp was then mixed with tamarind powder and calcium carbonate in a specific ratio. Experimental trials were carried out for different ratios of pulp, binder and hardener by varying proportions of tamarind powder and calcium carbonate. An optimized ratio was obtained based on the qualitative evaluation of mould ability, surface cracking, and hardness after curing. Samples were cured and ambient conditions.

**DIFFERENT TRIALS**

| TRIAL | FIBRE : BINDER : HARDENER | OBSERVATION |
|---|---|---|
| 1 | 9:10:7 | Brittle, cracks |
| 2 | 9:12:7 | improved but inconsistent |
| 3 | 9:15:7 | best outcome |
| 4 | 9:18:16 | surface not at all smooth |

**Fig -1**: TRIAL WITH EXCESS HARDENER

## 3. RESULTS

The optimized composite showed marked improvements in hardness, surface smoothness and mouldability over previous compositions. Initial rigidity was attained over 24 hours of drying and complete mechanical hardening took about 5 days. The composite could be moulded into varying geometries by altering mould size without compromising structural stability. Compared to starch compositions, the tamarind-bound composite showed lower levels of cracking and better moisture distribution.

**Fig -2**: MATERIAL IN MOULD BEFORE CURING

## 4. DISCUSSION

The experimental results highlight the importance of binder selection and moisture control in rice-stubble-based composites. Acid pretreatment negatively affected binder performance by increasing solubility, whereas alkali treatment improved fiber compatibility by partially removing lignin and enhancing fiber bonding [4]. Replacing food-based binders (wheat flour) improved sustainability and reduced variability between samples.

Tamarind powder proved effective as a natural binder by maintaining moisture equilibrium during curing, enabling gradual hardening and improved surface finish. However, extended curing time remains a limitation that may affect scalability. Future research should investigate accelerated curing techniques and alternative natural binders to further optimize performance.

**Fig -3**: SOFTENED STUBBLE

**Fig -4**: MATERIAL

## 4. LIMITATION AND FUTURE WORK

The primary limitation of the developed composite is the extended curing period of approximately five days required to achieve maximum hardness. Additionally, standardized mechanical testing was not conducted in this study. Future work will focus on quantitative strength characterization, accelerated drying methods, and long-term durability assessment under varying environmental conditions.

## 3. CONCLUSION

This study demonstrates the feasibility of producing a biodegradable, mouldable composite material from rice stubble using low-cost, natural additives. Through systematic experimentation and optimization, a structurally robust composite was developed that addresses key environmental and material challenges associated with agricultural waste utilization. The proposed approach offers a practical pathway for reducing residue burning while enabling sustainable material innovation.

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