Potential of Using Natural Fiber for Building Acoustic Absorber: A Review

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Abstract. Sustainability is one of the significant goals in the evaluation and promotion of building materials in the current society. This paper presents an evaluation of the potential of natural fiber for building acoustics absorber. This was done by comparing all aspects of sustainability including economy, social and environmental needs between the natural and synthetic fibers. Some features of natural fibers such as light weight, bio-degradability, low-cost, carbon-dioxide neutral, low consumption of energy and health aspects has been the major factors that contributed to its use in many construction applications. In addition to that, previous researches showed that sound absorbing materials with natural fibers have good acoustic properties in high frequency range similar with those synthetic fiber. However, high water absorption, prone to termite attack, less fire resistance and low strength are remaining the issues militating against the natural fiber for building acoustic absorber. Despite that, natural fibers have already been proven alternatives to synthetic fiber in building acoustic absorber thereby alleviating some sustainability issues associated with the use of synthetics materials in building acoustics.

1. Introduction
Synthetic fibers such as rock wool and glass wools are practically used as sound absorber in building industries. It is used for many applications in building and construction industry such as partition boards, floors, wall and roof tiles [1]. However, it was found that their negative effects to the environment were high and thus natural and sustainable acoustic materials are now of interest [2]. For these reason, natural fibers including derived from agro-waste, plants and industrial waste were selected. Such natural fibers like coir, pineapple, Sugarcane bagasse, jute, ramie, kapok, rattan etc. were currently investigated. Table 1 shows a few reviews studies on the area of natural fiber as a substitute to synthetic fiber in a building acoustics.
Table 1. Related studies on natural fibers for acoustic absorption

| Type of fibers                      | Acoustic characteristic                                                                 | Source of reference       |
|-------------------------------------|------------------------------------------------------------------------------------------|---------------------------|
| Hemp                                | Higher concentrations and alcalization at higher temperature gives good results in sound absorption coefficients properties. | Yilmaz et al. [3]        |
| Coir                                | Good acoustic properties at medium and high frequency ranges.                            | Fouladi et al. [4]       |
| Coconut                             | The increased in thickness of coconut increases the sound absorption coefficient of coconut fiber increase with the increases of flow resistivity. | Huang et al. [5]         |
| Date palm                           | Sound absorption properties of date palm fiber increases with the increases of flow resistivity. | Khidir et al. [6]        |
| Kapok                               | Hollow structure of kapok fiber help in good acoustic behavior.                          | Xiang et al. [7]         |
| Bamboo                              | Good absorption properties mostly at the higher frequency range.                         | Thilagvathi et al. [8]   |
| Tea-leaf                            | Better sound absorption properties than polyester.                                       | Ersoy and Kucuk [9]      |
| Wool                                | Low flow resistivity material resulted good sound absorption properties                   | Ballagh [10]             |
| Sugarcane bagasse                   | Resin proportion and the type influenced the sound absorption properties.                | Doost-hoseini et al. [11]|
| Ramie                               | Superior sound absorption properties over glass fiber reinforced sandwich structures.     | Zheng et al. [12]        |
| Jute                                | Result from modelling showed good agreement with experimental data.                     | Fatima et al. [13]       |
| Natural fiber mixed nonwoven composite | Excellent absorption properties in the mild to high frequency ranges.                  | Kucuk et al. [14]        |
| Windmill palm                       | Good for acoustic absorption materials.                                                 | Chen et al. [15]         |
| Kapok and milkweed fiber            | Good sound absorption and insulation properties.                                         | Liu et al. [16]          |
| Hemp shives                         | Good absorption properties at lower frequency range.                                     | Balciunasas et al. [17] |
| Cotton and cellulose fiber          | Sound absorption of natural fiber in thermoplastic form increases when the density is decrease. | Krucinska et al. [18]   |
| thermoplastic composites.           |                                                                                         |                           |
| Sisal fiber poly lactic acid bio-   | Produced highest sound absorption property compared with other composites.              | Jayamani et al. [19]     |
| composite                           |                                                                                         |                           |
| Luffa                               | Acoustic properties of luffa fiber are higher even for a small thickness when the matrix is not added. | Koruk and Genc [20]      |
| Luffa/epoxy composites              | Sound absorption properties of the composites were reduced by chemical treatment.       | Jayamani et al. [19]     |
| Bamboo fiber board                  | Better sound absorption properties more than plywood with same density.                 | Thilagavathi et al. [8]  |
| Jute composite materials            | It shows better acoustical properties than glass fiber.                                  | Fatima et al. [22]       |
| Kenaf and hemp                      | Better acoustical properties than glass fiber.                                          | Berardi and Iannace [23] |
| Kapok nonwoven fabric               | Model of absorption coefficient, thickness and flow resistance.                         | Liu et al. [7]           |
| Flax and polypropylene fiber        | The effects of porosity, air gap and pore diameter on sound absorption at lower frequency. | Merotte et al. [24]      |
| Bark cloth                          | Large porosity volume fraction is benefit to acoustic absorption property.               | Rwawiire et al [18]     |
| Polyurethane foams loaded with tea-leaf fiber and luffa cylindrical             | Good absorption properties at higher frequency range.                                   | Ekict et al. [25]        |
| Pineapple leaves                    | Acoustic absorption property improves significantly when the tea-leaf was added with the polyurethane. | Putral et al. [26]       |
| Oil palm                            | Achieve good sound absorption properties at above 1KHz frequency range                  | Yahya and Sheng [27]     |
This paper presents an evaluation on the potential of natural fiber for building acoustics absorber. This was done by comparing all aspects of sustainability including economy, social and environmental needs between the natural and synthetic fibers. Some features of natural fibers aspects that have been the major factors contributed to its use in many construction applications are reviewed. In addition to that, previous researches that showed the sound absorbing properties of sound absorber made with natural and issues related with high water absorption, prone to termite attack, less fire resistance are discussed.

