# Particleboards from Rice Husk: A Brief Introduction to Renewable Materials of Construction

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**GLOBALLY**, the construction industry is growing at a rapid pace as a consequence of increasing population and standard of living. High performance synthetic materials for construction such as glass fibre and carbon fibre reinforced composites are available today. However, these materials are mainly used for high-tech applications in aerospace and motor sports due to their high costs. Therefore, lightweight and high-strength wood and wood-based composite boards are still the preferred option for construction due to their reasonable costs. The growing shortage of wood has also led to the development of suitable alternative materials for construction. Rice husk particleboard is one such material which is being considered as a potential substitute for wood and wood-based board products.

Rice is a major food crop in many regions of the world. Global rice production in 2007 was approximately 638 million tonnes and Malaysia's contribution was 2.2 million tonnes [1]. Due to global demand, rice production is expected to grow from year to year. Rice husk (RH) is the outer covering of the rice grain and is obtained during the milling process. RH constitutes 20% of the total rice produced [2]. As a renewable material, the use of RH can eliminate waste disposal and support environmental protection.

Even though Malaysia is not a prominent rice-producing country, large quantities of RH are produced every year after the harvest season (November to March). Commercially, RH produced in Malaysia is grounded with broken rice to be used as animal feed. A large part of this agricultural by-product is burnt as fuel during rice processing and the resulting ash is sold as fertiliser. Other applications of RH are as silicon carbide whiskers to reinforce ceramic cutting tools, and as aggregates and fillers for concrete and board production. However, most of this agricultural by-product is simply disposed, thus representing an environmental problem.

## COMPOSITION OF RICE HUSK

The reasons behind the use of RH in the construction industry are its high availability, low bulk density (90-150kg/m$^3$), toughness, abrasive in nature, resistance to weathering and unique composition. The main components in RH are silica, cellulose and lignin. The composition of RH as a percentage of weight is shown in Table 1 [3].

RH contains high concentration of silica in amorphous and crystalline (quartz) forms. The presence of amorphous silica determines the pozzolanic effect of RH. Pozzolanic effect exhibits cementitious properties that increase the rate at which the material gains strength. The extent of the strength development depends upon the chemical composition of alumina and silica in the material. The external surface of the husk contains high concentration of amorphous silica which decreases inwards and is practically non-existent within the husk. The elemental composition of the surface and interior of the husk is summarised in Table 2 [3].

*Table 1: Main composition of RH*

| Composition | wt % |
|---|---|
| $SiO_2$ | 18.80 – 22.30 |
| Lignin | 9 – 20 |
| Cellulose | 28 – 38 |
| Protein | 1.90 – 3.0 |
| Fat | 0.30 – 0.80 |
| Other nutrients | 9.30 – 9.50 |

*Table 2: Elemental composition at different regions in a RH*

| Elemental composition | External husk surface wt % | Husk interior wt % | Internal husk surface wt % |
|---|---|---|---|
| C | 6.91 | 62.54 | 30.20 |
| O | 47.93 | 35.19 | 42.53 |
| Si | 45.16 | 2.27 | 27.27 |

## RICE HUSK BOARDS

Various types of board can be produced from rice husk. These by-products include particleboards, insulation boards and ceiling boards.

### Traditional Approach for Manufacturing Rice Husk Particleboards

Producing particleboard panels requires combining wood particles, such as wood chips, saw dust and rice husks with suitable binders while applying pressure in the presence or absence of heat. RH is quite fibrous by nature and requires little energy input to prepare the husk for board manufacture. RH

