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Weathering Characterization and Degradation Analysis of Landscape Wooden Buildings in Semi-Arid and Sandy Area

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Abstract: Wooden buildings play a very important role in China's construction and landscape architecture industry. In order to explore the weathering characteristics of the surface layer of landscape wooden buildings, the main causes of weathering were analyzed on the basis of summarizing the common types of weathering characterization. The results showed that the weathering characterization was mainly reflected in the surface defects of wood structures, such as cracking, discoloration, peeling, wind erosion wear, and so on. The coating technology on the surface of constructions was the main artificial factor affecting the surface defects of constructions. In the case of similar surface decoration conditions, sunlight and moisture were the main natural factors affecting the weathering of wooden buildings, which will promote the process of weathering.

Keywords: Wood structure building; Weathering phenomenon; Landscape vision; Landscape architecture

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1. Introduction

Landscape wooden buildings are exposed to outdoor environments for extended periods, resulting in discoloration, cracking, and damage caused by factors such as sunlight radiation, wind, rain, snow, dust, and fungi. These phenomena all affect the aesthetics and practicality of the buildings. In recent years, with the improvement of people's awareness of environmental protection and the improvement of the living environment, wooden buildings have gradually received more and more attention. However, most of the studies on wooden buildings focused on the aspects of building materials, structures, and cultural characteristics [1-5]. There were relatively few discussions on the surface visual characteristics of wooden buildings, especially the lack of studies on the surface characteristics of landscape wooden buildings caused by weathering. Then, in order to highlight the role of landscape architecture in the environmental landscape and enhance the overall environmental effect, it is of practical significance to explore the characterization of wood architecture with natural weathering defects for the semi-arid and sandy regional environment, which can provide a guideline for the design and application of

the visual performance of landscape wood architecture in the semi-arid and sandy region.

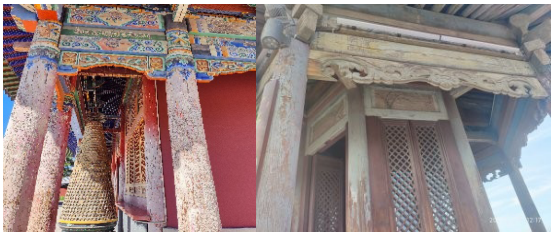
2. Overview of the study area

This paper takes Hohhot City as the study site, which is located in the middle and western part of Inner Mongolia, with an average annual temperature of 3.5–8°C, an average annual precipitation of 337–418 mm, and an average annual wind speed of 4.5 m/s in the wind-sand area of the Ordos Plateau to the west of Hohhot, of which the maximum wind speed can be up to 29 m/s, and ≥ 5 m/s sand-raising winds can be up to as many as 200–371 times throughout the year [6]. The climate is characterized by strong sunshine and large daytime temperature difference, which is a typical temperate continental monsoon climate.

3. Weathering characterization and types

The characteristics of the building surface were summarized through on-site research, which was manifested as surface discoloration, surface cracking, surface roughness, deepening of concavity and convexity, blistering and bulging of the coating surface, etc., which were mostly appearance defects. Classification was carried out based on the surface decoration characteristics of the wooden buildings, as shown in **Table 1**.

Table 1. Types of weathering characterization

Examples	Types
	Color changes: Surface fading, discoloration, dust, watermarks stains, and other phenomena. It mainly occurs on the surface of the outer component, forming a color difference with other parts.
	Linear cracking: Splitting, cracking, and other phenomena. The main formation site is in the surface and the port of the component, along the direction of the wood fiber, forming cracks and radial diffusion along the wood ray.
	Flaky peeling: Surface coating blistering, wrinkling, curling, peeling, etc. The main characteristics are that the coating part of the piece cracks, curls, and gradually forms flaky peeling.
	Wind erosion: Wind erosion is generally accompanied by cracks (not forming through cracks) on wood substrates or unpainted wood surfaces, resulting in changes in surface roughness, as well as noticeable bumps, erosion, and other textures.

4. Deterioration factors and analysis

Weathering acts directly on the surface of the building to induce changes in its appearance, and the damaged morphology could be observed by visual inspection. The main causes of deterioration could be divided into anthropogenic factors and environmental factors.