2. Comparison of natural fibers with synthetic fibers in building acoustic absorber

Joshi et al. [28] proved that natural fiber composite has much lower environmental impact compared to the synthetic fibers such as glass wool. Thus, natural fibers materials have been recommending as an alternative sound absorber material since its cheaper, lighter and environmentally friendly compare to synthetic materials which can be harmful to human health.

Natural fibers offer a high potential for building material especially acoustic absorber, since they are low-density material, cheap[28] and it’s renewable[28]. In addition to that natural fiber are able to recyclability and degradable, and has low consumption of energy, no health risk, and eco-friendly. Due to these aspects, Peter and Narayan [29] reported that natural fibers are very good materials in terms of sustainability. A comparison of various aspects between natural fibers and synthetic fibers is described in Table 2.

Table 2. Comparison between synthetic fibers and natural fibers [34].

| Aspects       | Natural fiber | Synthetic fiber |
|---------------|---------------|-----------------|
| Density       | Low           | High            |
| Cost          | Low           | Double          |
| Renewability  | Yes           | No              |
| Recyclability | Yes           | No              |
| Consumption of Energy | Low           | High            |
| Biodegradability | Yes           | No              |
| Carbon dioxide | No            | Yes             |
| Health risk   | No            | Yes             |
| Eco-friendly  | Yes           | No              |

Natural fiber is bio-degradable, derived from a renewable resources and require a small energy to process [30]. According to Bismarck et al. [31] on their investigation of carbon dioxide contribution of natural fibers in the environment during the growing and processing, it is concluded that natural fiber production were eco-friendly both at the growing and processing stages. Moreover, Mutnuri et al. [32] found through life cycle energy assessments that natural fiber consume less energy synthetic fiber.

Joshi et al. [28] suggested that there are some major areas that natural fibers can offered in helping and improving of the environment. Such as carbon lower emissions and improve fuel efficiency and recovered energy and carbon credits from end of life incineration. Whereas the synthetic fibers depend on energy for their production. In fact, synthetic fiber causes pollution to the environment especially disposal issues as a result of very large amount of synthetic fiber usage. For example, in US alone disposed over 25 million tons of plastics into the municipal solid waste stream in the year 2001, which accounted for over 11% of the total national waste [33]. Many states in the US have reached their landfill capacity in a shorter period of time and this makes landfill has major issue.