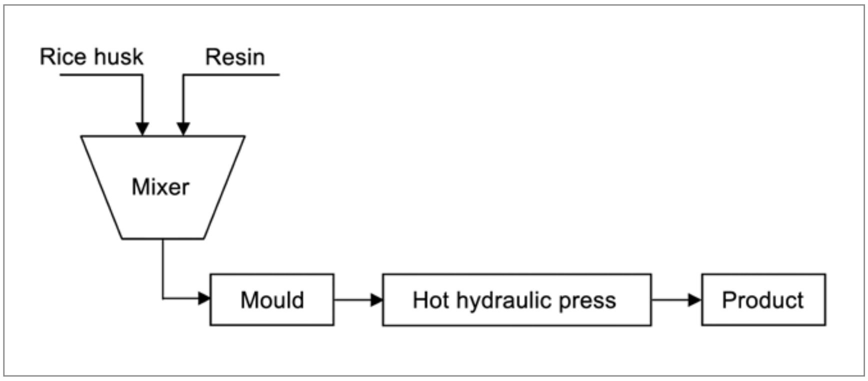


*Figure 1: Schematic of the process involved in the production of RH particleboards*

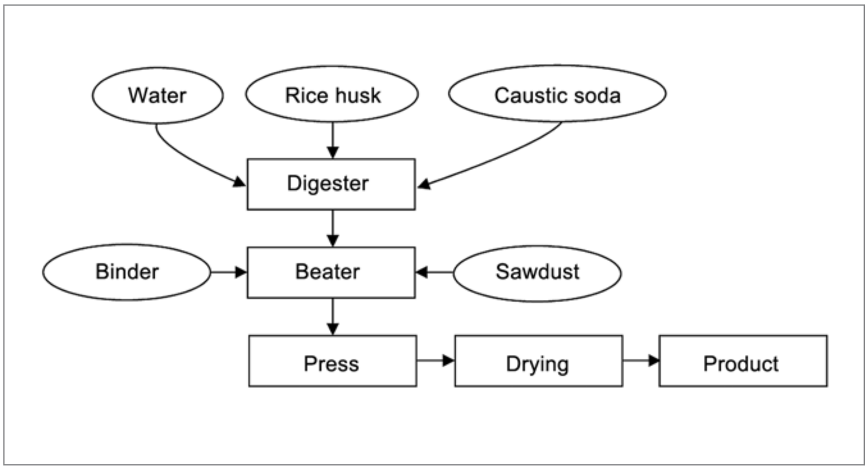


*Figure 2: Process flow diagram for producing RH ceiling board*

based particleboards are produced by spraying RH with thermosetting resins in a rotating mixer. This is followed by pressing in a hot-hydraulic press. Schematic of the particleboard production process is given in Figure 1. To make high quality RH boards, the husk is ground to fine powder.

A major drawback in the production of RH particleboards is the requirement of higher quantities of adhesive to yield board with acceptable properties. Water causes the boards to stain and warp. Once a particleboard becomes wet, it loses much of its tensile strength.

The positive aspect of these boards is that waste agricultural residues can be recycled to form a useful product. RH particleboards can be inexpensive alternatives to high-end cabinets, shelves and furniture. Depending on the manufacturer and quality of the resin, particleboard can be surprisingly durable.

The boards can be painted for decorative finishes. They can also be glued to each other or to decorative laminates using suitable adhesives. These boards can be used in building interiors such as wall or ceiling linings, panelling, partitioning and for providing insulation in buildings. The boards are classified as 'P' (not easily ignitable). This behaviour of the RH particleboard is similar to that of other wood-based boards by the BS 476: Part 5 test [5].

## Traditional Approach for Manufacturing Rice Husk Insulation Boards

The production process for RH insulation boards is similar to that of particleboards. The boards are generally made in different thicknesses, ranging from 4mm to 25mm. Their densities range from 500kg/m$^3$ to 900kg/m$^3$ for medium-density boards. For low-density RH boards, the density is less than 500kg/m$^3$. Low density boards possess better thermal and acoustic insulation properties compared to medium-density boards. These boards are resistant to attack by termites, wood-boring insects and wood decaying organisms [4].

## Classical Approach for Manufacturing Rice Husk Ceiling Boards

Many types of ceiling and roofing materials exist in the market, such as hard boards, paper boards, asbestos cement flat sheets and cellotex boards. The use of RH enables the production of much cheaper ceiling boards. It is produced by combing RH and sawdust [6]. Slurry is produced by heating RH with caustic soda. This slurry is then washed with water and beaten into pulp, to which sawdust (filler) and glue is added. The slurry is formed into sheets in the press and sun dried. The schematic process flow diagram for the production of ceiling board is given in Figure 2.

