Bamboo: The Material of Future

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\begin{abstract}
Increasing demand for wood and wood-based products is associated several environmental concerns. This has shifted the focus of researchers to explore alternative materials with similar properties. Bamboo in this context has emerged as the most promising alternative to wood. Though mankind is using bamboo in various applications yet recently it has emerged as a modern engineering material. The present paper explores the applications of bamboo in various applications. Traditional uses of bamboo including pulp, paper industry, building and handicraft are reported. The potential of utilization of bamboo lies in its usage in industrial applications. Recent research elucidates the high adsorption and antibacterial properties of bamboo-charcoal. Attempts are underway to utilize bamboo charcoal based composites for pharmaceutical and textile industry. Unique insulation properties of bamboo make the bamboo building eco-friendly. Green buildings and rooftops are also in the stages of development.

\textbf{KEYWORDS:} bamboo, modern engineering materials, Green buildings
\end{abstract}

1. \textbf{INTRODUCTION}

Bamboo is a grass belonging to \textit{Gramineae} family, distributed in tropical, subtropical and mild temperate zones between approximately 46\degree north and 47\degree south latitude. There are more than 90 genera of bamboo divided into about 1,200 species [17]. Bamboo is commonly found in Africa, Asia and Central, South America, some parts of Europe and North America. India is rich in Bamboo resources with 13.96 million Hectares Forest area. Bamboo of 123 species in 23 genera is available here (FSI 2011). Bamboos are widely distributed in India, especially in
semi dry and dry zone along plains and hilly tracts, usually up to an altitude of 1000 meters. The wide distribution of bamboo shows the enormous potential it possesses to develop bamboo-based industries in India. *B. bamboo* and *D. strictus* are the two genera constitute the highest proportions of bamboo forest in India (Liese, 1998). Main species are *D. Strictus* (45%), *B. Bambos* (13%), *D. Hamiltonii* (7%), *B. Tulda* (5%) and *B. Pallida* (4%). *D. strictus* is one of the predominant species of bamboo in Uttar Pradesh, Madhya Pradesh, Orissa, and Western Ghats (Limaye, 1952). *Dendrocalamus strictus* occupies 53 percent of total bamboo area in India. *D. strictus* species is available as thick-walled and sometimes with solid culms.

2. TRADITIONAL USES OF BAMBOO

In Asian countries, bamboo has been used for household utilities such as containers, chopsticks, woven mats, fishing poles, cricket boxes, handicrafts, chairs, etc. It has also been widely used in building applications, such as flooring, ceiling, walls, windows, doors, fences, housing roofs, trusses, rafters and purlins. It is also used in construction as structural materials for bridges, water transportation facilities and skyscraper scaffoldings. There are about 35 species now used as raw materials for the pulp and paper industry [12]. Bamboo is used in building industry since ancient times. Compared to steel, concrete and timber, less mass of bamboo is able to withstand more loads. Bamboo is one of the strongest building materials. The tensile strength of bamboo (28,000 pounds per square inch), is much higher than steel (23,000 pounds per square inch). It is reported that 50 times less energy is required to generate 1 m$^3$ per unit stress for bamboo as constructional materials as compared to steel or concrete. This makes bamboo a suitable alternative to steel in load bearing applications [14, 9]. High flexibility and growth rate, low weight to height ratio, provides bamboo extensive opportunities as building material. Hollow design is structurally superior to woody stem of timber. Density of various bamboo species is 700-800 kg/m$^3$. This is important factor to be considered while building designs. Bending stress at failure is 0.14 times mass per unit volume. High value of mass per unit volume for bamboo provides it greater strength of bending failure.

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Table 1: Specific properties of bamboo [21]

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>0.575-0.655</td>
</tr>
<tr>
<td>Bond stress</td>
<td>5.6 kg/cm²</td>
</tr>
<tr>
<td>Safe working stress in shear</td>
<td>115-180 kg/cm²</td>
</tr>
<tr>
<td>Safe working stress in compression</td>
<td>105 kg/cm²</td>
</tr>
<tr>
<td>Ultimate compressive stress</td>
<td>794-864 kg/cm²</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>1.5-1.0 x 105 kg/cm²</td>
</tr>
</tbody>
</table>

Usage of bamboo varies from household products to industrial applications. Figure 1 shows general utilization pattern of bamboo in various fields. Furniture, handicrafts, ladder, basket masking, fencing etc. are the traditional uses of bamboo. Physical and environment values of Bamboo make it the best choice for housing, handicraft, pulp and paper industry. Hollow internal structure makes it light weight, easy to work with and transport. Bamboo being easy to split is used in woven industry. Other uses include agricultural instruments, fishing tools, musical instruments.

![Figure 1 Different uses of bamboo](20)
Bamboo has versatile utility from handicraft to industrially developed manufactured products. Table 1 shows market share of various category of bamboo products. Market usage of bamboo is categorized as: traditional and new products.