With all the advantages of all aspects that natural fiber can offer to be as a construction material, this has caused the demand for natural fiber increased from 10% to 22% per year (Satyanarayana et al. [35]). The natural fiber market is also predicted to improve in sales from 16% to 30% per year. Thus, Bismarck et al. [31] opined that there is greater opportunity for other regions of the world to join the market in the
natural fiber production since there are more markets currently for natural fiber production in the United States and Europe which will soon be unable to meet market demands of this product.

3. Ability of Natural Fibers in Absorbing Sound.
Many researches have been carried out on the possibilities of using natural fiber instead of synthetic fiber for sound acoustic absorber due high capability of absorbing sound. The use of natural fiber for sound absorbing materials is very significant in the production of building absorber in the world today. In terms of sound absorption most of the natural materials tends to behave as porous absorbers materials. It is apparent that porosity is one of the factors that determine the absorption characteristics of any fibrous materials. Other factors such are fiber density and thickness. Porous sound absorbing materials have good acoustic properties in high frequency range but with a very weak absorption coefficient at low frequency range. One of the problem with using the natural fibers for building acoustic absorbers is the application of unsustainable material has a binder to bind the fibers together. For a natural fiber to meet the technical need of building acoustic absorber, the fibers has to be characterized and modelled. Natural fiber has to be characterized in order for the improvement in it is properties. This includes characteristics such as fire retardant, anti-fungus, flammability and stiffness.

According to Lee and Joo [36] in their studies observed that the effect of fiber content of non-woven fabrics on the sound absorption properties and found out that the non-woven that are produced with recycled fibers of different diameters having the same length performed better in sound absorption properties, mostly when there is increased in fiber content. The sound absorption coefficient of non-woven that has un-oriented web in the middle layer is very high at higher frequency range than the one with totally oriented web structure. Moreover Ersoy and Kucuk [9] investigated the sound absorption coefficient properties of tea leaves fiber. A layer of woven textile material and three layers of tea leaf fiber waste materials was tested, with and without backing in different configurations were tested. The experimental data indicated that the sound absorption properties of one cm thick tea leaf fiber waste material with backing is almost the same with nonwoven textile material. And also twenty millimeter thick layer of rigidly backed tea leaf fibers and nonwoven textile exhibit almost the same sound absorption coefficient in low frequency range.

Zulkifli et al. [37] observed the sound absorption coefficients of two natural fibers; oil palm fibers and coir fiber in their study. At the fabrication stage, coir fiber sheet was treated with latex and the oil palm fiber sheet was also treated with binder. Both the fibers were compressed under pressure using high precision hydraulic machine for 30 minutes to form the fiber sheets. The coir fiber shows a good sound absorption coefficient for higher frequencies but not too good in the lower frequencies region. The oil palm fiber shows a good absorption coefficient for higher frequency region than lower frequency region when observing the sound absorption coefficient of this material. The structural diversity of synthetic fibers can improve sound absorption coefficient when comparing with natural fiber. The different cross-sections of synthetic fiber such as triangle, hollow and circle are beneficial in improvement of acoustic absorption properties of the synthetic fibers. The sound absorption properties of polyester fiber was studied by Huang et al. [38]. It has been found that the polyurethane composite board can reach a value of 0.69 at lower frequency range. It shows improved sound absorption property in the lower frequency range.

4. Physical and Mechanical Strength of Natural Fibers
Natural fibers are tough, elastic and demonstrate good mechanical strength. The composite from natural fibers is introduced for commercial purpose and becomes a good alternative of synthetic fibers in many applications. The tensile strengths similarly the young’s modulus of natural fibers like coir, ramie, flax, hemp and sisal are less than that of synthetic fiber unremarkably utilized in building absorbers. However, the precise strength and modulus of a number of these natural fibers are quite comparable to glass fibers. For example, the superiority of pineapple mechanical properties compared to other natural fibers is due to its high content of alpha-cellulose and low microfibrillar angle. Coir, ramie, hemp, sisal, jute, flax and cotton are kind of natural fiber that possesses high strength and modulus.
The major advantages of natural fiber when comparing it with synthetic is that of good specific mechanical properties due to low energy consumption and density, on the other hand the disadvantages of natural fibers includes high moisture absorption, more inferior fire resistance and lower strength [39]. In general ramie fiber have the best property for structural applications. Sisal, jute and flax offers the best potentials of light weight, low cost and high strength. Overall, natural fibers have low densities and cheaper than synthetic fibers although the strength of synthetic is higher than that of natural fibers. Since natural fibers has specific modulus values, it can be preferable to synthetic fibers in applications where stiffness and weight are primary concern such as in the case of building absorber[39]. A comparison of various mechanical properties between natural fibers and synthetic fibers is shown in Table 3.

