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**ASSESSMENT OF WEATHERING IMPACT ON BAMBOO CULM LAMINATE AS A
CONSTRUCTIONAL MATERIAL: A REVIEW**

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Abstract

This paper reviews the influence of weathering on bamboo culm laminate has on the quality and aesthetic features as a potential material for construction purposes. Weathering is a process of wearing, and breaking down of a particular material due to exposure to factors like atmosphere and others over some time. Bamboo is a versatile fast-growing grass plant that belongs to the Poaceae family and has been used for centuries for making varieties of furniture items, musical instruments, and others.

Bamboo is a natural material that is susceptible to weathering or the process of deterioration due to exposure to various elements, including moisture, heat, and UV radiation; UV radiation increases, the lignin begins to break down, causing the bamboo to weaken and lose its structural integrity, when this plant is exposed to moisture, it can cause the material to swell, leading to cracks and splits, when bamboo is exposed to extremely low temperatures, it can freeze and become brittle, leading to breakage and cracking, warping, decaying and discoloration being changed in the chemical composition, and physical appearance of the bamboo furniture, floors, and other products, leading to an unappealing appearance and reduced durability of the material, as the lignin in bamboo breaks down and start to yellowish.

Hence, this study has been able to review and classify weathering into natural and artificial, where natural weathering has to do with the exposure of bamboo to natural conditions like sunlight, rain wind, and others while artificial weathering has to do with using laboratory equipment to recreate natural weathering conditions.

Keywords: Bamboo furniture, durability, weathering, UV radiation, heat

Introduction

Bamboo is a fast-growing plant that belongs to the grass family Poaceae, (Zishan. *et al.*, 2021). It is one of the most versatile plants on the planet, with thousands of uses in different cultures and industries (Muhammad, 2009). Its versatility comes from its exceptional strength and flexible nature, which allows it to be shaped and malleable. Upreti and Sundriyal, (2001) reported that Bamboo has been used for centuries in traditional cultures for everything from building homes and furniture to making musical instruments, and even as a food source. In modern times, bamboo has found new uses as a sustainable alternative to traditional materials like wood and plastic in everything from clothing to construction. Its broad range of applications and versatility have made it preferred among designers, builders, and consumers seeking eco-friendly and sustainable solutions. Whether you are looking for a sturdy building material or an environmentally friendly clothing fabric, bamboo has proven to be one of the most useful and versatile plants on the planet (Arslan, *et al.*, 2017). According to Maxim *et al.*, (2005) reported that Bamboo is an ancient woody grass that is widely distributed in tropical, subtropical, and mild temperate zones. Also, it was stated that it is a major non-wood forest product and that there are about 1200 species of bamboo in some 90 genera. In recent years, bamboo has gained popularity as an eco-friendly alternative to traditional materials like wood and plastic (Aiping and Yuling, 2014).

Bamboo is one of the fastest-growing plants in the world and is therefore considered a sustainable resource. Unlike wood, which takes decades to grow, replenish and grow up to 91cm in one day and reach maturity in just 3 to 5 years, Maxim *et al.*, (2005). Bamboo also has a strong root system that prevents soil erosion and can absorb more carbon dioxide compared to other trees, making it an excellent choice for reducing carbon emissions. Its versatility is also a plus, as it can be used for a variety of applications such as furniture, flooring, roofing, and even packaging materials (Ruiz-Sanchez, *et al.* 2019). Plus, it is biodegradable and can be easily composted, unlike plastic which can take hundreds of years to decompose. Its popularity as an eco-friendly alternative is also driven by the growing consumer demand for sustainable

products as people become more aware of the impact of their buying decisions on the environment (Maxim *et al.*, 2005; Mohamed Azmy, *et al.*, 2007).

Bamboo is a popular plant known for its exceptional strength and versatility. Being an ancient species of plant, has recently gained renewed interest for its strength and versatility, making it a popular material for a range of applications. The plant's durability is derived from its natural composition, as it is composed of long, straight fibers that give it a remarkable tensile strength, making it harder than oak or maple making it a popular choice for construction and storage purposes (Jin tok *et al.*, 2005). The plant is also renowned for its rapid growth rate, with some species growing up to two inches per hour, which makes it an excellent renewable resource that can be harvested sustainably (Ruiz-Sanchez, *et al.* 2019). These exceptional qualities have made bamboo an attractive option for flooring, fencing, furniture, and even clothing materials. As efforts to reduce our environmental impact continue to grow, bamboo is likely to remain a popular choice for its unique properties and eco-friendly nature, Jin tok *et al.*, (2005). It is widely considered as one of the fastest-growing and renewable plants, making it an excellent choice for sustainable materials in various industries, from construction to furniture-making. However, like any other organic material, bamboo is susceptible to weathering effects that can cause damage and deterioration Sorna Gowri, *et al.*, (2003). Weathering effects on bamboo refer to the chemical and physical changes that occur due to artificial or natural weather conditions such as rain, wind, sunlight, heat, and humidity (Ruiz-Sanchez, *et al.* 2019).

