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# Strength Properties of Rice Husk and Rice Straw polymer Board

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*Dedicated To*

*My Beloved Parents*

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# ABSTRACT

The objective of this work is to evaluate the mechanical and physical properties of polymer boards made with rice straw, rice husk and bonded with a polypropylene adhesive. Bangladesh is an agriculture based country. In this country rice is grown all most all over the whole part of the country and it also very cheap in our country. Considering these reasons rice husk and rice straw were chosen for manufacturing polymer board. Therefore, polymer board is an environmentally progress way of combining plastics and fiber. The composite typically consists of three major elements: rice husk, rice straw and thermoplastic. The mechanical properties of panels were evaluated by the modulus of rupture MOR and modulus of elasticity MOE. Physical properties such as density, moisture content, linear expansion, water absorption (WA) and thickness swelling (TS) in water were determined. The study evaluated two parameters: (1) the mass ratio of rice husk, rice straw and PP; and (2) pressing time; where pressure and temperature is remain constant. Maintaining rice husk and rice straw content at 60% (30%+30%) or less produced the best mechanical properties, and rice husk and rice straw content above approximately 70% (30%+40%) resulted in reduction of all physical and mechanical properties of polymer board. The results showed that pressing time has a great impact on board quality. This study showed that the density of board increase with the increase of polypropylene. On the other hand moisture content of board decreases with the increase of polypropylene. Other physical properties water absorption, linear expansion and thickness swelling don't show linear relation with rice husk, rice straw with polypropylene ratio. The study also indicated that the MOE and MOR is increase with the increase of polypropylene but after a point these again decrease with the increase of polypropylene. In the light of this study it was seen that the rice husk, rice straw with polypropylene ratio 35:30:35 for pressing time 20 minutes shows best result. This study suggests that this board can be very feasible economically and environmentally.

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# 1. Introduction

## 1.1. Background of the study:

Polymer boards are composite materials made of wood fiber/wood flour and thermoplastic(s) (includes PE, PP, PVC etc.). Polymer boards are still new materials relative to the long history of natural lumber as a building material. The most widespread use of polymer board in outdoor deck floors, but it is also used for railings, fences, landscaping timbers, cladding and siding, park benches, molding and trim, window and door frames, and indoor furniture (Clemons,2002).

The demand for polymer board representing 57% of the total volume of fiber-based panels has recently increased dramatically throughout the world, especially for housing construction and furniture manufacturing. Worldwide demand for polymer board has been steadily growing since then at a rate between 2 and 5% per annum (Gamagea *et al.*, 2009). In recent years, wood-based industries all over the world are facing difficulty in obtaining wood raw material. Deforestation, forest degradation, and increasing wood demand for wood-based panels has led to a shortage of raw materials in the wood industrial sector for a long time. As a result the use of renewable resources such as agricultural residues is now gaining increased interest in the production of composite panels.

Previous studies reported that the Agricultural by-product Rice husk could be used as a raw material for composite board manufacture, most of them concluded that major drawbacks of the RH composite boards were low flexural modulus and strength, and dimensional stability compared with the strand boards made from wood strands (Lee et al., 2003), (Osarenmwinda and Nwachukwu, 2007) and (Torkaman, 2010). Another drawback in the production of RH composite boards is the requirement of higher quantities of adhesive to yield board with acceptable properties (Torkaman and Yunus, 2009). As known, one of the most successful ways to improve dimensional stability and mechanical properties of wood-based panels is to increase resin content. Agricultural lignocellulosic fibers such as rice straw can be easily crushed to chips or particles, which are similar to wood particle or fiber, and may be used as substitutes for wood-based raw materials (Ajiwe et al., 1998). However, the amount of the required resin for the composite manufacture can be decreased when the Rice straws are used (Kwon et al., 2013).

Rice husk (RH) is an important by-product of the rice milling process and is a major waste product of the agricultural industry. FAO reported that about 0.23 t of the RH is generated per ton of rice produced (FAO, 2011). The RH is the hard, protective shell of the grain and is the main by-products of the rice milling process, which is available in fairly large quantities in certain agricultural areas. The main components of the RH are cellulose (25 to 35%), hemicellulose (18 to 21%), and lignin (26 to 31%), silica (15 to 17%), solubles (2 to 5%), and moisture content 7.5% (Ciannamea et al., 2010). The reasons behind the use of the RH in composite material industry are its high availability, low bulk density (90–150 $kg/m^3$), toughness, abrasive in nature, resistance to weathering and unique composition (Luduena et al., 2011).

On the other hand, Rice straw is also important agricultural residue about 596 million tons of rice and 570 million tons of rice straw produced annually in the world (Pathak et al., 2006 and Mohdy et al., 2009). At present, most of these residues are burnt in situ after harvest. Moreover, rice straw stems are hollow and tubular structures. When the straw is cut into small particles, some of the particles cannot be split and they maintain a tubular shape, which prevents the resin from reaching internal surfaces of the straw. In order to have and When a mixture of the Rice Husk and Rice straw are used in the composite board production, resin type and solids content giving optimum physical and mechanical properties should be determined. Favorable internal bonding strength within rice straw composite board, it is crucial that most of the straw be split to allow uniform resin distribution on both inner and outer straw surfaces. The main causes to select two raw materials (Rice Husk and Rice Straw) is their highly availability.

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer with a high melting flow index and low softening temperatures are commonly used to prepare composites with lignocellulosic materials (such as sisal, jute, and sugar cane bagasse, cellulose or wood). Polypropylene is also environmentally-friendly (Yam and Mak, 2013).

## 1.2. Objectives

1. To manufacture a Board from Rice Husk, Rice Straw and polypropylene
2. To evaluate the physical and mechanical properties of the Board and comparison with standard board.

# 2. Literature Review

## 2.1. General description of polymer board

### 2.1.1. Definition:

Polymer boards are composite materials made of wood fiber/wood flour and thermoplastic(s) (includes PE, PP, PVC etc.).

Chemical additives seem practically "invisible" (except mineral fillers and pigments, if added) in the polymer structure. They provide for integration of polymer and wood flour (powder) while facilitating optimal processing conditions (Clemons,2002).

In addition to fiber and plastic, polymer board can also contain other ligno-cellulosic and/or inorganic filler materials.

### 2.1.2. Uses:

Polymer boards are still new materials relative to the long history of natural lumber as a building material. The most widespread use of polymer board in North America is in outdoor deck floors, but it is also used for railings, fences, landscaping timbers, cladding and siding, park benches, molding and trim, window and door frames, and indoor furniture (Clemons,2002). Wood-plastic composites were first introduced into the decking market in the early 1990s. Manufacturers claim that polymer board is more environmentally friendly and requires less maintenance than the alternatives of solid wood treated with preservatives or solid wood of rot-resistant species. These materials can be molded with or without simulated wood grain details.

### 2.1.3. Production:

Polymer boards are produced by thoroughly mixing ground wood particles/fiber and heated thermoplastic resin. The most common method of production is to extrude the material into the desired shape, though injection molding is also used. Polymer board may be produced from either virgin or recycled thermoplastics including HDPE, LDPE, PVC, PP, ABS,PS, and PLA. Polyethylene based polymer boards are by far the most common. Additives such as colorants, coupling agents, UV stabilizers, blowing agents, foaming agents, and lubricants help tailor the end product to the target area of application. Extruded polymer board are formed into both solid and hollow profiles. A large variety of injection molded parts are also produced, from automotive door panels to cell phone covers.