### Table 3. Comparative mechanical properties of some natural fibers with synthetic fibers [34][40]

| Fiber | Young's modulus (Gpa) | Elongation (%) | Tensile strength (MPa) | Density (g/cm3) |
|-------|------------------------|----------------|------------------------|-----------------|
| Coir  | 4.0-6.0                | 15.0-30.0      | 10                     | 1.2             |
| Ramie | 44-128                 | 2.0-3.8        | 12-17                  | 1.5             |
| Hemp  | 70                     | 1.6            | 8                      | 1.48            |
| Sisal | 9.0-38.0               | 2.0-14         | 11                     | 1.33-1.5        |
| Jute  | 10-30                  | 1.5-1.8        | 12                     | 1.3-1.46        |
| Flax  | 27.6-80                | 1.2-3.2        | 7                      | 1.4-1.5         |
| Cotton| 5.5-12.6               | 3.0-10.0       | 8-25                   | 1.5-1.6         |
| Pineapple| 34.5-82.5            | 2.0            | 413-1627               | 1.4             |
| Carbon| 230.0-40.0             | 1.4-1.8        | 4000                   | 1.4             |
| Glass | 73                     | 3              | 2400                   | 2.55            |
| E-glass| 70.0                   | 2.5-3.0        | 2000-3500              | 2.5             |

5. **Issues on Natural fiber**

Although natural fibers have advantage over the synthetic fibers such as low cost and low density, there are many other challenges militating against the advancement of natural fibers into the field of building acoustic absorber. This is due to many reasons such as poor water absorbing capacity, lower mechanical properties, poor fire resistance and low resistant to termite effects. Except of fire resistance, all these issues can be improved with the use of innovative surface treatments, additives such as glue and coatings.

5.1 **Higher moisture Absorption**

Natural fibers are deliquescent in nature and has poor water absorbing properties, it’s mostly absorbed water from air, and this is due to their high cellulose content. The mechanical properties of these fibers can be improved effectively by improving the poor dimensional and environmental stability. Another ways of improving the fiber absorption characteristics is to develop a natural binders to hold the fiber to maintain good shape. Synthetic fibers on the other hand are good moisture resistance.

5.2 **Fire Resistance**

In most cases, natural fiber shows poor resistance to fire compare to synthetic fiber that could be a major setback of natural fiber for industrial applications such as in building acoustic absorber wherever inflammability and safety are thought-about to be the vital factors. This setback poses challenges for natural fibers to compete with synthetic fibers. Natural fibers have a lower decomposition temperature since they are non-thermoplastic compared to synthetic fiber. Natural fibers primarily composed of hemicellulose, cellulose, lignin and inorganic nonflammable substances. The flammability of natural fiber is often increase.
by high content of cellulose. The cellulose decomposes at a very high temperature, whereas hemicellulose decomposes at a lower temperature and forms additional fire-retardant gases.

6. Conclusions
The study aims to look at the potential of using natural fiber as an alternative to synthetic fibers in the production of building acoustic absorber. Many researchers have looked on how to replace the conventional synthetic fibers with natural fibers in the production of building absorber because as light weight, biodegradability, lower cost, carbon-dioxide neutral, low energy consumption and health aspects. The natural fibers such as pineapple, hemp, sisal and jute have impressive mechanical properties. Notwithstanding, with all these benefits of natural fibers, some problem is still impending its application in building absorber such as poor fire resistance properties and higher moisture absorption. This research will contribute to a greater interest in the use of natural fiber for cost-effective building absorber in the construction industry.

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