These weathering effects can occur in two forms: natural weathering and artificial weathering, Fei, (2017). Natural weathering involves exposure to weather conditions such as sunlight, rain, and wind; whereas artificial weathering occurs by using laboratory equipment to recreate natural weathering conditions (Ke-Chang *et al.*, 2012). This paper, therefore, appraised the weathering effects on bamboo culm laminate, including their causes, signs, and prevention, and alleviates their impact on bamboo wood as a constructional material, Rosu, *et al.*, (2010).

Causes of weathering effects on bamboo

Exposure to uncontrolled moisture can lead to rotting, warping, and cracking. High temperatures and UV radiation can also cause discoloration and weakening of the bamboo. Additionally, insects and fungi damage the bamboo, leading to decay and structural instability (Sorna Gowri, *et al.*, 2003; Tolvaj, *et.al* 2013). Properly treating and maintaining bamboo can help to mitigate weathering effects and prolong the life of the bamboo material. Numerous factors contribute to weathering effects on bamboo culm laminates, such as;

1. UV Radiation: According to Hai-xia, *et al.*, (2018) reported that Ultraviolet (UV) radiation from sunlight can break down the lignin and cellulose that make up the bamboo fibers, leading to color changes and loss of structural integrity. Ultra Violet (UV) radiation is one of the primary causes of weathering effects on bamboo (Sorna Gowri, *et al.*, 2003). Exposure to UV radiation can lead to the degradation of the plant's physical and chemical structure through a process called photodegradation, (Mitra, 2014).

This process can result in a range of issues, including surface erosion, changes in coloration, and loss of strength. One of the main ways in which UV radiation affects bamboo is by breaking down its lignin, the material that gives the plant its strength and stiffness. Lignin acts as a natural sunscreen, protecting the underlying cellulose fibers from UV damage (Cogulet, *et al.*, 2016). However, as exposure to UV radiation increases, the lignin begins to break down, causing the bamboo to weaken and lose its structural integrity (Siew, *et al.*, 2019). This can lead to cracking, splitting, and the eventual collapse of the plant. Another effect of UV radiation on bamboo is the alteration of its coloration, Cogulet, *et al.*, (2016). Bamboo exposed to UV radiation will gradually change from its natural hue to a yellow or brown color. This is due to the breakdown of the plant's chlorophyll pigments, which are responsible for the green coloration (Mitra, 2014). The loss of chlorophyll can have aesthetic implications, leading to a less visually appealing appearance. Finally, UV radiation can also cause surface erosion in bamboo. As the lignin breaks down, the surface of the bamboo becomes rough and pitted,

which can make it more susceptible to moisture infiltration and decay (Cogulet, *et al.*, 2016). This erosion can also lead to a loss of texture and grip, making the bamboo less suited for applications such as flooring, decking, or furniture. Overall, UV radiation is a significant contributor to the weathering effects on bamboo, Tolvaj, *et.al* (2013).

Protection from UV radiation through various measures such as coatings, stains, and paints can help to slow or even prevent the deterioration of bamboo due to exposure to sunlight. It is essential to weigh the natural aesthetic appeal of bamboo against its susceptibility to UV degradation, particularly when considering whether to use it as a building or decorative material, (Cogulet, *et.al.*2016; Tolvaj, *et.al* 2013).

2. Temperature Fluctuations: Extreme temperature variations can cause the bamboo to expand and contract, leading to cracks and splitting. Temperature fluctuations play a significant role in the weathering of bamboo (Vasile, *et al* (2018). As a natural material, bamboo is sensitive to environmental changes, including temperature changes. Bamboo is a type of grass that is known for its strength and durability, but it is not immune to the effects of weathering. (Yujiao Wang, *et al.*, 2022).

