1. Background of research

- Need for development of environmentally friendly natural materials
  - Sick House Syndrome
    - Atopic allergy from chemicals contained in the indoor materials of new house
  - Deficiency of raw materials
    - Drastic increase of raw material cost
  - Weak points of woods
    - Low strength - chemical coating
- Need for composites with high strength-to-weight ratios using natural(bamboo) fibers
2. Advantages & disadvantages of bamboo

**Advantages**
- Rapid growth (2 months) and utilization (after 2-3 years), unnecessary of planting except once, abundance in supply (Southeast Asia)
- Good mechanical strength, high thermal conductivity, natural elegant color, water resistance, unnecessary of chemical coating
- Natural fiber: fabrics, bamboo reinforced polymeric composites.
- Plentiful mineral elements

**Disadvantages**
- Cylindrical shape
- Cracking easily upon drying (parallel to longitudinal direction)
- Getting musty easily when humid (due to plentiful organic nutritive elements)
☞ Bamboos have been used only for indoor materials and limited so much in their utilization.
3. Flattening Methods of bamboo

Flattening of bamboo can overcome the cylindrical shape of bamboo, consequently diversifies a use of bamboo.

- Cutting and gluing
  - Cutting into many small rectangular shape pieces → removal of the outer and the inner surface parts → gluing

- Grooving and gluing
  - V-shape grooves at the surface of bamboo → gluing
  - Removal of the outer and the inner surface parts
  ⇒ sacrifice of strength and water resistance of bamboo surface

- Thermo mechanical treatment (this work)
  - Flattening bamboo without cutting and gluing process
  - Scratch and wear resistant due to original skin
4. Flattening by thermo-mechanical treatment

4.1 Flattening of cylindrical green bamboos without node

- Cylindrical green bamboos (Korean king bamboo, O.D: about 80–100 mm, L:250–400mm, t:5–7mm (cutting and cleaning))
- Then the bamboos were placed in an oven at the temperature of about 200°C. (partial opening)
- After waiting for bamboo to be opened enough the bamboos were put into the flattening machine which could flatten bamboo gradually in transverse direction
- Temperature of flattening:150–200°C, Flattening speed:10–20 cm/min
⇒The rectangular-shape bamboo plates without crack.
4.2 Schematic diagram of the machine for flattening cylindrical bamboo without node.
4.3 Flattened bamboos without node obtained by the thermo mechanical treatment.
4.4 Flattening of cylindrical bamboos with no
des

- Cylindrical green bamboos (Korean king bamboo, O. D: about 80–100 mm, L:1250mm, t:5–7mm)
- Removal of extruding parts of node outside
- Cutting into 2 pieces
- Removal of internally extruding parts of nodes
- Flattening by machine
4.4 Schematic diagram of the machine for flattening hemi-cylindrical bamboos with nodes

- Temperature of flattening: 150–200 ℃
- Flattening speed: 30–100 cm/min depending on the thickness, the moisture contained and the age of bamboo
4.5 Flattened bamboos with nodes obtained by the thermo mechanical treatment

(natural surface)

(abraded surface)
5. Flattening of bamboo at various conditions

- Flattening partially by natural drying
- Flattening partially by heating
- Flattening completely by thermo-mechanical treatment
  - Compressing (flattening)
  - Heating (drying-contracting, toughness↑)
6. Mechanism of Partial Flattening by a Natural Drying

6.1 Shape Change of a crack in bamboo with drying at RT

Artificial crack

Cf: Tempered Glass

\[ t=0, \sigma_c<0 \]
\[ t=0.7\text{hrs}, \sigma_c<0 \]
\[ t=16.5\text{hrs}, \sigma_c<0 \]
\[ t=2\text{days}, \sigma_c<0 \]
\[ t=7.7\text{days}, \sigma_c=0 \]
\[ t=11\text{days} \]
\[ t=90.8\text{days} \]
6.2 The weight changes of a green bamboo during drying at 25°C.

- a: Compressive stress (No flattening)
- b: Partial flattening
- c: Large crack opening (Partial flattening)
6.3 Flattening Mechanism of a Green Bamboo by Thermo-Mechanical Treatment

- **Comp. stress (strain)**
  - High temp.: Fast drying, larger comp. strain
  - Leading to larger contraction

- **Tensile stress (strain)**
  - Low temp.: slow drying, smaller comp. strain
  - Leading to smaller contraction

- **Heating**
  - Thermal softening ↑ → prevention from cracking
  - Drying speed ↑ → contraction
  - Thermal expansion → Over flattening

- **Pressing**
  - Different strain
  - Flattening & cracking

- **Flattening**
  - Resulting from pressing and heating effects
7. Applications of flattened bamboos

Floor and Wall
Bamboo floor, wall and tea table with ground skin
Bamboo floor with ground skin
Bamboo tables
Bamboo plates and veneer boards
Printed patterns on flattened bamboo plates 🌿
Flattened bamboo plates with printed patterns

Name card case

Cellphone cover

Ink printing