In some manufacturing facilities, the constituents are combined and processed in a pelletizing extruder, which produces pellets of the new material. The pellets are then re-melted and formed into the final shape. Other manufacturers complete the finished part in a single step of mixing and extrusion (Stark,2001).

### 2.1.4. Advantages and Disadvantages:

Polymer boards do not corrode and are highly resistant to rot, decay, and Marine Borer attack, though they do absorb water into the wood fibers embedded within the material. They have good workability and can be shaped using conventional woodworking tools. Polymer boards are often considered a sustainable material because they can be made using recycled plastics and the waste products of the wood industry or agricultural residue. Although these materials continue the lifespan of used and discarded materials, and have their own considerable half life; the polymers and adhesives added make polymer board difficult to recycle again after use (Gibson, 2008). They can however be recycled easily in a new polymer board, much like concrete. One advantage over wood agricultural product is the ability of the material to be molded to meet almost any desired shape. A polymer board member can be bent and fixed to form strong arching curves. Another major selling point of these materials is their lack of need for paint. They are manufactured in a variety of colors, but are widely available in grays and earth tones. Despite up to 70 percent cellulose content (although 50/50 is more common); the mechanical behavior of WPCs is most similar to neat polymers. Neat polymers are polymerized without added solvents (Carraher, 2014). This means that polymer board have a lower strength and stiffness than wood, and they experience time and temperature-dependent behavior (Hamel, 2011). The wood particles are susceptible to fungal attack, though not as much so as solid wood, and the polymer component is vulnerable to UV degradation (Morrell, 2006). It is possible that the strength and stiffness may be reduced by moisture absorption and freeze-thaw cycling, though testing is still being conducted in this area. Some polymer board formulations are also sensitive to staining from a variety of agents.

As time goes on, product defects have become well known. The industry leader (Trex Company, Inc.) has been involved in numerous lawsuits with home owners and installers in regards to mildew, discoloration and increased weakness in the fiber of the materials. As of mid 2008, Trex has replaced over 37,000 decks in regards to the issues previously stated and had to change their 'maintenance-free' claims to 'low-maintenance' explaining that decking would require cleaning multiple times every year to remove mildew spots.

Once more, in 2013, Trex notified consumers in 16 western states who may have purchased defective Trex decking product suffering from surface flaking to contact the company for replacement materials. Trex has previously announced that a small percentage of decking boards manufactured at its Fernley, Nevada plant between 2002 and 2007 suffered from surface flaking due to a manufacturing problem.

## 2.2. General description of rice husk

### 2.2.1. Rice husk:

Rice hulls (or rice husks) are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice hulls can be put to use as building material, fertilizer, insulation material, or fuel.

**Figure: 2.1 Rice husk**

### 2.2.2. Production:

Rice husks are the coatings of seeds, or grains, of rice. To protect the seed during the growing season, the husk is formed from hard materials, including opaline silica and lignin. The hull is mostly indigestible to humans.

Winnowing, used to separate the rice from husk, is to put the whole rice into a pan and throw it into the air while the wind blows. The light husk are blown away while the heavy rice fall back into the pan. Later pestles and a simple machine called a rice pounder were developed to remove husk. In 1885 the modern rice hulling machine was invented in Brazil. During themilling processes, the husks are removed from the raw grain to reveal whole brown rice, which may then sometimes be milled further to remove the bran layer, resulting in white rice.

Table 2.1: Typical analysis of rice husk (Muthadhi A and Kothandaraman S, 2007)

| Property | Range |
|---|---|
| Bulk density (kg/m3) | 96-160 |
| Hardness(Mohr's scale) | 5-6 |
| Ash (%) | 22-29 |
| Carbon (%) | $\approx 35$ |
| Hydrogen (%) | 4-5 |
| Oxygen (%) | 31-37 |
| Nitrogen (%) | 0.23-0.32 |
| Sulphur (%) | 0.04-0.08 |
| Moisture (%) | 8-9 |

### 2.2.3. Cost of rice husk:

Rice husk is a waste product that farmers previously struggled to dispose of due to its large volume. Today it is a traded commodity with a growing variety of usees. You may have heard that rice husk is free. It can be. At rice farm hundreds of kilometers from a port, awawy from roads and rivers, and up a hill. Anywhere else farmers sell it to millers, and millers have to collect it via truck or more typically barge, transport it to mills clean and grind it, pack it, transport it to port, and load it. The cost of this forms the majority of the cost.

## 2.3. General description of Rice straw

Straw is the only organic material available in significant quantities to most rice farmers. About 40 percent of the nitrogen (N), 30 to 35 percent of the phosphorus (P), 80 to 85 percent of the potassium (K), and 40 to 50 percent of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity (Ponnamperuma, 1984).

Straw is an agricultural by-product, the dry stalks ofcereal plants, after the grain and chaff have been removed. Straw makes up about half of the yield of cereal crops such as barley, oats, rice, rye and wheat. It has many uses, including fuel, livestock bedding and fodder, thatching and basket-making. It is usually gathered and stored in a straw bale, which is a bundle of straw tightly bound with twine or wire. Bales may be square, rectangular, or round, depending on the type of baler used (Schnitzer et al, 2014).

Straw is removed from the field, burned in situ, piled or spread in the field, incorporated in the soil, or used as mulch for the following crop. Each of these measures has a different effect on overall nutrient balance and long-term soil fertility. Where S-free mineral fertilizers are used, straw may be an important source of S; thus, straw burning should not be practiced. In contrast, burning effectively transforms straw into a mineral K nutrient source, and only a relatively small amount of K is lost in the process. The effect of straw removal on long-term soil fertility is much greater for K than for P. Spreading and incorporation of straw, however, are labour-intensive tasks, and farmers consider burning to be more expedient. Straw is also an important source of micronutrients such as zinc (Zn) and the most important influence on the cumulative silicon (Si) balance in rice.

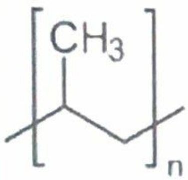
**Figure: 2.2 Rice straw**

## 2.4. General description of Polypropylene:

### 2.4.1. Polypropylene:

Polypropylene (PP)also known aspolypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. General information of Polypropylene is given below-

**Table- 2.2. General information of Polypropylene**

| | |
|---|---|
| Polypropylene | |
|  | |
| IUPAC name<br>poly(propene) | |
| Other names<br>Polypropylene; Polypropene;<br>Polipropene 25 [USAN];Propene polymers;<br>Propylene polymers; 1-Propene | |
| Identifiers | |
| CAS number | 9003-07-0 |
| Properties | |
| Molecular formula | $(C_3H_6)_n$ |
| Density | 0.855 g/cm$^3$, amorphous<br>0.946 g/cm$^3$, crystalline |
| Melting point | 130 to 171 °C (266 to 340 °F; 403 to 444 K) |
| Except where noted otherwise, data are given for materials in their standard state (at 25 °C (77 °F), | |

### 2.4.2. Chemical and physical properties:

Most commercial polypropylene is isotactic and has an intermediate level of crystallinity between that of low density polyethylene (LDPE) and high density polypropylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene.