Weathering is the process in which natural forces, such as temperature, humidity, and sunlight, cause physical and chemical changes to materials over time. Temperature fluctuations cause the bamboo to expand and contract, which can result in cracking, warping, and splitting, (Nurul, 2014). When bamboo is exposed to high temperatures, it can become brittle and dry, making it more vulnerable to damage from other weathering factors, such as wind and rain. On the other hand, when bamboo is exposed to extremely low temperatures, it can freeze and become brittle, leading to breakage and cracking, Wu, *et al* (2009). In addition to physical damage, temperature fluctuations can also affect the chemical composition of bamboo. Temperature changes can cause the bamboo to release volatile organic compounds (VOCs) into the air. These compounds can react with other pollutants in the air, such as nitrogen oxides, and create ozone, which is a harmful air pollutant, (Yujiao Wang, *et al.*, 2022).

To prevent weathering damage from temperature fluctuations, bamboo is often treated with preservatives and coatings to protect it from moisture and UV radiation (Rudi, *et al.*, 2019). Bamboo is also commonly used for outdoor furniture, flooring, and building materials due to its natural resistance to insects and rot. In conclusion, temperature fluctuations can have a significant impact on the weathering of bamboo. Bamboo is a sensitive material that requires protection from environmental factors to maintain its durability and strength over time (Yujiao, *et al.*, 2022; Nurul, 2014).

3. Moisture: Bamboo is a natural absorber of moisture. When bamboo is exposed to moisture, it can lead to swelling, warping, and rotting. Moisture is a critical factor affecting the weathering of bamboo (Rudi, *et al.*, 2019). Bamboo is a natural material that is highly sensitive to changes in moisture levels. Moisture plays a significant role in the aging process of bamboo, affecting both its appearance and durability, Aymerich, *et.al.*, (2012). When bamboo is exposed to moisture, it can cause the material to swell, leading to cracks and splits. This can result in a weakened structure, making the bamboo less durable and less resistant to weathering. Additionally, prolonged moisture exposure can lead to mold growth, which can further damage the bamboo and cause discoloration (Aymerich, *et. al.*, 2012; Rudi, *et al.*, 2019). On the other hand, a lack of moisture can also harm bamboo. Dry conditions can cause the bamboo to become brittle and prone to cracking, also reducing its durability. It's essential to maintain proper moisture levels when it comes to bamboo. It's recommended to use a sealer or protective coating to prevent moisture from penetrating the bamboo (Wu, *et al* (2009). Additionally, it's important to avoid prolonged exposure to rain or high humidity, as this can lead to moisture damage. Proper storage and maintenance of bamboo also play a vital role in preventing moisture-related weathering. In conclusion, moisture is a critical factor in the weathering process of bamboo. Proper care and maintenance can help prevent damage caused by moisture, ultimately preserving the durability and appearance of the bamboo (Siew, *et al.*, 2019).

4. Mechanical stress: Wind, hail, and other physical forces can cause mechanical stress on the bamboo, leading to cracks and breakages, Rudi, *et al.*, (2019). Mechanical stress is a major factor in the weathering of bamboo. As a natural material, bamboo is vulnerable to mechanical stress caused by natural forces, such as wind and precipitation, as well as human activities such as harvesting and processing. Mechanical stress can cause the bamboo to crack, split, or break (Siew, *et al.*, 2019; Wu, *et al* 2009).

Wind and precipitation can cause the bamboo to bend and twist, leading to deformations and structural changes (Yujiao, *et al.*, 2022). This can result in a reduction in the overall strength and durability of the bamboo over time. The harvesting and processing of bamboo can also lead to mechanical stress, Yujiao, *et al.*, (2022). During harvesting, the bamboo stalks are often cut and transported to the processing facility. The handling and transport of the bamboo can result in surface damage, such as scratches and dents that can weaken the material. Processing techniques such as cutting, splitting, and bending can also cause stress on the bamboo (Wu, *et al* (2009).

Environmental factors such as temperature and moisture levels can exacerbate the effects of mechanical stress on bamboo. High temperatures and moisture levels can accelerate the rate of degradation caused by mechanical stress, affecting the bamboo's physical appearance and overall durability. Preventing mechanical stress can be challenging, but it is necessary to preserve the structural integrity and longevity of bamboo products. Wu, *et al* (2009). Proper harvesting techniques that minimize damage to the bamboo stalks, and careful handling during transport and processing can help reduce mechanical stress. Additionally, proper environmental control measures, such as protection from high wind and heavy precipitation, can help prevent damage to bamboo structures over time (Elisabet, *et al.*, 2022).

