INTRODUCTION

Background

Lignocelluloses materials such as bamboo can be used as raw material of Oriented Strand Board (OSB). The bamboo has been processed into an extended diversity of products ranging from domestic household products to industrial applications, especially as an alternative substitute for wood in producing pulp, paper and composite boards. There are many advantages of bamboo which includes fastest growing plant, availability for the housing, regenerates plant, bamboo is very composite product.

OSB is a structural composite products and one of the wooden panels that are designed to replace the plywood (Nishimura et al. 2004). Production trends in the forest product industry indicated less production of structural plywood and increased production of composite wood panels like OSB. OSB is a performance-rated structural panel engineered for uniformity, strength, versatility, and workability. It is utilized internationally in wide array of applications, including building construction, flooring, partitioning packing as and parts in furniture and automotive products (SBA 2004). OSB has a viable potential in time of curtailed timber supplies due to reducing forest, demand from conservation groups and public for saving the environment and more stringent logging regulations.

The performance of OSB is mainly affected by adhesive penetration in to strand, higher penetration can enhance its performance. Resin type and its content significantly influence the properties of wood based composites. The use of higher resin loading levels and more advanced resin systems, such as Methylene Diphenyl Diisocyanate (MDI) can directly improve strength and dimensional stability of the wood composites panels (Norita et al. 2008; Sumardi et al. 2008). However Utilization of isocyanides glue in making of OSB can increase production cost because the price expensive relative but free formaldehyde emission (Marra 1992).

According to Saad (2008) that of face-core ratio of 50:50 with the levels of isocyanides adhesive glue 6% yield of Betung bamboo OSB with the best quality standard JIS A 5908-2003. Face-core ratio greater will increase the strength (MOE and MOR) in length parallel testing OSB will reduce the power otherwise
the OSB wide parallel testing. A lot of bamboo species can be used as structural material in the Sudan, such as bamboo Betung, bamboo Andong and bamboo Tali, it’s very promising to be used as material for OSB. With those considerations, the study about properties of oriented strand board from mixing bamboo is needed.

**Objectives**

The purpose of this research was to determine the properties of OSB made from mixing bamboo bonded with isocyanides resin, specific objective are:

- To evaluate the effect of strand combination on the physical properties, mechanical properties and durability of OSB against termites attack.
- To find out the best composition of OSB made from mixing bamboo.

**Benefit of this Research**

The result of this research are expected to be able to give information of exploiting of bamboo as one alternative of source of raw material to support accomplishment of industrial raw material of processing of wood and at the same time creates friendly product.

**Research Hypothesis**

Strand combination gives real influence on the physical, mechanical properties and durability of OSB against termites attack.
LITERATURE REVIEW

Bamboo

Bamboo is one potential alternative raw material and very promising because of the abundant availability, rapid growth, and easily cultivated (Muin et al. 2006). Bamboo is a perennial grass and included in the subfamily Bambusoidae, family Graminiae with woody stems and beruas-sections. There are about 87 genera and more than 1500 kinds of bamboo in the world, and about 100 species of which have important economic value (Diver 2001). The data presented by Maoyi and Bay (2004) showed the increasing number of known species of bamboo, which are more than 1200 kinds of them found in Asia. Bamboo has many benefits, both ecological benefits as well as industrial raw materials. In ecological terms, bamboo is very beneficial for the environment because it produces a very high biomass. Bamboo forest biomass can produce seven times more than the trees. Therefore the role of bamboo forests as producers of oxygen \((O_2)\) and absorbing carbon dioxide \((CO_2)\) in the interest of the global ecosystem is very important, especially in tropical areas where natural forest has declined drastically. Other ecological functions are the ability to prevent erosion because it can strengthen the bonds holding soil particles and water runoff. Because of the diverse ecological functions, bamboo is a plant that can be used for the cultivation of marginal lands (PT Bamboo Nusantara).