4.1. Anthropogenic factors

According to the form of surface treatment of wood substrates and coating process:

(1) On wood surfaces with thicker putty priming and then painting, in addition to decorative function, it also has anti-corrosion and insect and fire prevention functions (**Figure 1-1**). The coating structure could be roughly divided into "topcoat-primer-substrate" three layers, because the topcoat was not directly related to the substrate, so it forms flaky cracking under the weathering effect.

(2) After simple treatment to make the surface smooth, the wood was directly coated with paints, wood oils, and other coatings. It should serve as surface decoration and protection of the substrate (**Figure 1-2**). The coating structure could be divided into "paint film-substrate" two layers. The paint film gradually ages due to weathering, coupled with the moisture and drying shrinkage of the wood, the paint film gradually peels off in the direction of the substrate texture/crack.

(3) The surface of the wood undergoes leveling treatment instead of surface finishing, allowing visualization of the material (**Figure 1-3**). The earlywood portion of the wood was more easily worn away by sand erosion, leaving the latewood portion with a raised grain pattern, resulting in an uneven appearance.

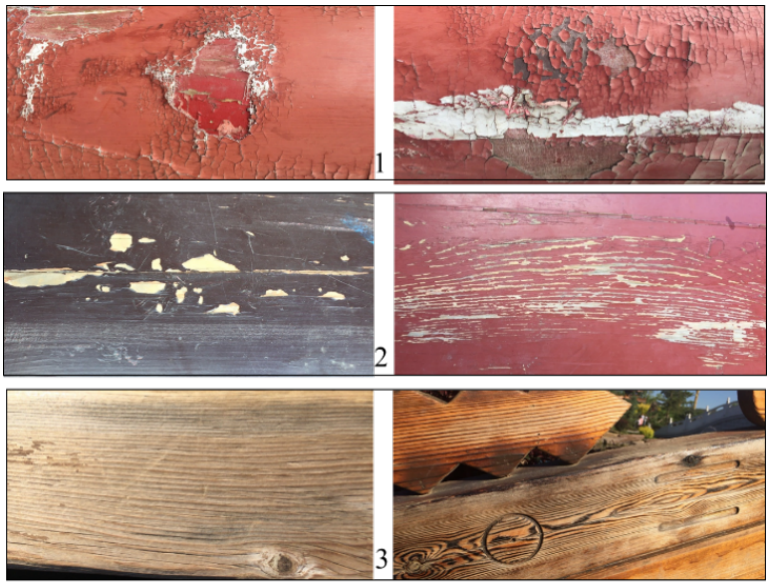


Figure 1. Examples of surface treatment forms

4.2. Environmental factors

When wood was exposed outdoors, its surface changes were caused by sunlight, moisture, temperature, and other environmental factors, which could be briefly summarized into the following three categories.

(1) Sunlight (ultraviolet rays)

With sunlight as the trigger, indoor/outdoor or sunny/shady could produce different characterization differences as shown in **Figure 2**. Ultraviolet light is the main driving force for photodegradation of

wood surfaces. Wood absorbs light energy at many different wavelengths, and the photodegradation of wood occurs after the absorption of light energy. Trees are divided into early- and late-season timber within the annual rings. The early-season timber, which is looser, would be more susceptible to photodegradation, which was reflected in the appearance of a larger concave-convex wave pattern (**Figure 2-A**). On the other hand, because sunlight promotes the coating paint aging, it would form coating aging, with volatile loss and stress formation. Degradation is intensified by coating, resulting in loss of luster, color change, interface penetration and surface cracking, and other phenomena **(Figure 2-B**).

Figure 2. Examples of surface changes caused by sunlight

(2) Moisture (precipitation and relative humidity)

The moisture content of wood was the main factor. In the process of wood weathering, precipitation promotes the loss of photochemical decomposition produced by leaching, resulting in the erosion of the wood surface; repeated changes in daytime temperature differences and relative humidity of the environment would contribute to the cracking of the wood surface, which allowed daylight and moisture to penetrate deeper into the inner layers, thus accelerating weathering. As shown in **Figure 3**, because the water absorption (moisture) of the cross-section of the wood should be larger than that of the radial and chordal sections, the degree of wetting and drying increases, and repeated wetting and drying also aggravates the degree of weathering, resulting in the cracked parts of the wood columns being concentrated in the ports and expanded along the fiber direction.