Signs of weathering effects on bamboo

1. Discoloration: As the lignin in bamboo breaks down, the material may start to yellow or tan. The discoloration is a telltale sign of weathering effects on bamboo, indicating changes in the

chemical composition and physical appearance of the material, Yujiao, *et al.*,(2022). Natural weathering processes such as sun exposure, humidity, and temperature variations can all contribute to the discoloration of bamboo, eventually leading to structural changes. Sun exposure is one of the primary causes of discoloration in bamboo. Ultraviolet (UV) rays from the sun can penetrate the surface of bamboo, leading to the breakdown of lignin, a natural polymer that gives bamboo its rigid structure (Hai-xia, *et al.*, 2018).

This breakdown process results in a loss of color and an overall weakening of the bamboo material. Over time, prolonged exposure to sunlight can cause the bamboo to become brittle and prone to cracking. Humidity is another major factor that contributes to the discoloration of bamboo, Tumirah,*et al.*,(2023). Moisture can lead to the growth of mold, mildew, and other fungi, which can cause staining and discoloration of the bamboo surface. In addition, prolonged exposure to moisture can lead to the deterioration of the bamboo fibers, ultimately compromising the structural integrity of the material. Temperature variations can also result in discoloration of bamboo. Extreme temperatures can cause the bamboo fibers to contract and expand, leading to cracks and eventual discoloration (Tolvaj, *et al.*,2013).

Additionally, fluctuations in temperature can cause changes in the chemical composition of the bamboo, leading to changes in its physical appearance. In summary, discoloration is a clear sign of weathering effects on bamboo (Tumirah, *et al.*,2023). Factors such as sun exposure, humidity, and temperature fluctuations can all contribute to the discoloration process, leading to a loss of color and overall weakening of the bamboo material (Tolvaj, *et al.*,2013). Regular maintenance and protective coatings can help prevent discoloration and prolong the lifespan of bamboo products (Ralf and Gundula, 2019).

2. Splintering and cracking: As bamboo dries out, it can become brittle, leading to splinters and cracks (Luís, 2022). Splintering and cracking are common signs of weathering effects on bamboo. Because bamboo is a natural material, it is subject to various environmental factors that can cause deterioration over time (Upreti, *et al.*, 2001). One of these primary factors is

changes in moisture, temperature, and mechanical forces such as wind or pressure. When bamboo is exposed to these elements, it may begin to dry out and lose its natural moisture content. As a result, the bamboo can become brittle, making it more susceptible to splintering and cracking (Luís, 2022; Wu, *et al* 2009).

This is especially true when the temperature fluctuates from hot to cold, causing the bamboo to expand and contract. In addition to temperature changes, wind, and pressure can also cause splintering and cracking in bamboo. When exposed to strong winds or pressure, bamboo may become stressed and weakened, increasing the likelihood of splintering and cracking. To prevent splintering and cracking in bamboo, it is essential to protect the material from these environmental factors as much as possible, (Luís, 2022). This can be achieved by regularly coating bamboo with natural oils, such as linseed or tung oil, to help maintain the moisture content within. Additionally, building structures with proper support can help minimize the stress and pressure placed on bamboo, reducing the likelihood of splintering and cracking (Kent Bhavna, and Michael, 2012; Wu, *et al* 2009).

3. Warping: According to Muhammad, (2009) reported that Bamboo can warp and twist due to exposure to moisture and temperature changes. It is a durable and renewable natural material that has been used for centuries in various applications. Unfortunately, bamboo is susceptible to weathering, which can cause warping and other forms of damage. Warping is a common sign of the weathering effect on bamboo and can severely affect the structural integrity of bamboo-based products (Tolvaj, *et al.*,2013). Warping occurs when bamboo dries out too quickly, or when it is exposed to temperature and humidity changes. In a bamboo pole or board, for example, warping can cause the bamboo to bend or twist inwards or outwards, causing cracks and weaknesses in the material. Warping can also occur on bamboo furniture, floors, and other products, leading to an unappealing appearance and reduced durability. Weathering is the primary cause of warping in bamboo (Tolvaj, *et al.*, 2013; Mitra, 2014).