This allows polypropylene to be used as anengineering plastic, competing with materials such asacrylonitrile butadiene styrene (ABS). Polypropylene is reasonably economical, and can be madetranslucent when uncolored but is not as readily made transparent as polystyrene, acrylic, or certain other plastics. It is often opaque or colored using pigments. Polypropylene has good resistance tofatigue. The melting point of polypropylene occurs at a range, so a melting point is determined by finding the highest temperature of a differential scanning calorimetry chart. Perfectly isotactic PP has a melting point of 171 °C (340 °F). Commercial isotactic PP has a melting point that ranges from 160 to 166 °C (320 to 331 °F), depending on atactic material and crystallinity. Syndiotactic PP with a crystallinity of 30% has a melting point of 130 °C (266 °F) (Maier et al 1998). The melt flow rate (MFR) or melt flow index (MFI) is a measure of molecular weight of polypropylene. The measure helps to determine how easily the molten raw material will flow during processing. Polypropylene with higher MFR will fill the plastic mold more easily during the injection or blow-molding production process. As the melt flow increases, however, some physical properties, like impact strength, will decrease. There are three general types of polypropylene: homo polymer, random copolymer, and block copolymer. The comonomer is typically used with ethylene. Ethylene-propylene rubber or EPDM added to polypropylene homo polymer increases its low temperature impact strength. Randomly polymerized ethylene monomer added to polypropylene homo polymer decreases the polymer crystallinity, lowers the melting point and makes the polymer more transparent.

### 2.4.3. Degradation:

Polypropylene is liable to chain degradation from exposure to heat and UV radiation such as that present in sunlight. Oxidation usually occurs at the tertiary carbon atom present in everyrepeat unit. A free radical is formed here, and then reacts further with oxygen, followed by chain scission to yield aldehydes and carboxylic acids. In external applications, it shows up as a network of fine cracks and crazes that become deeper and more severe with time of exposure.

For external applications, UV-absorbing additives must be used. Carbon black also provides some protection from UV attack. The polymer can also be oxidized at high temperatures, a common problem during molding operations. Anti-oxidants are normally added to prevent polymer degradation. Microbial communities isolated from soil samples mixed with starch have been shown to be capable of degrading polypropylene (Cacciari et al, 1993).

### 2.4.4. Industrial processes:

Traditionally, three manufacturing processes are the most representative ways to produce polypropylene (Sinn et at, 1995).

Hydrocarbon slurry or suspension: Uses liquid inert hydrocarbon diluents in the reactor to facilitate transfer of propylene to the catalyst, the removal of heat from the system, the deactivation/removal of the catalyst as well as dissolving the atactic polymer. The range of grades that could be produced was very limited. (The technology has fallen into disuse).

Bulk (or bulk slurry): Uses liquid propylene instead of liquid inert hydrocarbon diluents. The polymer does not dissolve into diluents, but rather rides on the liquid propylene. The formed polymer is withdrawn and any unreacted monomer is flashed off.

Gas phase: Uses gaseous propylene in contact with the solid catalyst, resulting in a fluidized-bed medium.

### 2.4.5. Manufacturing:

Melt processing of polypropylene can be achieved via extrusion and molding. Common extrusion methods include production of melt-blown and spun-bond fibers to form long rolls for future conversion into a wide range of useful products, such as face masks, filters, diapers and wipes.

The most common shaping technique is injection molding, which is used for parts such as cups, cutlery, vials, caps, containers, house wares, and automotive parts such as batteries. The related techniques of blow molding and injection-stretch blow molding are also used, which involve both extrusion and molding.

The large number of end-use applications for polypropylene is often possible because of the ability to tailor grades with specific molecular properties and additives during its manufacture. For example, antistatic additives can be added to help polypropylene surfaces resist dust and dirt. Many physical finishing techniques can also be used on polypropylene, such as machining. Surface treatments can be applied to polypropylene parts in order to promote adhesion of printing ink and paints.

# 3. Materials and Methods

## 3.1 Methods and Procedure

### 3.1.1 Manufacturing of polymer boards

#### 3.1.1.1 Selecting Variables

There are two types of variables, i.e. dependent and independent. In this study, temperature and pressure was the independent variable. Temperature is fixed at 180ºc and pressure is 4 mpa. According to Jan Benthien and Heiko Thoemen, (2012) temperature has little effect on mechanical properties of FPC board. Different study shows that 4 mpa pressures are better for producing good quality FPC board. On the other hand, melting temperature of polypropylene is ranges 130-160°C. So that fixing temperature at 180°C is very reasonable for this study.

Beside this, Fiber-plastic ratio and pressing time are the dependent variables. Nadir A. et al., (2011) say that time condition has a vital impact on mechanical and physical properties also. Fiber and plastic are quite difference in their nature, i.e. Fiber is hydrophilic and plastic is hydrophobic. A lot of study proved that Fiber-plastic ratio combination has a great effect on FPC board.

#### 3.1.1.2 Experimental Design

Three level of rice husk (RH) and rice straw (RS) to polypropylene (PP) mixing ratio (30:40:30, 35:30:35 and 30:30:40) and two pressing time (15 and 20 minute) for each ratio was used to manufacture composite boards in the Wood Technology Laboratory of Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh.

Table 3.1: **Formulations of manufacturing composite boards.**

| Formulations | RH contents (%) | RS contents (%) | PP contents (%) | Pressing time (minute) |
|---|---|---|---|---|
| R1P1 | 30 | 40 | 30 | 15 |
| R2P1 | 35 | 30 | 35 | 15 |
| R3P1 | 30 | 30 | 40 | 15 |
| R1P2 | 30 | 40 | 30 | 20 |
| R2P2 | 35 | 30 | 35 | 20 |
| R3P2 | 30 | 30 | 40 | 20 |

### 3.1.1.3 Collection of Raw Materials

Rice husk was collected from the local market of Khulna, Bangladesh and rice straw was collected from the nearby village of Khulna University and polypropylene (PP) was collected from a market of Dhaka, Bangladesh as raw material for the manufacturing of polymer board.

### 3.1.1.4 Preparation of Raw Materials

To obtain polymer-boards with good strength, smooth surfaces, and equal swelling, manufacturers ideally using a heterogeneous material with a high degree of slenderness (long, thin particles), no over-size particles, no splinters, and no dust is needed. For the purpose of preparing samples the rice husk was screened to separate the dust. Then the PP granules were processed by grinder to pass through a mesh screen.

### 3.1.1.5 Particle Drying

After processing, the raw materials was kept in an electrically heated lab scale oven (Model NO: DHG-9101-ISA After removing the top 10 cm the rice straw stalks was cut. and S.N.-5054) at 103± 2$^0$C for 24h to dry them.

### 3.1.1.6 Mixing

When raw materials were prepared then mixing is done manually by hand-shaking.

### 3.1.1.7 Mat Formation

After mixing of materials, the mats were formed manually on a steel plate. The average mat thickness of each type of board was eight times of the targeted board thickness (5mm).