Utilization of bamboo as an industrial raw material is often found on construction products, stairs, fences, container, furniture, and some handicraft products. In addition to the common use of bamboo, the bamboo is to use a more appropriate and more extensive, few studies about the characteristics and basic properties have been implemented. Dransfield and Widjaya (1995) wrote in her study of the anatomy of bamboo columns consisting of approximately 50% of parenchyma, 40%, 10% fiber and connective cells (vessels and save tubes). Parenchyma and connective cells are more common in the inside of the column, whereas more fibers found on the outside. While the joint arrangement connecting fibers between the book has a tendency to grow from the bottom up while parenchyma reduced. The results of the study (Londono et al. 2002) showed that species of bamboo *Guadua angustifolia* from Columbia consisting of 40% fiber,
51% parenchyma, and vascular tissue 9%. The research by Latif et al. (1990) on the type of *Bambusa vulgaris*, *Bambusa blumeana*, and *Gigantochloa scortechinii* between the age of 1 - 3 years showed that the size of vascular bundle (the ratio of radial: tangential) and fiber length positively correlated to the MOE and the proportion of the voltage at the boundary. They explained that bamboo has a longer fiber will be more rigid if the size of vascular bundle was greater. The relationship between fiber lengths with shear determination is negative. Fiber wall thickness correlated positively with the press and the MOE determination but negatively correlated with MOR.

Li et al. (2004) reported that the mechanical properties of bamboo increases with increasing age. Thiers research further suggested that increased concentrations of vascular bundle from the inside out (Li et al. 2007). in the same study also found that there was an increase of the significant weight of 1-year-old bamboo and 3 years due to the increased of number of cells in the vascular bundle and the secondary cell wall thickening. But despite *holocellulose* and lignin content klaxon also increased at the age of 3 years but its value is relatively small. So with extractive content also increased from age 1 year to 3 years of age.

The results of research on the chemical properties of bamboo and raised by Li et al. (2004) which stated that bamboo has a cellulose content ranged from 42.4% - 53.6%, lignin levels ranged between 19.8% - 26.6% while the levels of pentose 1.24% -3.77%, ash content of 1.24% - 3.77%, silica content 0,10% - 1.28%, extractive content (solubility in cold water) 4.5% - 9.9 %, extractive content (solubility in hot water) 5.3% - 11.8% and the extractive content (solubility of benzene in alcohol) 0.9% - 6.9%. Research conducted by Li et al. (2007). Showed that the bamboo *Phyllostachys pubescent* increased content of *α-holocellulose* and cellulose from the base to the tip of the rod, but the lignin content (klaxon) and ash levels are not significantly different. The outer layer has a degree *holocellulose* rod, *α-cellulose*, and lignin (klaxon) the highest compared to other parts and have the levels of extractive and ash levels are lowest. On the other hand, the silica content of the epidermis is three times higher than the deepest layers of bamboo.
Further research on the physical properties of bamboo proposed by Dransfield and Widjaja (1995) which stated that the bamboo water content increases from the bottom up from age 1 - 3 years, but then declined in bamboo older than 3 years. Increased water content in the wet season compared with the dry season. Further research by Hadjib and Karnasudirdja (1986) showed that some of the things that affect the physical and mechanical properties of bamboo are age, height position, diameter, thick bamboo meat, the position of the load (in a book or a segment), the radial position from the outside to the inside and levels bamboo water. Unlike the wood-dimensional change after water levels dropped below the fiber saturation point, and the diameter of the cell walls of bamboo experienced immediately after the bamboo shrinkage water loss. Bamboo with older age (3 years) has a stability dimension that is higher than younger bamboo (1 year) (Latif 1993). Results of research by Lee et al. (1994) showed that the shrinkage in the radial direction is much larger than the double dual tangential direction, while shrinking in the direction of relative longitudinal negligible.

Multifunctional bamboo panels are made by combining the product with bamboo stall round people using adhesive has been developed. Type bamboo panels can be used as a component of the walls, floors, beams, roof cover, and concrete printer. Noermalicha (2005) has developed a laminated arch design of bamboo as a phenomenon of technology-based design using Betung bamboo, bamboo ropes, and bamboo buggy. Utilization of bamboo as raw material of cement composite board has been done by Suhasman et al. (2008). In these studies found that the use of bamboo at different age classes (young bamboo, mature, and old) with conventional methods was to produce cement board with the same relative quality.

Overview of Betung Bamboo (Dendrocalamus asper (Schult.f.).