Natural weathering processes such as rain, wind, and sunlight can cause the bamboo to expand and contract, resulting in warping. Rain, for example, can seep into the bamboo and cause it to swell. Direct sunlight, which contains UV rays, can break down the natural fibers of the bamboo, leading to warping and other forms of weathering (Tolvaj, *et al.*, 2013; Mitra, 2014). To prevent warping in bamboo products, it is essential to ensure adequate protection from the elements. One method is to coat bamboo with oil or another protecting to create a barrier against moisture and UV rays, (Mitra, 2014).

Another approach is to keep bamboo products away from direct sunlight or moisture, such as placing them under shade or storing them in a covered area. In conclusion, warping is a significant sign of weathering in bamboo, which can cause structural damage to bamboo-based products if left unchecked. Protecting bamboo from weathering elements such as moisture and UV rays is essential to prevent warping and ensure the durability of bamboo products (Muhammad, 2009; Mitra, 2014).

4. Decay: When bamboo is exposed to moisture and insects, it can lead to rotting. Preventing and alleviating weathering. Bamboo is a natural material that is highly appreciated for its strength, durability, and versatility (Rudi, *et al.*, 2019). However, like any natural material, bamboo is subject to wear and tear over time. One of the most common types of bamboo wear is decay, which occurs when the bamboo is exposed to moisture and other environmental factors that promote the decomposition of the material (Siew, *et al.*, 2019; Muhammad, 2009). Decay is characterized by the degradation of the cell walls that make up the bamboo structure. This process begins when microorganisms such as fungi and bacteria begin to colonize the bamboo. These organisms break down the structural components of the bamboo, including the lignin, cellulose, and hemicellulose, which are responsible for the strength and rigidity of the material. As the decay processes progresses, the bamboo may become soft and spongy, and may eventually disintegrate completely (Mitra, 2014). Signs of decay may include visible discoloration, cracks, splits, and a musty odor. It is often accompanied by other forms of

weathering, such as warping and buckling. To prevent or slow down the decay of bamboo, it is important to protect it from prolonged exposure to moisture, high heat, and direct sunlight, (Siew, *et al*, 2019). This can be achieved through proper storage and handling techniques, such as keeping the bamboo dry and out of direct sunlight when not in use. Additionally, bamboo can be treated with preservatives and coatings that help to prevent decay and extend its lifespan (Rudi, 2019). It is caused by the degradation of the structural components of the material and is often accompanied by other forms of wear and tear. Proper storage and handling techniques, as well as the use of preservatives and coatings, can help to prevent decay and extend the life of bamboo products (Rudi, 2019; Mitra, 2014).

Effects and Ways of preventing weathering on Bamboo

1. Stain and Seal: Applying a wood stain and sealant can help protect the bamboo from UV radiation and moisture. Bamboo is a natural material that is highly valued for its strength, durability, and sustainability (Siew, *et al*, 2019). However, like any natural material, bamboo is subject to weathering, which can have a significant impact on its appearance and structural integrity. Two of the main effects of weathering on bamboo are staining and the need for sealing. Staining is a common sign of weathering on bamboo. Over time, exposure to the elements can cause the surface of the bamboo to darken or discolor. In some cases, mold or mildew can also develop on the bamboo, which can leave behind unsightly stains (Rudi, 2019; Mitra, 2014).

This type of weathering can not only affect the appearance of the bamboo but also weaken its structure. To prevent staining and protect the bamboo from further weathering, it is important to seal the material. Sealing bamboo involves applying a protective coating to the surface of the material, (Siew, *et al*, 2019). This can be done with a variety of products, including natural oils, varnishes, or specialized sealers designed for use on bamboo (Olaf, 2011). The sealer creates a barrier that helps to prevent moisture from penetrating the surface of the bamboo, thus preventing further weathering. When applying a sealer to bamboo, it is

important to choose a product that is specifically designed for use on this type of material (Rudi, 2019; Mitra, 2014).

This will help to ensure that the sealer provides adequate protection without damaging the bamboo. In addition, it is important to follow the manufacturer's instructions carefully to ensure that the sealer is applied correctly. In conclusion, weathering can have a significant impact on the appearance and structural integrity of bamboo, (Olaf, 2011). Staining is a common sign of weathering that can be addressed by sealing the material. Sealing bamboo helps to prevent moisture from penetrating the surface, which can help to protect the material and extend its lifespan (Siew, *et al*, 2019). The sealing of bamboo crosscut ends reduced the rate of decay,(Olaf, 2011). If you have bamboo products in your home or garden, it is important to be proactive in protecting them from weathering to ensure they stay strong, beautiful, and functional for years to come (Siew, *et al*, 2019).