### 3.1.1.8 Hot Pressing

After mat formation, a steel sheet was placed onto the mat. At the same time the temperature, pressure and pressing time of electric hot press was fixed and then it was switched on to rise temperature. When temperature was reached $170^0$C then mat was given between the plates of hot press and switched on the pressure. The temperature and pressure buttons was switched off after completing pressing time (15 or 20min). Then each type of board was retained another 25 minutes under pressure. Therefore the total press time was about 40 or 45 minutes.

## 3.2 Laboratory test

Physical and mechanical properties were tested in the laboratory of Forestry and Wood Technology Discipline, Khulna University, Khulna and Department of Civil Engineering, Khulna University of Engineering and Technology, Khulna. The properties was tested according to the procedures defined in the American Society for Testing and Materials (ASTM) standard D1037 (ASTM, 1994a).

### 3.2.1 Physical Properties

#### 3.2.1.1 Density

Density of each sample was measured in the laboratory of Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh.

Density was calculated by following formula,

$D = \frac{m}{v}$ ……………… Equation 1. (Desch and Dinwoodie, 1996).

Where,

$D$ = Density

$m$ = Mass of the sample

$v$ = Volume of the sample

#### 3.2.1.2 Moisture Content

The moisture content was measured from the difference in weight after the sample had been drying in the oven at 103±2$^0$C until constant weight was reached. Initial and final weight of the sample was measured by electric balance (model: AX600).

It was calculated by following formula,

mc (%) = $\frac{m_{int} - m_{od}}{m_{od}} \times 100$ ……… Equation 2. (Desch and Dinwoodie, 1996).

Where,

mc = moisture content (%)

$m_{int}$ = Initial ass of the sample (g)

$m_{od}$ = Oven-dry mass of the sample (g)

### 3.2.1.3 Water Absorption

The water absorption was measured from different in weight of the sample before and after 24 hours immersion in water and weight was measured by electric machine. The water absorption was calculated by the following formula,

$A_w (\%) = \frac{m_2 - m_1}{m_1} \times 100$ ……… Equation 3. (Young quist *et al.*, 1997)

Where,

$A_w$ = Water absorption (%)

$m_2$ = The weight of the sample after immersion in water

$m_1$ = The weight of the sample before immersion in water

### 3.2.1.4 Linier Expansion

Linier expansion was measured by digital calipers from the difference in length of the sample before and after 24 hrs immersion in water. It was calculated by the following formula,

Linear expansion (%) = $\frac{l_2 - l_1}{l_1} \times 100$ ……… Equation 4. (Youngquist *et al.*, 1997)

Where,

$l_1$ = Length of the sample before immersion in water in mm.

$l_2$ = Length of the sample after immersion in water in mm.

### 3.2.1.5 Thickness Swelling

The thickness swelling was measured from the difference in thickness before and after 24hrs immersion in water with the digital calipers. It was calculated by the following equation,

$G_t (\%) = \frac{t_2 - t_1}{t_1} \times 100$ ……… Equation 5. (Youngquist *et al.*, 1997)

Where,

$G_t$ = Swelling (%)

$t_2$ = Thickness of the sample after immersion in water

$t_1$ = Thickness of the sample before immersion in water

## 3.2.2 Mechanical Properties

### 3.2.2.1 Modulus of Rupture (MOR)

Modulus of Rupture (MOR) was measured by the Universal Testing Machine (UTM), (Model no: UTM-100, Serial No: 11/98-2443). The MOR was calculated by the following formula-

$MOR = \frac{3PL}{2bd^2}$ ………… Equation 6. ( Desch and Dinwoodie, 1996).

Where,

MOR = Modulus of Rupture in $N/mm^2$

$P$= load in N

$L$ = span length in mm,

$b$ = width in mm,

$d$ = thickness in mm

### 3.2.3.2 Modulus of Elasticity (MOE)

Modulus of Elasticity (MOE) was measured by the University Testing Machine (UTM), (Model no: UTM-100, Serial No: 11/98-2443). The MOE was calculated by the following formula-

MOE = $\frac{P'L^3}{4\Delta' bd^3}$ ……………… Equation 7. ( Desch and Dinwoodie, 1996).

Where,

MOE = Modulus of elasticity in $N/mm^2$

P'= load in N at the limit of proportionality

$L$ = span length in mm,

$B$ = width in mm,

$d$ = thickness in mm

Δ' = deformation of the board in mm at the limit of proportionality

### 3.3 Analysis of Data

The data was collected and analyzed by Excel 2007 and SPSS statistics 20 6.12 for ANOVA (Analysis of variance) and LSD (Least significance Difference).

# 4. Results and discussion

## 4.1 Results:

### 4.1.1 Physical Properties

#### 4.1.1.1 Density:

The density of board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 1189.75 Kg/m$^3$, 1398.86 Kg/m$^3$, 1478.55 Kg/m$^3$, 1233.42 Kg/m$^3$, 1411.36 Kg/m$^3$ and 1468.41 Kg/m$^3$ respectively (Fig. 4.1). Rice husk and rice straw to polypropylene of 30:30:40 for pressing time 15 minute shows highest value and ratio of 30:40:30 for pressing time 15 minute shows lowest value.

Same ratio of rice husk and rice straw to polypropylene give different value for different pressing time.

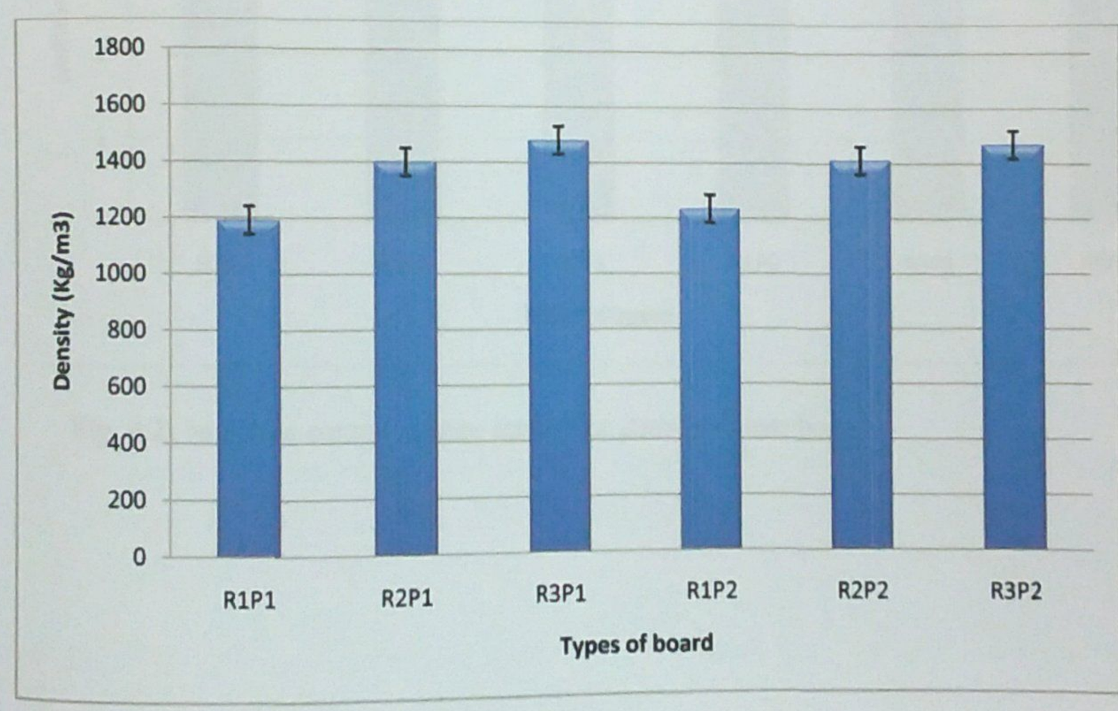



**Fig. 4.1:** Density of rice husk- rice straw polymer board

### 4.1.1.2 Moisture content

It was found that the moisture content of board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 3.95%, 3.56%, 3.15%, 4.56%, 4.16% and 3.26% respectively (Fig. 4.2). Highest value is 4.56% and lowest value is 3.15%.