Bamboo has a Latin name Betung Dendrocalamus asper (Schult,) Backer ex Heyne. Betung Bamboo is also having a many local names for cultivars of green called Betung, Beto (Manggarai), Bheto (Bajawa), and Statues (Tetum), whereas for black cultivars called Bheto Laka (Bajawa). In the Lesser Sunda Islands, Betung bamboo scattered occurred everywhere, but grows best in places that are less juicy but lecil trunk diameter. This type of bamboo is habitat on
alluvial soil in the humid tropical areas and wet, but bamboo is also grown in dry areas and high plains (Widjaya 2001).

Betung Bamboo is a cheap building materials and strong, but in its use of bamboo is very popular type of powder. This powder content closely related to the content of starch substance in Betung bamboo. To reduce the starch content of existing substances should be an effective treatment before the bamboo is used as building material (Prawirohatmojo 1979). Based on research Hadjib and Karnasudirdja (1986) Betung bamboo has physical and mechanical properties as shown in Table 1.

Table 1 Physical and Mechanical Properties of Betung Bamboo.

<table>
<thead>
<tr>
<th>No.</th>
<th>Physical and Mechanical Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MOR perpendicular (kg/cm²)</td>
<td>342.47</td>
</tr>
<tr>
<td>2.</td>
<td>MOR parallel (kg/cm²)</td>
<td>416.57</td>
</tr>
<tr>
<td>3.</td>
<td>MOE (kg/cm²)</td>
<td>53173.0</td>
</tr>
<tr>
<td>4.</td>
<td>Specific gravity (g/cm³)</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Taxonomy

Domain: Eukaryota
Kingdom: Plantae
Subkingdom: Viridaeplantae
Phylum: Tracheophyta
Subphylum: Euphyllophytina
Infra phylum: Radiatopses
Class: Liliopsida
Subclass: Commelinidae
Superorde: Poanae
Order: Poales
Family: Poaceae
Subfamily: Bambusoideae
Tribe: Bambuseae
Genus: Dendrocalamus
Specific epithet: asper
Botanical name: Dendrocalamus asper

Overview of Tali Bamboo (Gigantochoa Apus (J.A. and J.H. Schultes) Kurz).

Bamboo rope with a Latin name Gigantochoa apus (JA and JH Schultes) Kurz), has a strap Pring area, Pring apus (Java), awi rope (Sunda). Bamboo rope
are scattered throughout Java, but also grows wild in National Park and Meru Alas Purwo Betiri. Original habitat of bamboo rope is a humid tropical region and dry. Bamboo rope is symposia, meetings, and upright (Widjaya 2001). Some physical and mechanical properties of bamboo rope *Ginoga* based on research (1987) included static bending strength, fortitude press parallel fibers, shear strength, tensile strength perpendicular to fibers, strength sides, density, water content, and stiffness. The complete value of physical and mechanical properties of bamboo learn presented in Table 2.

Table 2 Physical and Mechanical Properties of Tali Bamboo.

<table>
<thead>
<tr>
<th>No</th>
<th>Physical and Mechanical Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Determination of static bending</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Proportion of tension in the limit (kg/cm²)</td>
<td>327</td>
</tr>
<tr>
<td></td>
<td>b. Voltage on a broken line (kg/cm²)</td>
<td>546</td>
</tr>
<tr>
<td></td>
<td>c. Modulus of elasticity (kg/cm²)</td>
<td>10100</td>
</tr>
<tr>
<td>2.</td>
<td>Press parallel fibers (maximum stress, kg/cm²)</td>
<td>504</td>
</tr>
<tr>
<td>3.</td>
<td>Shear strength (kg/cm²)</td>
<td>39,5</td>
</tr>
<tr>
<td>4.</td>
<td>Perpendicular tensile tenacity fibers (kg/cm²)</td>
<td>28,3</td>
</tr>
<tr>
<td>5.</td>
<td>Strength sides (kg/cm²)</td>
<td>58,2</td>
</tr>
<tr>
<td>6.</td>
<td>Weight type</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Specific gravity (g/cm³)</td>
<td>0,63</td>
</tr>
<tr>
<td></td>
<td>b. client dried (16.42%)</td>
<td>0,58</td>
</tr>
<tr>
<td>7.</td>
<td>At determination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. On the inside (kg/cm²)</td>
<td>45,1</td>
</tr>
<tr>
<td></td>
<td>b. Tangential direction (kg/cm²)</td>
<td>31,9</td>
</tr>
</tbody>
</table>

**Taxonomy**

Domain: **Eukaryota**  
Kingdom: **Plantae**  
Subkingdom: **Viridaeplantae**  
Phylum: **Magnoliophyta**  
Subphylum: **Euphyllophytina**  
Infra phylum: **Radiatopses**  
Class: **Liliopsida**  
Subclass: **Commelinidae**  
Superorde: **Poanae**  
Order: **Poales**  
Family: **Poaceae**  
Genus: **Gigantochloa**  
Specific epithet: *levis*  
Botanical name: Gigantochloa levis
Overview of Andong Bamboo (*Gigantochloa verticillata* (Willd.) (Munro)).