The boards with the admixture of RH and sawdust have a higher tensile strength (32N/m$^2$) compared to only RH boards (22N/m$^2$) and are comparable to commercial ceiling boards (23.5N/m$^2$).

## ADHESIVES IN PARTICLEBOARDS

Adhesive is a compound that adheres or bonds particles together. Adhesives are produced from either natural or synthetic sources. Some adhesives produce extremely strong bonds and are becoming increasingly important in the modern construction industry. Resin is a natural or synthetic compound which is highly viscous in its natural state and hardens with treatment. Typically, resin is soluble in alcohol but not in water. Resin is used as varnishes and adhesives.

Adhesives are essential and extensively used in wood-based composite products. Adhesive type and cure schedule vary according to the composite application. Adhesives used in the manufacture of particleboard should be flexible and soft to respond to the dynamic effects of swelling and shrinkage, yet impart the required strength.

The adhesive must also withstand the rigours of particleboard manufacturing with sufficient flow to increase particle coverage. Excessive flow, however, will displace adhesive droplets from the glue line into the interstices, thus producing particleboards with inferior properties. Similarly, insufficient flow reduces surface coverage resulting in substandard particleboards.

## SYNTHETIC ADHESIVES

Commonly used synthetic adhesives in the manufacture of particleboards are phenol-formaldehyde and urea-formaldehyde.

### Phenol-Formaldehyde (PF)

PF resin creates strong and water resistant bonds, but requires the longest press times and highest temperatures. Cured PF are inherently dark and are undesirable for decorative products such as furniture and panelling. The modulus of elasticity (MOE) and modulus of rupture (MOR) of RH particleboards with PF as binder are 2.6GPa and 13MPa [7]. In the case of ground RH, the modulus drops to 1.6GPa and 7MPa [8].

### Urea-Formaldehyde (UF)

UF resin is inexpensive and used where surface smoothness is required but not high water resistance. UF is extensively used in particleboard manufacturing for interior applications such as furniture and cabinetry. However, it has a disadvantage of formaldehyde emissions at high temperature. Chemical bonds between urea and formaldehyde are weaker than PF and are easily cleaved by moisture. The MOE and MOR of RH particleboards made with UF are 1.9GPa and 10MPa [7].

## NATURAL ADHESIVES

In early 1900s, adhesives were derived from agricultural resources until the introduction of petroleum resins in the early 1930s. In recent times, the term 'biodegradable' is commonly used to denote environmentally friendly products which, in plastics, describe all degradable plastics through microorganisms such as bacteria, fungi and algae. The main challenge with the use of biodegradable adhesives is that they are predominantly water soluble. This limitation limits their outdoor applications or in a moisture rich environment. Two natural adhesives discussed here in the manufacture of RH particleboards are soybean protein and starch.

### Soybean Adhesive

Soybean is inexpensive and is a widely available food material. Soy protein concentrate as such or modified with alkali can be used as an adhesive. The cure schedule followed is similar to the RH boards made from synthetic resins. The MOE and MOR of soy protein based boards are 2GPa and 8MPa respectively [7].

### Starch Adhesive

Starch is an easily available and inexpensive biodegradable material. Starch is a white powder which is typically tasteless and odourless. Starch grains are fine crystals or lumps, depending on their origin within the plant kingdom. Available starches include corn starch, potato starch, sago and tapioca. Starches are modified to increase their stability against excessive physical conditions, to change their texture, to vary gelatinisation time or to modify their characteristics for particular applications.

Modified starch is prepared by treating starch or starch granules with modified agents, causing the starch to be partially degraded. Modified starch is normally used as an adhesive, stabiliser or emulsifier. Modified starch may be converted into instant starch which thickens and gels without heat or a cook-up starch which must be cooked like regular starch. Modified starch may, therefore, be specifically formulated to be used as a resin for adhesives in particleboards production.