Rice husk and rice straw to polypropylene ratio of 30:40:30 for pressing time 20 minute shows highest value and ratio of 30:30:40 for pressing time 15 minute shows lowest value.

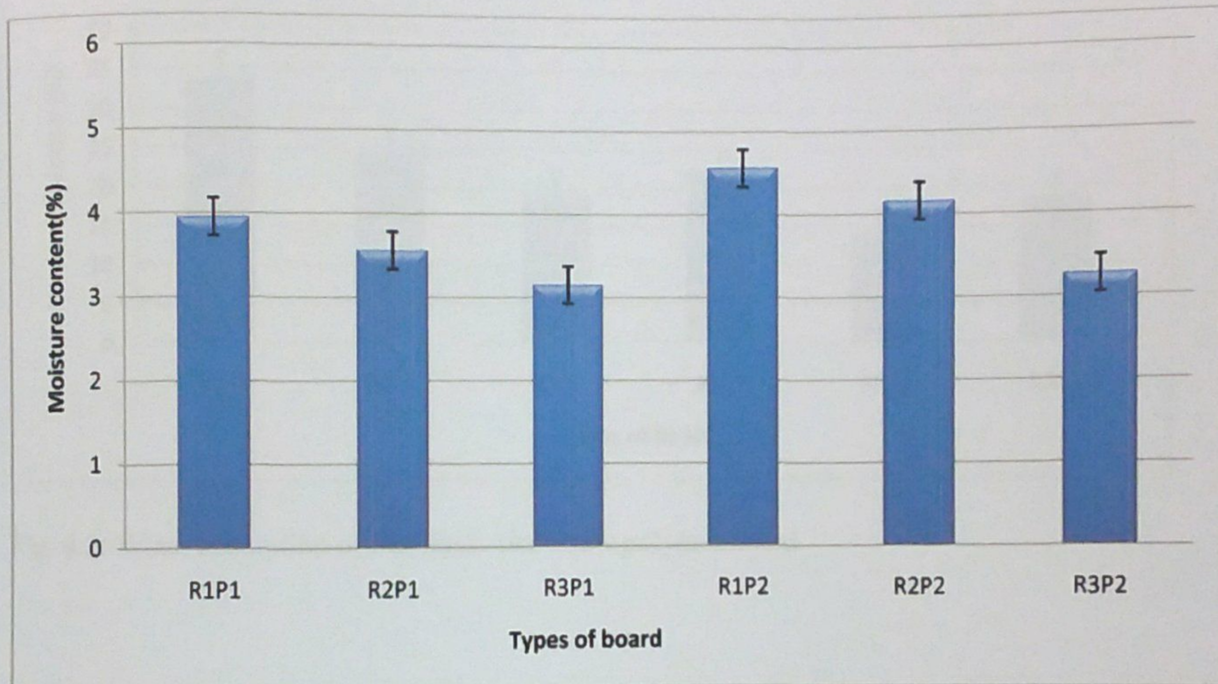



**Fig. 4.2:** Moisture content of rice husk- rice straw polymer board

#### 4.1.1.3 Water Absorption

It was found that the absorption of water by rice husk-rice straw polymer board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 34.09%, 24.53%,19.24%,22.56%, 14.24%, 18.68% respectively after 24 hours immersion in water (Fig. 4.3).

Rice husk and rice straw to polypropylene ratio of 35:30:35 for pressing time 20 minute shows best result. On the other hand ratio of 30:40:30 for pressing time 15 minute shows highest value.

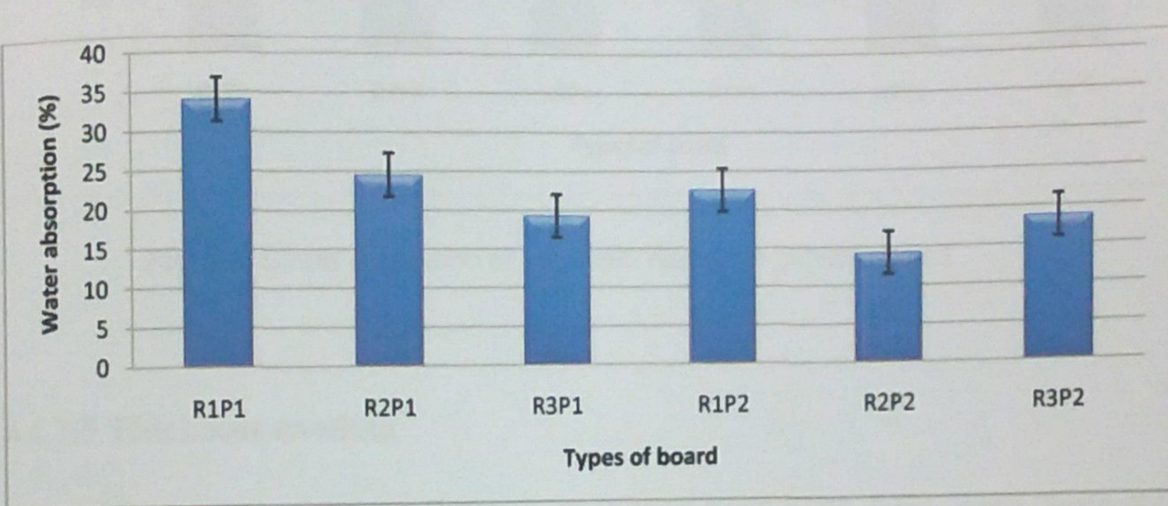



**Fig. 4.3:** Water absorption of rice husk- rice straw polymer board

#### 4.1.1.4 Linear Expansion

After 24 hours immersion in water, it was found that the linear expansion of rice husk- rice straw polymer board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 1.30%, 0.56%, 1.14%, 1.10%, 0.43% and 0.47% respectively (Fig. 4.4).

Among the different types of rice husk-rice straw polymer board ratio of 30:40:30 for pressing time 15 minute shows highest value and ratio of 35:30:35 for pressing time 20 minute shows lowest value.