Bamboo has the name of the horse cart gombong Pring, Pring buggy, Pring letter (Java), awi buggy, and awi gombong (Sunda). Bamboo is spread across the island of Java with there habitat growing in lowland until height of 1500 mm and grows well in humid tropical areas with clumps symposia, upright and dense (Widjaya 2001). Hadjib and Karnasudirdja (1986) stated in there research, that the physical and mechanical properties of bamboo buggy is as follows: specific gravity of 0.55 g/cm$^3$ for a bamboo horse cart, press the parallel determination of 293.25 kg/cm$^2$, modulus of elasticity 23,775 kg/cm$^2$, and the maximum bending strength of 128.31 kg/cm$^2$.

**Taxonomy**

Domain: **Eukaryota**
Kingdom: **Plantae**
Subkingdom: **Viridaeplantae**
Phylum: **Magnoliophyta**
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Class: **Liliopsida**
Subclass: **Commelinidae**
Superorde: **Poanae**
Order: **Poales**
Family: **Poaceae**
Subfamily: **Bambusoideae**
Tribe: **Bambuseae**
Genus: **Gigantochloa**
Specific epithet: *verticillata*
Botanical name: Gigantochloa verticillata

**Oriented Strand Board (OSB)**

OSB are panel products made of aspen or poplar (as well as southern yellow pine in the US) strands or wafers bonded together under heat and pressure using a waterproof phenolic resin adhesive or equivalent waterproof binder. Oriented strand board (OSB) was developed in the late seventies. OSB is made of aspen-poplar strands, southern yellow pine or mixed hardwood species. However, the strands in the outer faces of OSB are normally oriented along the long axis of the panel thereby, like plywood, making it stronger along the long axis as compared to the narrow axis. The strands used in the manufacture of OSB are from 80 to
150 mm (3-1/8 to 6) long in the grain direction and less than 1 mm (1/32") in thickness. In Canada, OSB are manufactured to meet the requirements of the Canadian Standards Association (CSA) standard *CAN/CSA O325.0, Construction Sheathing* or the standard *O437 Series on OSB*. For engineered applications, OSB can also be certified to meet the requirements of CSA O452, *Design Rated OSB*.

In the U.S., the requirements of *PS 2, Performance Standard for Wood-Based Structural-Use Panels* must be met. PS 2 is a voluntary product standard published by the National Institute of Standards and Technology of the US Department of Commercial. OSB is efficient additions to the family of wood building materials because:

- They are made from abundant, fast growing, small diameter aspen poplar or pine to produce an economical structural panel.
- The manufacturing process can make use of crooked, deformed, small diameter trees which would otherwise have little commercial value, thereby maximizing forest utilization.
- Many strength-reducing defects are removed during manufacturing, and any remaining defects are evenly dispersed throughout the panel, resulting in consistent strength properties.
- The orientation of strands gives increased strength properties along the long panel dimension (strength axis) of OSB. For wafer board, random alignment of the wafers gives more consistent strength properties throughout the panel.
- Specific strength properties can be achieved by adjusting the orientation of strand or wafer layers.

**Uses of OSB**

Some specialty products are made for siding, rim boards, stair treads, concrete formwork, or treated or foil-faced sheathing. OSB is also used as the web material for most types of prefabricated wood I-joists, and as outer skins in structural insulated (foam-core) panels. The panels are cut and machined using regular carpentry tools. Tungsten carbide tipped blades are recommended.
Application of OSB

The physical and mechanical properties of OSB make it suitable for a wide range of structural and non-structural applications. OSB is widely employed in the U.S., Canada, and Japan, practically replacing plywood for many applications in residential construction and has also been gaining recognition in the commercial construction industry (Brochmann et al. 2004; Gu et al. 2005).