(3) Other factors

Wind and sand could directly cause mechanical abrasion of wood surfaces, and the stronger the wind and the more sand there is, the more severe the abrasion. A loose wood surface that had already been subjected to light deterioration could easily be washed away by sand and wind, reducing the surface roughness and blurring the characteristics of wind erosion (**Figure 4-1**).

The higher the temperature, the faster the light deterioration and oxidation, but sustained high/low temperatures on the deterioration of wood was not as obvious as the above factors. Rather, the difference in temperature between day and night coupled with the role of humidity would cause weathering of the wood surface coating (**Figure 3**, **Figure 4-2**).

In addition, polluting gases such as sulfur dioxide and nitrogen oxides produced by industrialization (acid rain) were undoubtedly the factors affecting the weathering of wood. Sulfur dioxide and nitrogen oxides corrode wood, possibly in the form of acid rain, or through direct absorption of sulfurous acid into the wet wood surface for acidic corrosion. However, in relation to the natural and industrial conditions of the study area, the effect of

sulphones on weathering was rather insignificant.

Sunlight and moisture were the most destructive factors triggering a cascade of chemical changes on the surface of the wood. Considering the arid and windy geographical characteristics of the research area, airborne pollutant gases (acid rain) were significantly less influential than temperature differences and wind erosion.

Figure 3. Examples of surface changes caused by moisture

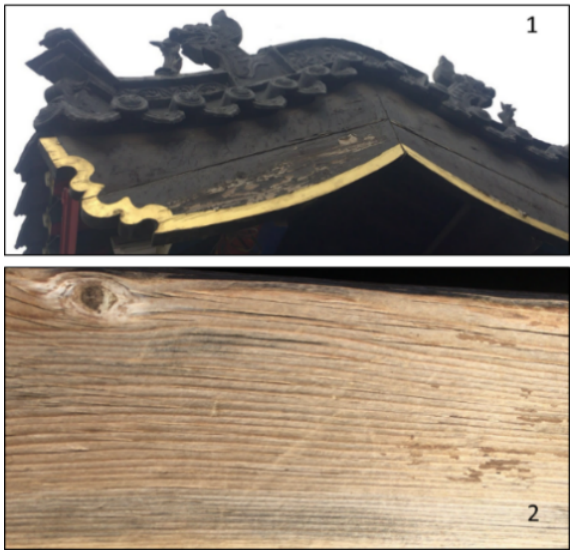


Figure 4. Examples of surface weathering morphology

5. Conclusion

In summary, the weathering characterization of the landscape wooden buildings in the study area was reflected in the surface defects of the wooden structures. The coating process and structure of the structure's surface were the main anthropogenic factors affecting the surface morphology. In contrast, sunlight and moisture were the primary environmental factors affecting the weathering of wooden buildings under similar surface decoration conditions. Regardless of whether the surface of a wooden building was coated or uncoated, strong sunlight and low humidity environmental conditions were particularly likely to cause surface cracking and discoloration phenomena and contributed to increased weathering. In addition, wind, sand, and temperature differences also influenced the weathering process on wooden building surfaces, which was characterized by cracking, peeling of coatings, and changes in surface roughness.

Weathering is a dynamic phenomenon that cannot be eliminated. Then, the construction and design of landscape wooden buildings and other related work should focus on how to slow down and reduce the impact of weathering. For example, in processing and production, we should pay attention to the selection of locally suitable wood and control the moisture content of wood and the use of similar humidity; improve the surface coating process through the formation of a permeable layer on the surface rather than paint film. In terms of design, comprehensive consideration was given to the current situation of the site, geographical factors, and local humanities and historical and cultural backgrounds. With the development of wooden buildings, the decorative, functionality, and durability of the appearance and form of landscape wooden buildings were becoming increasingly important, and the problems related to weathering need to be studied and explored in greater depth.

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Disclosure statement

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