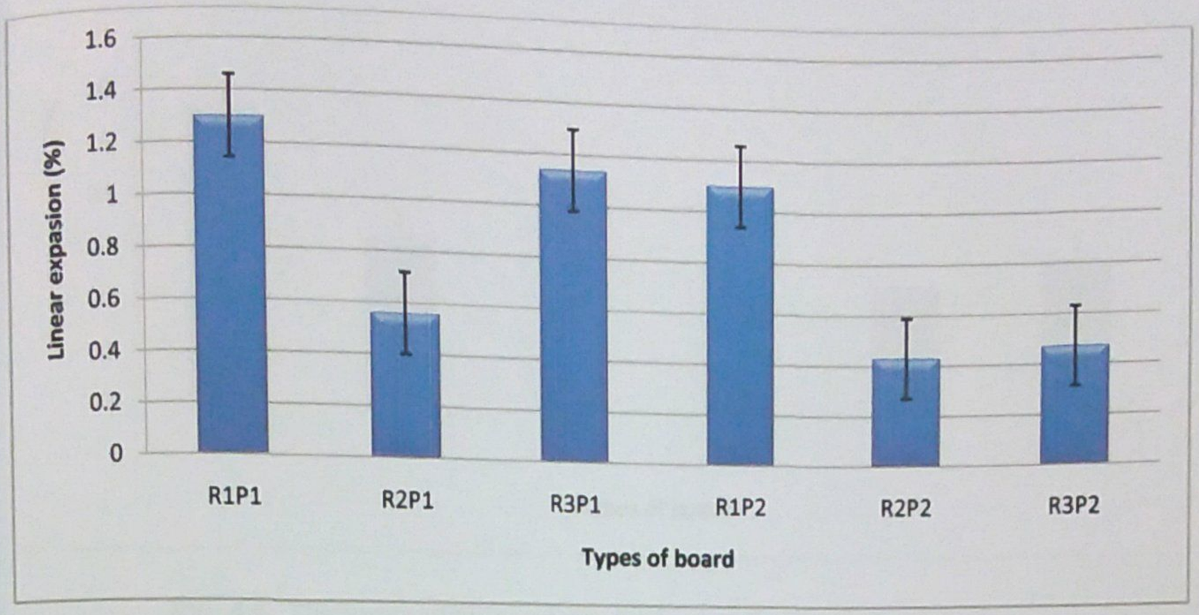



**Fig. 4.4:** Linear Expansion of rice husk- rice straw polymer board

#### 4.1.1.5 Thickness swelling

The thickness swelling of rice husk-rice straw polymer board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 28.32%, 16.41%, 20.28%, 18.46%, 12.84%, 15.38% respectively after 24 hours immersion in water (Fig. 4.5).

Among the different types of rice husk- rice straw polymer board ratio of 30:40:30 for pressing time 15 minute shows highest value and ratio of 35:30:35 for pressing time 20 minute shows lowest value.

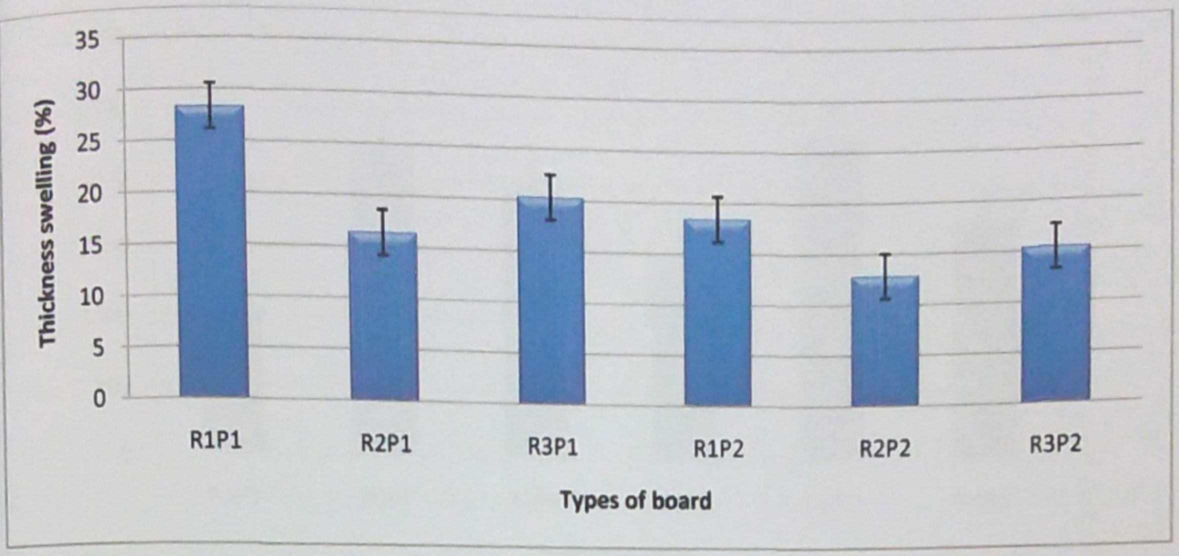



**Fig. 4.5:** Thickness swelling of rice husk- rice straw polymer board

## 4.1.2 Mechanical Properties

### 4.1.2.1 Modulus of Elasticity (MOE)

The Modulus of Elasticity (MOE) of rice husk- rice straw polymer board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 1174.23 N/mm$^2$, 2242.27 N/mm$^2$, 1967.43 N/mm$^2$, 1467.84 N/mm$^2$, 2374.62 N/mm$^2$ and 1746.43 N/mm$^2$ respectively (Fig. 4.6).

Rice husk rice straw to polypropylene ratio of 35:30:35 for pressing time 20 minute shows highest value and ratio of 30:40:30 for pressing time 15 minute shows lowest value.

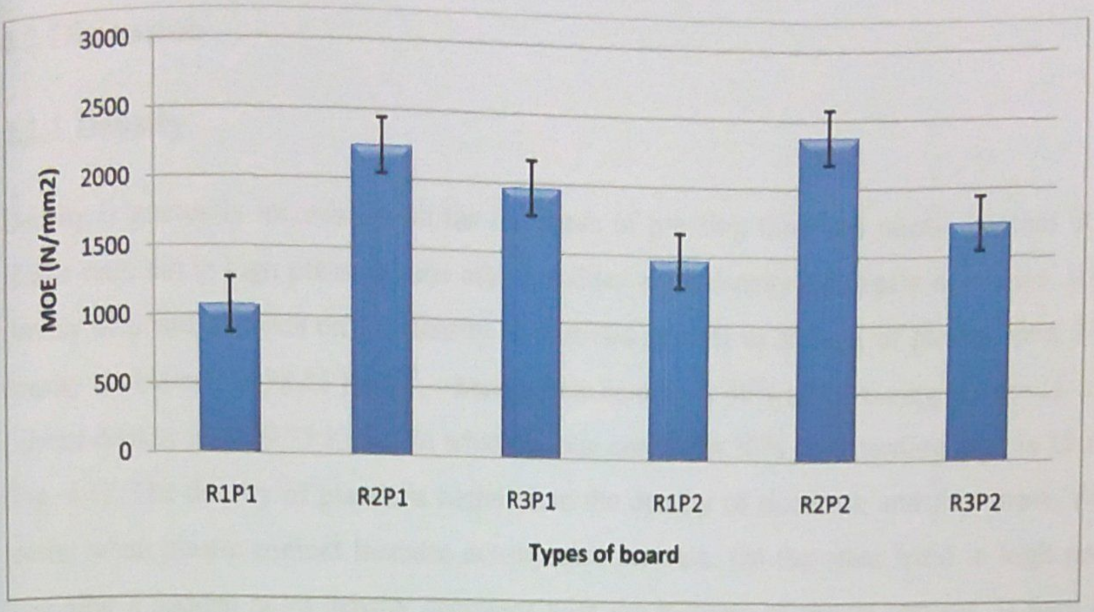



**Fig. 4.6:** Modulus of Elasticity of rice husk- rice straw polymer board

### 4.1.2.2 Modulus of Rupture (MOR)

The Modulus of Rupture (MOE) of rice husk- rice straw polymer board R1P1, R2P1, R3P1, R1P2, R2P2 and R3P2 are 15.42 N/mm$^2$, 22.36 N/mm$^2$, 18.48 N/mm$^2$, 16.74 N/mm$^2$, 24.41 N/mm$^2$ and 18.73 N/mm$^2$ respectively (Fig. 4.6).