Oriented strand board is the most commonly used structural engineered wood panel in new residential housing construction in North America. OSB is aggressively-replacing plywood as the primary sheathing used in new construction in North America. Approximately 65% of the 43 billion square feet of construction sheathing used in 2005 consisted of OSB. While the remaining 35% consisted of plywood sheathing (Adair 2005). OSB and plywood share the same exposure durability classifications: Interior. Exposure 1 (95% of all structural panels). Exposure 2 and Exterior (SBA 2009). They share the same set of performance standards and span ratings. Both materials are installed on roofs, walls and floors using one set of recommendations. Installation requirements prescribing the use of all-clips on roofs, blocking on floors and allowance of single layer floor systems are identical.

Manufacture of OSB

The process described here is general and may vary in detail from one manufacturer to another but it is always comprised of log conditioning, stranding or wafering, drying, blending, forming, pressing, and final processing. Freshly cut logs are taken from the log storage yard and placed in hot water ponds. The soaking softens the wood to facilitate debarking and making of strands or wafers, thereby reducing the amount of fines and slivers generated. To maintain effectiveness, hot pond temperatures are increased in cold weather conditions. After conditioning, the logs are debarked and fed into a machine with sharp knives. This stranded or waterier cuts the log pieces into strands or wafers along the grain. The strands or wafers are conveyed to wet storage bins and are screened.
after drying to remove fine particles. Most mills process core and surface strands and wafers separately and then deposit them together in layers to form the mat.

The strands or wafers are placed in large cylindrical dryers where they are dried to a moisture content of three to seven percent. While in the dryer, the strands or wafers rotate slowly minimizing breakage of the strands while ensuring consistent moisture content. When dry, the strands or wafers proceed to the blender where they are mixed with resin and wax. The small quantity of hot wax (about 1.0 to 1.5 percent of the weight of wafers) sprayed on the wafers helps to distribute evenly the powdered or liquid phenol-formaldehyde resin or polyurethane binder (2.0 percent to 3.5 percent by weight or more). Resins or binders are of the thermosetting type, which means they can't be softened by heat or moisture once fully cured. The strands or wafers are continuously weight metered to ensure the proper quantities enter the blenders so that the correct resin coverage is achieved (SBA 2009).

The forming machine arranges the strands or wafers in several layers to form a mat on stainless steel press sheets or on a continuous belt. For OSB, the strands for the faces are usually oriented parallel with the long direction of the panel (machine direction) and the core layers are either cross-oriented or laid random. For wafer board, the wafers are randomly deposited. The size of the mats varies with the press size, but generally, one mat will be large enough to produce several standard sized panels. In multi-opening presses, the mats are placed in the press accommodating from 10 up to 24 sheets at a time. Each mat sits between a pair of heated platens. When all the mats have been inserted, the press is closed under heavy pressure.

The layup of the mat and the press operation are important in ensuring proper panel thickness. The duration of the press cycle varies from plant to plant and with the desired thickness of the board. For example, a press cycle of 3-1/2 minutes might be required for 6.35mm (1/4) thick panels, and eight minutes for 15.5mm (5/8) panels. The heat and pressure polymerize the resin or binder gluing the strands or wafers together strongly into a rigid panel. In newer plants, some presses are long and continuous rather than the more conventional stacked multi-opening presses. In those presses a continuous mat enters the front end of the
press. Finished board exits the rear end of the press, which is then cut to the required size with flying cross-cut saws.

**Factors affecting the properties of OSB**

There are many factors affecting the final board properties. Among the major factors are wood species and its density, strand quality, strand size, aspect ratio of the strand, strand orientation, resin type, layer structure, pressing parameter, board moisture content and board density (Maloney 1993). Almost all of these factors interact with each other in one way or another. A change in any of these factors will result in a change in many of the other related factors in the board process. Consequently, each factor cannot be thought of as an individual entity which can be manipulated easily to control the board process as one sees fit. However, once it is recognized that there is an interrelationship between a numbers of factors, a more complete grasp of the process can be attained and actual manipulation can be successfully employed for controlling much of the process (Maloney 1993).