2. Apply protective coatings: Apply protective coatings such as polyurethane or varnish to reduce the effects of weathering (Ozlem, 2015). Bamboo is a natural material that is highly valued for its strength, durability, and sustainability. However, like any natural material, bamboo is subject to weathering, which can cause damage over time. Some of the effects of weathering on bamboo include discoloration, warping, decay, and cracking (Olaf, 2011; Patience, *et.al*, 2023). To protect bamboo against the effects of weathering, it is essential to apply protective coatings. Protective coatings help to prevent moisture penetration and provide a barrier against the elements (Ozlem, *et. al*.2015). They can also enhance the natural beauty of bamboo and extend its lifespan. There are several types of protective coatings available for bamboo, including varnish, paint, and oil (Patience, *et.al*, 2023). Each type of coating comes with its advantages and disadvantages, so it is essential to choose the right one based on the specific needs of your bamboo application. Varnish is a type of protective coating that provides a glossy, durable finish. It is ideal for outdoor use because of its excellent resistance to water and UV rays. Varnish can also prevent discoloration and fading, making it an excellent choice

for bamboo furniture, bamboo flooring, and other outdoor bamboo applications. Paint is another type of protective coating that can be used for bamboo (Olaf, 2011; Patience, *et.al*, 2023).

It provides a thicker layer of protection than varnish and can cover up any discoloration or damage to bamboo. However, paint can also hide the natural beauty of bamboo and may not be suitable for some applications. Oil is a natural protective coating that can be used to enhance the natural beauty of bamboo while protecting it from the elements. It is ideal for indoor bamboo applications, such as bamboo cutting boards, bamboo cabinets, and other bamboo furniture. However, oil may not be as effective as varnish or paint for outdoor bamboo applications because it can attract dirt and grime (Ozlem, *et al.*, 2015). Applying protective coatings is an essential step in preventing the effects of weathering on bamboo. The right type of protective coating will depend on the specific needs of your bamboo application. Regardless of the coating you choose, regular maintenance is necessary to ensure that bamboo remains protected and beautiful for years to come (Fei, 2022).

2. Store indoors: Keep bamboo furniture or materials indoors to prevent exposure to moisture and temperature changes (Tumirah, *et al.*, 2023). Bamboo is a popular natural material that is often used for flooring, furniture, and other indoor applications. While bamboo is known for its durability and strength, it can still be affected by weathering over time.

To help protect bamboo from the effects of weathering, it is important to store it indoors when not in use. When bamboo is exposed to changes in temperature and humidity, it can become warped, cracked, or discolored. This can affect both the appearance and the structural integrity of the bamboo (Fei, 2022; Tumirah, *et al.*, 2023; Maxim, *et al.*, 2005). Storing bamboo indoors can help protect it from the elements, as well as from pests and other potential sources of damage. When storing bamboo indoors, it is important to keep it in a dry, well-ventilated area (Fei, 2022). This can help prevent mold and mildew from forming on the bamboo, which can cause discoloration and even degrade the bamboo fiber over time. Additionally, storing bamboo in a cool, dry place can help prevent warping and cracking. If you are storing bamboo furniture

or other larger items, it is important to ensure that they are not placed in areas where they may be bumped or jostled (Tumirah, *et al.*, 2023; Maxim, *et al.*, 2005).

This can cause parts to become loose or even break off, which can be difficult and expensive to repair. Instead, store bamboo furniture and other large items in a secure location where they will not be disturbed. Overall, storing bamboo indoors can help protect it from the effects of weathering, which can prolong its lifespan and maintain its beauty and durability over time. With proper storage and care, bamboo can be a long-lasting and sustainable material that can provide both form and function in a wide range of applications (Patience, *et al.*, 2023).