Among the different types of rice husk- rice straw polymer board ratio of 30:40:30 for pressing time 15 minute shows lowest value and ratio of 35:30:35 for pressing time 20 minute shows highest value.

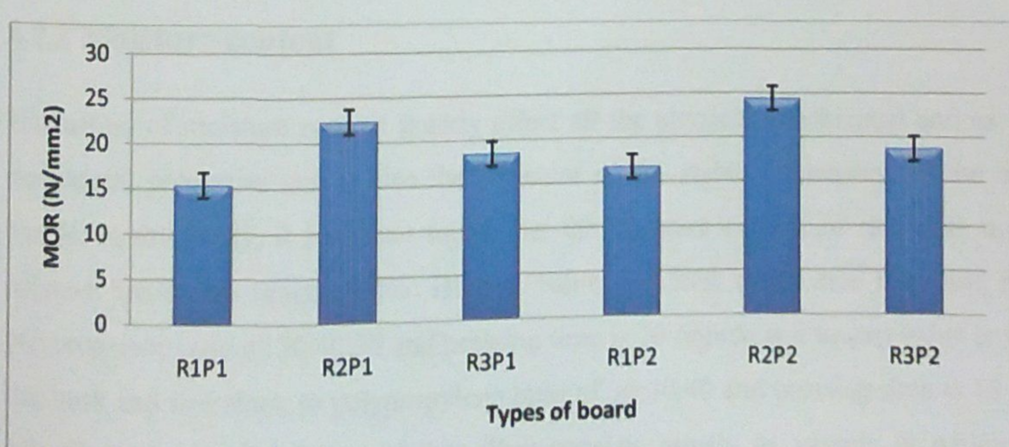



**Fig. 4.7:** Modulus of Rupture of rice husk- rice straw polymer board

## 4.2 Discussion

### 4.2.1 Density

Density is gradually increases with the increases of pressing time and plastic content in fiber-plastic ratio but in high pressing time after a sudden point density also again decreases. Actually density of board depends on the density of particles as well as amount of plastic used. Highest density is obtained 1478.55 Kg/m$^3$, where plastic content is 40% and pressing time is 15 minute. Lowest density is 1189.75 Kg/m$^3$ in which plastic content is 30% and pressing time is 15 minute (Fig. 4.1). The density of plastic is higher than the density of rice husk and rice straw. For this reason when plastic content increase density also increase. On the other hand in high pressing time after a sudden point density decreases with the increase of plastic content. It may be for some chemical change in fiber or plastic. Fibers are composed of various organic materials and therefore their thermal treatment leads to a variety of physical and chemical changes. Thermal degradation of those fibers leads to deterioration of their physical and mechanical properties. It also results in the generation of gaseous products, when processing takes place at temperatures at 180° C or above, which can create high porosity and low density (Georgopoulos et al. 2005; Jacob and Thomas, 2008). ANOVA table for density is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of 0.976. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

### 4.2.2 Moisture content

Fluctuation of moisture content greatly affect all the physical, mechanical and as well as non-mechanical properties and it also the indicator of the stable dimensions of the manufactured boards. In this study, it has been found that the moisture content of rice husk and rice straw polymer board was ranges 3-4%. Highest value is 4.56% where rice husk and rice straw to polypropylene ratio of 30:40:30 and pressing time is 20 minute and lowest value is 3.15% where rice husk and rice straw to polypropylene ratio of 30:30:40 and pressing time is 15 minute (Fig. 4.2). Endra et al. (2012) stated that fiber consists mostly of vessels in which moisture is absorbed. But plastic that has hydrophobic nature and tends to impede the entry of water into plastic board. Pressing time has very slight effect. Moisture content increases very slightly with the increasing of pressing time. It's might be happened that increasing pressing time breakdown the structural bond of plastic and also increases the water affinity due to chemical bond with fiber. ANOVA table for moisture content is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of 0.864. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

### 4.2.3 Water Absorption

Absorption of water is also an indicator of physical and mechanical properties. In this study, it has been found that the moisture content of rice husk and rice straw polymer board was ranges 14-34%. Highest value is 34.09% where rice husk and rice straw to polypropylene ratio is 30:40:30 and pressing time is 15 minute and lowest value is 14.24% where rice husk and rice straw to polypropylene ratio is 35:30:35 and pressing time is 20 minute (Fig. 4.3). Absorption of water is decrease with the increase of plastic content but after a sudden point it again decreases with the increase of plastic content. It may be for raw material that means rice husk and rice straw greatly affected by water and may be also for chemical change of plastic. Absorption of water decreases with the increasing of pressing time. It may be for filling the free space of rice husk and rice straw in high pressing time. ANOVA table for water absorption is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of 0.648. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

### 4.2.4 Linear Expansion

Linear expansion is an indicator of physical and mechanical properties. In this study, it has been found that the moisture content of rice husk and rice straw polymer board was ranges 0.43%-1.30%. Highest value is 1.30% where rice husk and rice straw to polypropylene ratio is 30:40:30 and pressing time is 15 minute and lowest value is 0.43% where rice husk and rice straw to polypropylene ratio is 35:30:35 and pressing time is 20 minute (Fig. 4.4). This variation of linear expansion may be due to the compactness of fiber. If pressing time is raised then linear expansion reduces. It may be for high bonding capacity of fiber and plastic in long time heat. ANOVA table for linear expansion is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of 0.713. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

### 4.2.5 Thickness swelling

Thickness swelling of rice husk and rice straw polymer board in this study was ranges 12-29%. Highest value is 28.32% where rice husk and rice straw to polypropylene ratio is 30:40:30 and pressing time is 15 minute and lowest value is 12.84% where rice husk and rice straw to polypropylene ratio is 35:30:35 and pressing time is 20 minute (Fig. 4.5). The variation of thickness swelling may be due to the variation in the characteristic of microscopic structures (cells, cell lumen and the average micro-fibrillar angle in the cell walls etc) of rice husk and straw or adhesive. It was found that pressing time has no or very slight effect on linear expansion. Fiber-plastic ratio has a great effect on linear expansion, because linear expansion of plastic is very low in appropriate condition it prevent the linear expansion of boards. ANOVA table for thickness swelling is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of 0.811. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

### 4.2.6 Modulus of Elasticity (MOE)

This study shows the Modulus of Elasticity (MOE) of rice husk and straw polymer board was ranges 1100-2300 N/mm$^2$. Highest value is 2374.62 N/mm$^2$ where rice husk and rice straw to polypropylene ratio is 35:30:35 and pressing time is 20 minute and lowest value 1174.23 N/mm$^2$ where rice husk and rice straw to polypropylene ratio is 30:40:30 and pressing time is 15 minute (Fig. 4.6). It was found that pressing time has very little effect but fiber-plastic ratio greatly affects Modulus of Elasticity (MOE). It may be for the elastic capacity of plastic. But when pressing time rise then elastic capacity of plastic may be slightly reduces. ANOVA table for MOE is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of

0.836. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

According to Desch and Dinwoodi (1996), the Modulus of Elasticity (MOE) is 2500 $N/mm^2$ is standerd.