**Wood species**

Species is one of the most significant factors in the OSB process. It interacts virtually with every other variable that can be imagined in the process. It determines how low in density the final board can be. The most important species variable governing board properties is the density of the wood raw material itself. The density or specific gravity has been the important factor in determining which species are used for manufacture of OSB. In general terms, the lower-density woods will produce panels within the present desired specific gravity ranges, usually with strength properties superior to the higher-density species (Maloney 1993). Although it is technically possible to produce OSB from wood of any density, boards made from dense woods become so heavy that they are difficult to handle and expensive to ship (Bowyer 2003). Early OSB mills primarily utilized aspen because of its low density, low cost, and wide availability.

OSB mills can use almost any low-to-medium-density species that is widely available (Bowyer 2003). Aspen (Populus tremuloides), southern pines (Finns
spp.), inontery pine (Pinus radiata), sweet gum (Liquidambar styraciflua), yellow poplar (Liriodendron tulipifera), birch (Betula spp.). Spruce (Picea spp.) and fir (Abies spp.) are several wood materials used in commercial OSB (Bliss 1989; Wane 2000; Wu and Piao. 1999). These woods have relatively low density. Species of relatively high density, such as beech, are often mixed with these species to maintain acceptable board properties. The reason for the preferential use of the relatively light species is that they can be compressed into medium-density OSB with the assurance that sufficient antiparticle contact area is developed during the pressing operation to achieve good bonding.

To produce satisfactory contact between strands in the board, it is usually necessary to compress the board to a density 1.2-1.6 times than the strands initial densities (Bowyer et al. 2003). This ratio between board density and wood density is called the compression ratio. Maloney (1993) pointed out that a compression ratio of 1.3 is a good guideline for determining the minimum board density for a medium-density board. Using this guideline, it would be expected that satisfactory OSB could be produced using wood with density ranging 0.3-0.5 g/cm$^3$ (Maloney 1993). Caesar (1997) reported that wood having density less than 0.35 g/cm$^3$ cannot be densified sufficiently to achieve good strength, whereas very high density board will blow, because the steam generated inside the board during pressing cannot escape. Wood species of density more than 0.75 g/cm$^3$ may create stranding difficulties and produce a lot of fines. Moreover, the strands are stiff and brittle which make it more difficult to be compressed to form mat.

**Strand geometry**

Strand geometry is one of the most important factors determining the properties and appearance of OSB. In general, longer and thinner strands improve properties by providing more actual contact area and better stress transfer. They yield a higher degree of permanent set after densification at elevated temperatures and significantly decrease thickness swelling and linear expansion (industry Canada 2009).

Several aspects of board performance are directly affected by strand geometry (Maloney 1993): 1. Mechanical properties such as bending strength,
bending stiffness, tensile strength parallel to the surface, tensile strength perpendicular to the surface (internal bond), wood screw holding power, and nail holding strength. 2. Board surface characteristics, particularly surface smoothness of face and edges, which in turn affect finishing and secondary gluing characteristics. 3. Moisture responses such as moisture absorption from liquid or vapor phase and corresponding changes in dimensions, mechanical properties, and surface characteristics. 4. Behavior in machining operations such as sawing, boring, routing, shaping, planning, and sanding.

Slenderness and aspect ratios can be used to estimate strand orientation and particle behavior of the board. They can be expressed by length, width and thickness information. Slenderness ratio can be described as particle length divided by its thickness. Generally the particle becomes more slender when the ratio is higher. Particle with ratio over one will be longer than its thickness and thus will amenable to orientation. Particle with high slenderness ratio can be aligned to increase the board strength (Maloney 1993). Slenderness ratio can be related to certain board characteristics such as contact area in the mat. Mechanical properties of the finished board, and the consumption of binder in board (Moslemi 1974). Greater quantity of resin per unit surface area of particle is needed if the ratio value is lower.

Aspect ratio is measured by dividing particle or flake length by its width. A particle cannot be oriented if having aspect ratio of one (square shape). Maloney (1993) suggested that good orientation could be achieved in board at aspect ratio of at least three. According to Shuler et al. (1976), and Kuklewski et al. (1985). An aspect ratio of two is enough to produce board with superior properties. The southern pine strands used in three OSB mills in North America were recorded to have size approximately 76.2-88.9 mm, 6.4-38.1 mm, and 0.51-0.64 mm in length, width and thickness, respectively (Biblis 1989). used strands from a commercial mill that consist 85% southern pine (Pinus spp.) and 15% regional medium density hardwoods (sweet gum, tupelo gum, yellow-poplar, willow, etc) with slenderness ratio of 108-152 and aspect ratio of 2-4. Suzuki and Takeda (2000) produced OSB from sugi (Cryptomeria japonica) with the target geometry 20 mm in width. 0.6 mm in thickness, and length of 30. 50 and 70 mm.
The study concluded that modulus of rupture (MOR) and modulus of elasticity (MOE) of the boards in the parallel direction increased with increasing the strands length. In accordance with the Suzuki and Takeda (2000) work, a study by Chen et al. (2008). With average strand length between 71 mm and 128 mm and strand slenderness ratio between 1 and 10, indicated higher slenderness ratio were associated with higher concentrated static load (CSL) ultimate load and MOR, MOE, and shear properties in both major and minor directions and lower CSL deflection.