3. Proper cleaning and maintenance: Keep the bamboo clean and remove any buildup of algae, mold, or other organisms that can cause decay. Bamboo is a natural material that is highly valued for its strength, durability, and sustainability, Nurul, *et.al* (2014). However, like any natural material, bamboo is subject to weathering, which can cause damage over time. Proper cleaning and maintenance can help preserve the beauty and strength of bamboo, even in harsh weather conditions. The first step in cleaning bamboo surfaces is to remove any loose dirt, dust, or debris. (Maxim, *et al.*, 2005)

This can be done with a soft-bristled brush or a vacuum cleaner with a brush attachment. Avoid using abrasive materials or harsh chemicals, as these can damage the bamboo fibers and leave unsightly scratches or stains. Once the surface is free of debris, a damp cloth or sponge can be used to wipe the bamboo down. Use a mild, natural cleaning solution such as vinegar and water or mild dish soap and warm water to remove any remaining dirt and stains. Be sure to wring out the cloth or sponge well before wiping down the bamboo to prevent excess water from seeping into the fibers (Nurul, *et.al*,2014). After cleaning, it's important to dry the bamboo thoroughly. Use a clean, dry cloth to wipe down the surface and remove any excess moisture. Avoid leaving bamboo surfaces wet for extended periods, as this can cause warping or discoloration. In addition to regular cleaning, proper maintenance is critical to extending the lifespan of bamboo (Auwalua and Dickson, 2019).

Applying a protective coating or sealant can help protect bamboo from weathering and other forms of damage. A high-quality bamboo oil or sealant can be applied with a clean cloth or brush, following the manufacturer's instructions (Patience, *et.al.*,2023). Finally, it's important to avoid exposing bamboo to excessive moisture or UV radiation, as this can cause significant damage over time. Using shades, curtains, or blinds can help protect bamboo surfaces from direct sunlight, while using a dehumidifier can help reduce the risk of mold or mildew growth, Patience, *et.al.*,(2023). In conclusion, proper cleaning and maintenance can play a significant role in preserving the beauty and strength of bamboo over time. By following these simple steps, homeowners can keep their bamboo surfaces looking radiant and performing their best for several years, (Laxmikant, 2014; Ozlem, *et.al.*, 2015).

Natural and Artificial weathering

1. Natural Weathering Process: Bamboo is a natural material that changes color over time due to exposure to various elements. The natural color of bamboo ranges from light green to yellowish-brown, depending on the species, Patience, *et.al.*,(2023). As the bamboo ages, it undergoes a natural weathering process, which changes its color and texture. The first stage of the bamboo weathering process is the leaching of bamboo's sugars, a process called decolorization (Viet Ha, 2010). In this stage, bamboo undergoes a color change to a light-yellow color as the sap or moisture naturally evaporates from the inclusions in the culm wall (Patience, *et.al.*,2023). The second stage of the weathering process is the loss of the culm's outer layer, resulting in a flaky, rough, and fibrous surface. During this stage, the bamboo undergoes natural cracking or splitting, developing small crevices, and fine splinters (Arslan, *et al.*, 2017; Achenza, 2006).

2. Human-Induced Weathering: Aside from natural weathering, human activities may cause the bamboo to deteriorate rapidly. Factors such as poor design, poor maintenance, and poor treatment can contribute to how much damage the bamboo suffers. Humid climates subject bamboo to natural rotting and fungal damage when they come in contact with moisture or other

organic substances. In some cases, bamboo structures or furniture may not have been treated, leading to degradation over time, Arslan, *et al.*,(2017). Treated bamboo products, on the other hand, like furniture with varnish or oil coatings, are less susceptible to weathering compared to untreated materials (Youming, 2022).

General Effect of Weathering on Bamboo

The primary effects of weathering on bamboo culm laminates include changes in color, strength, and durability. The natural color of bamboo changes to a light yellow or gray patina, making it look aged. The color change, however, does not affect the strength properties of bamboo, Arslan, *et al.*,(2017). The change in strength comes from the fibrous surface of weathered bamboo, which is prone to splintering or splitting. Splitting also makes bamboo less useful for structural purposes. Weathered bamboo in furniture and structures is also less durable because the fibers are less tightly packed. Because of this, moisture and rot-causing fungi may easily penetrate and spread in the bamboo (Arslan, *et al.*2017: Wu, *et al* 2009).

Conclusion

Bamboo weathering is a natural process that affects its color, strength, and durability. Human-induced activities like poor design, maintenance, and insufficient treatment can accelerate bamboo's weathering. It is essential to treat bamboo products to prolong their lifespan and improve their strength and durability. Proper treatment and maintenance of bamboo products require understanding the natural weathering process of bamboo. By comprehending the process and its effects, bamboo products can last longer, which helps reduce waste and conserve resources.

Weathering effects on bamboo can lead to significant damage and deterioration, affecting the material's durability and longevity. By understanding the causes of weathering effects and taking preventive measures, we can prolong the lifespan of bamboo and ensure its sustainable use in various industries.

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