### 4.2.7 Modulus of Rupture (MOR)

In this study, it has been found that the Modulus of Rupture (MOR) of rice husk and rice straw-propylene board was ranges 15-25 $N/mm^2$. Highest value is 24.41 $N/mm^2$ where rice husk and rice straw to polypropylene ratio is 35:30:35 and pressing time is 20 minute and lowest value 15.42 $N/mm^2$ where rice husk and rice straw to polypropylene ratio is 30:40:30 and pressing time is 15 minute (Fig. 4.7). It was found that when plastic content increase Modulus of Rupture (MOR) also increases but after a sudden point it again decreases. It may be for the nature of plastic. Plastic may be bonded highly with other materials than itself. On the other hand when pressing time is raised then Modulus of Rupture (MOR) also rises. May be in long pressing time materials get more time for proper mixing and bonding. ANOVA table for MOR is shown in (table appendix-) the model was fitted because it presents the value of $R^2$ of 0.965. Two factors (ratio and pressing time) were found to be statistically importance at a confidence level of 95%.

## Conclusion:

Effective utilization of agricultural products may be possible by using rice straw and rice husk as an alternative raw material in board industry. It may help to reduce pressure on forest. The present study has shown that rice husk and rice straw along with polypropylene can be successfully utilized to make polymer board with useful physical and mechanical properties. In the light of the preliminary results of this study, the density of board increase with the increase of polypropylene. On the other hand moisture content of board decreases with the increase of polypropylene. Other physical properties water absorption, linear expansion and thickness swelling don't show linear relation with rice husk-polypropylene ratio. That means optimization is essential to manufacture good board. The results indicate that the MOE and MOR is increase with the increase of polypropylene but after a point these again decrease with the increase of polypropylene. Maximum physical and mechanical properties can be improved for increasing pressing time. So pressing time is a very important factor for rice husk and rice straw polymer board. In the light of results it is seen that the rice husk and rice straw to polypropylene of ratio 35:30:35 for pressing time 20 minutes shows best result. So matching of ratio with temperature and pressing time is actually should be the main concern for manufacturing good boards. Rice husk and rice straw polymer board is soundness both economically and environmentally, and the availability of rice husk and rice straw in our country is high. So further study is necessary to improve the mechanical and physical properties of rice husk and rice straw polymer board.

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# Appendix

## Table 1: ANOVA for density

ANOVA

**Dependent Variable: Density**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 74163.376 | 3 | 24721.125 | 67.734 | .015 |
| Intercept | 11153021.020 | 1 | 11153021.020 | 30558.632 | .000 |
| Ratio | 73810.249 | 2 | 36905.125 | 101.118 | .010 |
| Time | 353.127 | 1 | 353.127 | .968 | .429 |
| Error | 729.942 | 2 | 364.971 | | |
| Total | 11227914.339 | 6 | | | |
| Corrected Total | 74893.318 | 5 | | | |

a. R Squared = .990 (Adjusted R Squared = .976)

## Table 2: ANOVA for Moisture content

ANOVA

**Dependent Variable: MC**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 1.415 | 3 | .472 | 11.550 | .081 |
| Intercept | 85.428 | 1 | 85.428 | 2091.267 | .000 |
| Time | .290 | 1 | .290 | 7.109 | .117 |
| Ratio | 1.125 | 2 | .563 | 13.770 | .068 |
| Error | .082 | 2 | .041 | | |
| Total | 86.925 | 6 | | | |
| Corrected Total | 1.497 | 5 | | | |

a. R Squared = .945 (Adjusted R Squared = .864)

**Table 3: ANOVA for water absorption**

ANOVA

Dependent Variable: WA

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 195.349 | 3 | 65.116 | 3.608 | .225 |
| Intercept | 2963.259 | 1 | 2963.259 | 164.206 | .006 |
| Time | 83.477 | 1 | 83.477 | 4.626 | .164 |
| Ratio | 111.872 | 2 | 55.936 | 3.100 | .244 |
| Error | 36.092 | 2 | 18.046 | | |
| Total | 3194.700 | 6 | | | |
| Corrected Total | 231.441 | 5 | | | |

a. R Squared = .844 (Adjusted R Squared = .610)

**Table 4: ANOVA for linear expansion**

ANOVA

Dependent Variable: Linear expansion

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | .666 | 3 | .222 | 5.150 | .167 |
| Intercept | 4.167 | 1 | 4.167 | 96.637 | .010 |
| Time | .167 | 1 | .167 | 3.865 | .188 |
| Ratio | .499 | 2 | .250 | 5.792 | .147 |
| Error | .086 | 2 | .043 | | |
| Total | 4.919 | 6 | | | |
| Corrected Total | .752 | 5 | | | |

a. R Squared = .885 (Adjusted R Squared = .713)

## Table 5: ANOVA for thickness swelling

ANOVA

**Dependent Variable: TS**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 134.672 | 3 | 44.891 | 8.170 | .111 |
| Intercept | 2079.109 | 1 | 2079.109 | 378.395 | .003 |
| Time | 55.998 | 1 | 55.998 | 10.192 | .086 |
| Ratio | 78.674 | 2 | 39.337 | 7.159 | .123 |
| Error | 10.989 | 2 | 5.495 | | |
| Total | 2224.771 | 6 | | | |
| Corrected Total | 145.661 | 5 | | | |

a. R Squared = .925 (Adjusted R Squared = .811)

## Table 6: ANOVA for MOE

ANOVA

**Dependent Variable: MOE**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 984353.270 | 3 | 328117.757 | 9.472 | .097 |
| Intercept | 20067129.792 | 1 | 20067129.792 | 579.299 | .002 |
| Ratio | 977351.836 | 2 | 488675.918 | 14.107 | .066 |
| Time | 7001.434 | 1 | 7001.434 | .202 | .697 |
| Error | 69280.744 | 2 | 34640.372 | | |
| Total | 21120763.806 | 6 | | | |
| Corrected Total | 1053634.014 | 5 | | | |

a. R Squared = .934 (Adjusted R Squared = .836)

**Table 7: ANOVA for MOR**

**AVOVA**

**Dependent Variable: MOR**

| Source | Type III Sum of Squares | df | MeanSquare | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 57.242 | 3 | 19.081 | 46.559 | .021 |
| Intercept | 2248.083 | 1 | 2248.083 | 5485.583 | .000 |
| Time | 2.184 | 1 | 2.184 | 5.329 | .147 |
| Ratio | 55.058 | 2 | 27.529 | 67.174 | .015 |
| Error | .820 | 2 | .410 | | |
| Total | 2306.145 | 6 | | | |
| Corrected Total | 58.062 | 5 | | | |

a. R Squared = .986 (Adjusted R Squared = .965)