**OSB structure: layer and face to core ratio**

Mat or layer forming is one of the important stages in OSB manufacturing. Forming in OSB production means mechanical action applied to the strands in order to force them to adopt a desired orientation and position. Strands and layers in OSB can be aligned to provide panel products with much greater bending strength and stiffness in the oriented or aligned direction (Maloney 1993). Layer structures again interact with most of the major parameters involved in producing boards, and manipulation can change the level of strength possible through orientation.

Oriented strand board is normally produced in three layers in which the core layer is perpendicular to surface layers. However, there are also some producer increases the core layers purposely to meet certain product requirements. For example, a company in U.S. produced four layers OSB with two face layers and two core layers bonded with phenol resins (Huber Engineered Woods, 2009). A study used one strand layer was performed by Del Menezzi et al. (2005). And found that thickness swelling of the board can meet the requirement of Canadian Standard (CSA 0437-93) for grade O-1 panels.

Several studies determined the effect of layer structure on the properties of OSB. Sumardi et al. (2007). Produced OSB with three different layer structures. The results revealed that bending strength (MOE and MOR) of unidirectional oriented homogenous board (UNMD) in parallel direction were higher than three-layered OSB with a cross-oriented core layer (3OSB).
Conversely bending strength of 3OSB in the perpendicular direction was higher than UN1D board. Similar results were obtained by Hermawan et al. (2006).

The layers in OSB production are arranged into some proportion of face to core ratios. Commercial boards normally have face to core weight ratio of approximately 50:50 (Wu and Piao, 1999). Similar ratio was followed by many studies in OSB manufacture (Pichelin et al. 2001; Sumardi et al. 2008; Wang et al. 2000).

**Adhesive for OSB**

**Poly (Diphenyl Methane Diisocyanate), MDI**

MDI has become a common resin used in OSB production, despite costing significantly more than PF. Like PF, it produces waterproof bonds suitable for use in Exposure 1 classified panels. In fact, the nature of its adhesion to wood makes its performance better than PF when exposed to moisture. Unlike PF, MDI does not primarily form mechanical bonds with the wood substrate; it is also capable of forming covalent chemical bonds with wood. These chemical bonds are stronger and more stable than mechanical linkages, so manufacturers can potentially use less resin to achieve similar, or greater, performance with lower adhesive loadings than PF. Lower resin loading saves money, which can help to offset the increased cost per unit of adhesive (wood based panel international 2009). The surface of wood is rich in chemical functional groups called hydroxyl groups (–OH). MDI resins are terminated in isocyanides groups (–N=C=O), which can react with the hydroxyl groups on wood, forming urethane linkages. A combination of factors such as the non-polar, aromatic component of MDI resins, and the existence of the urethane linkages as part of a cross-linked network help to make cured MDI resins resistant to hydrolysis. Some advantages associated with using MDI adhesive include:

- greater tolerance for higher moisture content wood
- lower press temperatures
- Faster press cycles may be possible.

As discussed regarding the use of powdered PF, greater tolerance for higher moisture content wood and lower press temperatures can result in energy savings. The combination of reduced costs (energy savings and lower resin usage) and
increased productivity (reduced press cycle time) can help offset the additional cost of the adhesive. Because of the chemistry involved, MDI-bonded products can be used in more demanding applications where increased water resistance is required. Potential disadvantages associated with MDI use include:

- The need to use mold releases since MDI will bond to metal surfaces and stick panels to press platens and cauls.
- A greater need to monitor environmental conditions around the press and blenders, due to health risks associated with uncured MDI in aerosol form.
- Special storage considerations to protect MDI from contact with atmospheric moisture which can cause procure.
- Questions remain regarding the resistance of MDI-bonded products to deformation under long-term loading conditions.