### 3. FUTURE POTENTIAL OF UTILIZATION

Golden Revolution in bamboo market began with introduction of bamboo in industrial sector. India and China considered bamboo as industrial material since the early 1990s. Exact statistics on trade on bamboo is insufficient because of unavailability of custom codes and national market analysis [17]. International trade in Bamboo is expected to be between $5 and $10 billion. Local trade at village level is often not recorded officially. India plays an important role in global bamboo market. Worlds 80% bamboo forests are in India, China and Myanmar (~ 198 lakh ha). Although India contributes 45% to the world bamboo production, its share in global market is only 4.5 % [18]. With the implement of proper management and preservation techniques utilization potential of bamboo can be achieved properly.

<table>
<thead>
<tr>
<th>Bamboo item</th>
<th>Market size, 2003 (Rupee Crore)</th>
<th>Market potential 2015 (Rupees Crore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoots</td>
<td>5</td>
<td>300</td>
</tr>
<tr>
<td>Timber substitution</td>
<td>10,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Plyboard</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>Plyboard for truck, railways</td>
<td>1000</td>
<td>3400</td>
</tr>
<tr>
<td>Bamboo Matboards</td>
<td>-</td>
<td>3908</td>
</tr>
<tr>
<td>Bamboo Flooring</td>
<td>100 for export, 100 for Domestic</td>
<td>1950</td>
</tr>
<tr>
<td>Pulp</td>
<td>100</td>
<td>2088</td>
</tr>
<tr>
<td>Furniture</td>
<td>380</td>
<td>3265</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>-</td>
<td>861</td>
</tr>
<tr>
<td>Housing</td>
<td>-</td>
<td>1163</td>
</tr>
<tr>
<td>Road</td>
<td>-</td>
<td>274</td>
</tr>
<tr>
<td>Miscellaneous (pencil, matches etc.)</td>
<td>394</td>
<td>600</td>
</tr>
</tbody>
</table>

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Bamboo utilization as alternative wood materials may be divided up into following broad categories. Processing being simple requires no special skill and equipment. Thus low initial investment cost is required to grow bamboo. Bamboo plant is found to be an effective carbon sink and effective in mitigation of greenhouse effect [3].

The market for green building material is wide. Multistory buildings with green roof top are reported to consume much less energy than conventional building materials [6]. Provision of bamboo as material of construction will not only provide comfortable temperature zone inside the house but also helps to reduce indoor air pollution. Zhang and Niu [23] reported the material of construction is responsible for 60% of total volatile organic compounds (TVOCs) in residential buildings. Studies of Hoang et al. [6] highlighted the fact that buildings based on bamboo have better indoor air quality and less ozone level in inside air.

Bamboo is known to have superior energy conservation properties as compared to conventional building materials [10]. Insulation properties of bamboo in construction industry makes the building more eco-friendly.

Charcoal obtained from pyrolysis of bamboo biomass is known to possess high surface area and better absorption properties than wood charcoal [2]. This makes it beneficial for various biomedical applications. Bamboo charcoal coated with nano-particles spinel ferrite (Ni0.5Zn0.5Fe2O4) spinel ferrite, forming a core-shell structure, and introduced into epoxy resin was found to be a microwave and Infrared energy absorber. Bamboo charcoal’s amalgamation with long with silver nano-particle resulted in microwave absorption properties in 2-18 GHz [22].

Bamboo is recognized as one of the most popular bio-resources, capable of adsorbing toxin in blood as well, and hence is useful in blood purification process. Chou et al. [5] reported the effectiveness of bamboo charcoal for removal of Ciprofloxacin, which is largely available in pharmaceutical industrial waste. The adsorption capacity of this charcoal was found to be 613 mg/g much higher than charcoal obtained from other sources.

Anti-bacterial properties of bamboo charcoal was reported by Choi and Ahn [4]. Growth of S. mutans reduced by 58% on bamboo charcoal medium (Concentration: 2% and 5%). Yang et al. [6] reported the high antibacterial efficiency of bamboo silver composites. With 18 hours of inoculation, Bacterial colonies of Gram-positive S. aureus were found to be completely killed and with complete the percentage reduction of bacterial growth. In addition to this, above mixture showed strong antibacterial properties against Ciprofloxacin-resistant P. aeruginosa (CRPA), E. coli and E. coli JM109, and B. subtilis bacteria.
Studies performed by Pi et al. [19] showed that roof tops spread with bamboo based charcoal with lower temperature compared to non-green roof tops. Comparison of heat fluxes of conventional roof top and bamboo charcoal roof top showed that 10% reduction in temperature during summer months. Contrary to conventional buildings, heat balance for the greening area during the day and night were found to be negative and positive.

Chou et al. [4] attempted to improve the conversational efficiency of Dye-sensitized solar cell (DSSC) using bamboo charcoal. Titanium dioxide and bamboo charcoal composite were mixed using dry mixing method and were applied to the working electrode of DSSC. Appropriate choice of mass ratio of this mixture, can provide electrode the maximum conversational efficiency than conventional methods.

4. CONCLUSION

Prospects of bamboo utilization as material of future are bright. Traditional uses of bamboo include building and construction as well as paper industry. Handicraft and furniture industry also rely on bamboo as major raw material. In modern houses, green housing, roof top based on bamboo can be developed to reduce the load of electricity. Recent studies show the potential of bamboo based charcoal composites are associated with high surface area and absorption properties. Their utilization in water purification and treatment of pharmaceutical wastes are under the stage of development.

REFERENCES


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