## MODIFIED STARCH ADHESIVE PARTICLEBOARDS

In this experiment, a specially prepared modified starch is formulated to produce RH particleboards. The RH particleboards are then made using a mixture of modified starch (MS) and wood fibre (WF) together with raw RH made available from a rice milling factory. WF is made up of shredded paper boxes disposed from packaging.

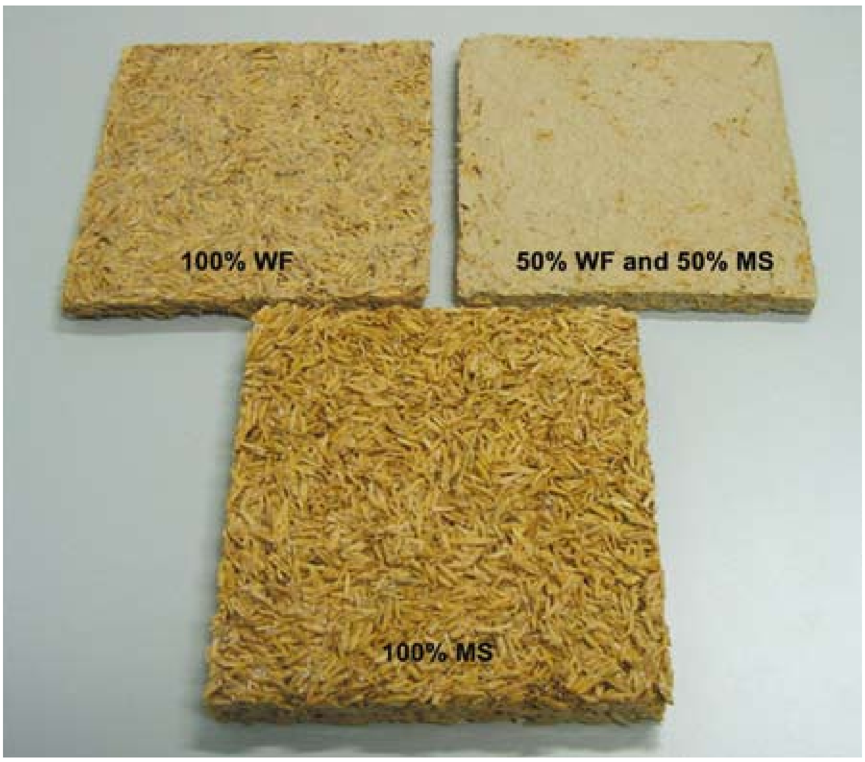


*Figure 3: 100% WF, 50% WF with 50% MS, and 100% MS based RH particleboards*

Traditional pressing boards are produced by laying the mat on a wire mesh and drying it in an oven. However, these RH particleboards are produced by placing the mixture on a flat surface mould and drying it under the sun.

Figure 3 shows RH particleboards produced with 100% WF, 50% WF plus 50% MS and 100% MS by weight. An equal amount by weight of RH is added to the mixture.

Physical examination of these boards showed that wood fibre content increases the bending strength. Further research is being conducted to determine the physical properties attributed to these boards for commercial applications. Research is also being conducted to determine the formulation of MS to be used for future RH particleboards production.

## CONCLUDING REMARKS

RH can be utilised in the manufacture of particleboards, ceiling boards and insulation boards. The use of biodegradable adhesives could reduce the use of synthetic adhesives based on petroleum resources and its ill effects. These materials could provide competitive composite boards for construction and, at the same time, be environmentally friendly. Developing countries should make an effort to harness the potential of the abundantly available RH. Efficient utilisation could serve as a revenue for the nation.

Since the construction industry is a growing industry, the use of renewable resources such as RH can reduce the strain on forest resources and form an excellent replacement for wood and wood based composite materials. Further research should be conducted to determine the composition of MS and WF that produce the optimum strength for RH particleboards to be used in the construction industry.

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