**Board density**

Board density is a powerful factor affecting board properties. In most cases, an increase in board density results in a concomitant improvement in physical properties in particleboard. It has been found that a board density of 0.15 to 0.20 g/cm³ above that of the whole wood is necessary to achieve minimum physical properties, unless low-density products are purposely being made. Higher density board is associated with higher strengths, more difficult machining characteristics, higher cost per unit volume, and a greater degree of dimensional instability in water soaking and exposure to high humidity. On the contrary, low density board offers better insulating characteristics, higher dimensional stability, lower strength, and less unit cost.

In practice, the easiest way to improve most board properties is usually to increase the board density. Zhang *et al.* (1998) studied the effects of two different density levels and found that increase of board density resulted in higher internal bond strength, wood screw holding power, Brinell hardness and also increased thickness swelling of the board. Sumardi *et al.* (2007). Produced OSB at five density levels: density 0.49, 0.57, 0.65, 0.73, and 0.81 g/cm³. The study found that the mechanical properties (MOR, MOE, and internal bond (IB) strength) increased with increasing board density.
The increased board density results in more intimate contact between the strands in the mat being compressed into the final board, hence it uses resin effectively. Increasing density also causes more wood to be present to resist mechanical loads. This combination of effects results in board strengths being approximately proportional to the square of board density over the usual density range.

Density profile

In the manufacture of composite boards, with similar input of raw materials. Hot pressing method is the most significant factor that influences the final board properties. During hot pressing, the interaction among heat, moisture, and pressure gives rise to non-uniform deformation of the elements, and results in an uneven density distribution along the thickness direction of the board. This density profile typically resembles a U-shape. With peak density appearing near the board surfaces, and the lowest density in the core region (Maloney 1993). illustrated typical U-shape density profile and its definitions (Wong 1999). Furnish characteristics, configuration, and compressibility. MC and its distribution; and hot pressing conditions, including type, temperature, closing speed, pressure and duration, are among the critical factors affecting the formation of density profile (Maloney 1993).

The presence of this vertical density gradient has been reported to result in higher bending strength, but lower internal bond and interlaminar shear. A steep density gradient in low-density particleboard could cause shear failure to occur before the specimen fails in tension or compression during bending, hence reducing the modulus of rupture (Kawai et al. 1986).

Extractive substances

All woods contain extractives. These minor components can be readily extracted from wood with neutral organic solvents or water. Extraneous substances are extremely variable in composition and quantity both between and within (sapwood vs. heart wood) species (Maloney 1993). They may include hydrolysable or condensed tannins, flavonoids, and lignin. stilbenes, fatty acids, resin acids, other complex terpenoids, waxes, sterols, sugars, cyclitols and starch.
Extractives in wood may range between 5% and 30% in quantity (Maloney 1993). Although extractives occur as minor, non-structural constituents in the cell walls and cell cavities, they often are of decisive importance in contributing to many of the characteristic properties and possible uses of wood, such as its odour, color, light stability, flammability, hygroscopicity. Density, strength properties, decay and insect resistance, and permeability (Hse and Kuo. 1988). Extractives often alter the surface properties of wood, which in turn affects adhesion properties and finishing characteristics.

Difficulties may arise in gluing wood species with high extractive contents. This is especially true in gluing tropical hardwoods. Such gluing difficulties have been attributed to extractive contamination resulting from the migration of extractives to the wood surface during drying. Extractive-contaminated wood surfaces often result in low strength and less durable glue bonds. Extractives may cause gluing difficulties in the following ways (Hse and Kuo. 1988): 1. Heavy deposits of extractives on the gluing surface block the reaction sites, thus preventing the anchoring of adhesives. 2. Chemical incompatibility between the extractives and adhesives results in inferior glue bonds. 3. Extractives influence the wet ability and polarity of the wood surface so that the wet ability-permeability relationship of a particular adhesive is changed. 4. Extractives affect the curing and setting characteristics of adhesives. These gluing interference mechanisms may act individually or they may act as combined effects.

Maloney (1993) reported that extractives affected on adhesive consumption and its curing rate, poor water resistance properties of the finished product, problems with blows during the pressing, delaminating after pressing, and change board color.