Research on the Degradation Mechanism of Historical Building Materials

Wenshu Li, Hao Yuan, Zishuo Gao
School of Civil and Transportation Engineering, Beijing University of Civil Engineering and Architecture, Beijing, China

Abstract: This study will explore the destruction mechanism of historical building materials and provide scientific basis for the protection of cultural heritage. Through literature review and case analysis, this paper systematically investigates the failure process and influencing factors of main historical building materials such as stone, wood, brick, ceramic tile and metal. This study considers environmental factors, biological erosion, human activities, chemical reactions, etc. Is the main cause of material deterioration. According to the research results, this paper puts forward the protection strategy of combining environmental control, biological control, maintenance technology and maintenance. These results emphasize the necessity of thoroughly understanding the destruction mechanism, formulate effective protection plans, prolong the life of cultural heritage and protect human civilization.
***Keywords*:** historical building materials; degradation mechanisms; influencing factors; protection strategies; cultural heritage preservation

1. Introduction

As an important witness of human civilization, historic buildings embody rich historical, artistic and scientific values. However, with the passage of time and the change of environment, these structural materials will inevitably decompose in different ways, which poses a serious threat to the long-term preservation of cultural heritage. A deep understanding of the aging mechanism of historical building materials is very important for formulating scientific protection strategies and prolonging the life of buildings. The purpose of this study is to systematically examine the decomposition process and elements of important historical building materials, analyze the influence of various decomposition mechanisms on the effectiveness of materials, and formulate corresponding comprehensive protection strategies based on these data. Therefore, this paper first reviews the types and characteristics of historical building materials, and then analyzes the aging mechanism of stone, wood, brick, tile and metal in detail. The effects of environmental factors, biological erosion, human activities and chemical reactions on material degradation are also discussed. Finally, on the basis of studying the deterioration mechanism, this paper puts forward the targeted protection strategy, which provides a scientific basis and practical guide for the protection of historical buildings.

2. Types and Characteristics of Historical Building Materials

There are many kinds of historical building materials, mainly including stones, wood, bricks and tiles, and metals. Each material has its unique physical and chemical characteristics, which determines its application and durability in historical buildings. Stone is famous for its strength and durability, and is widely used in structural and decorative elements. Common stones are granite, marble and sandstone. As a renewable resource, wood plays an important role in building structure, especially on the roof and ground. Ceramic tiles are widely used as building materials in history because they are easy to manufacture and build.

Metal materials such as iron and copper are mainly used for decoration and functional parts. These materials are favored because of their high strength and good plasticity, but they are easily corroded. The specific chemical composition and physical structure of various materials directly affect the weather resistance and aging resistance. For example, the mineral composition and structural characteristics of stone determine its anti-pollution ability, and the contents of cellulose and lignin in wood affect its anti-pollution ability. Understanding the characteristics of these materials is the basis of studying their degradation mechanism and the key to formulating effective protection strategies.[1]

3. Analysis of Degradation Mechanisms of Major Historical Building Materials

Degradation of rocks is mainly caused by atmospheric action, including dual mechanisms: physical action (due to sudden changes in temperature, freezing cycles and crystallization of salts) leading to surface cracking, and chemical action (reaction of water and oxygen leading to soluble salts) leading to structural weakening. The porous structure increases the penetration of water and salt.[2]

Wood degradation has biophysical synergistic characteristics of destruction. Bioerosion (fungi, insects, etc.) degrades cellulose directly, while expansion and contraction due to the wet-dry cycle produce internal stress cracks. The wet environment accelerates decomposition, creating a vicious cycle of weakening strength.

Brick and tile degradation manifests as salt-frost composite damage unique to porous media: water absorption and salt accumulation continuously build crystallisation and frost heave pressures, compounded by chemical dissolution in acidic environments, ultimately causing surface powdering and layered peeling.

Metal degradation follows dual chemical and mechanical pathways: electrochemical corrosion (iron/copper corresponding to moist oxidation and natural oxidation) creates surface pits, while fatigue crack propagation under cyclic loads leads to sudden fractures. Differences in electronic activity and environmental media of various metals result in characteristic corrosion patterns, such as the layered peeling of iron rust and the dense oxide film of copper patina.[3]

4. Factors Affecting the Degradation of Historical Buildings

Environmental factors are one of the main factors affecting the degradation of historical buildings. Due to changes in temperature and humidity, materials will expand and harden. This is more obvious in stone and wood materials. Extreme temperature accelerates the aging of materials, and high humidity provides necessary conditions for biological erosion and chemical reaction. Rainfall, especially acid rain, will increase the chemical corrosion of materials. Air erosion will wear the surface of materials, especially in historical buildings in windy areas. Light, especially ultraviolet rays, will accelerate the decomposition of organic matter such as wood and some coatings. Another important factor is biological erosion. Plants growing on the surface of buildings such as molds, tiles and stairs can improve the aesthetic value of buildings, but they may also destroy building materials. The existence of microorganisms such as bacteria and fungi may cause biodegradation of materials. Especially in wood and organic coatings. Insects such as termites and edible birds seriously damage the wood structure, and insects bite and destroy building materials. Human intervention in the degradation of historical buildings can not be ignored. Excessive use or touch during travel will accelerate the wear of materials. Improper protective measures (for example, using incompatible maintenance materials) can also lead to material decomposition. The process of urbanization has brought new challenges such as air pollution and soil change, and destroyed historical buildings.

Chemical reactions are an important driving force for material degradation. Oxidation processes cause rusting of metal materials and degradation of organic materials. Acid-base reactions erode stone, brick and tile, and metal materials, altering their chemical composition and structure. Dissolution mainly occurs in porous materials such as stone and brick and tile, leading to reduced material strength and surface damage.

5. Historical Material Protection Strategies Based on Degradation Mechanisms

The use of temperature and humidity control equipment in environmental control can reduce the risk of material expansion and compression, the air filtration system can minimize the chemical corrosion of pollutants, and the improved drainage system can prevent floods. Biological control aims to purify plants, prevent root damage, inhibit harmful organisms by physical and chemical means, and inhibit microbial decomposition by antibacterial means. There are three stages of recovery technology. Remove surface pollutants in a non-destructive way, such as laser cleaning or microscope. Strengthening fragile structures with nano-materials or traditional processes. Repair damaged parts and maintain authenticity by using raw material proportioning technology. Maintenance management focuses on the establishment of digital monitoring system, real-time monitoring of material quality deterioration through sensor network, formulation of preventive maintenance mechanism and regular maintenance plan, and training of experts to effectively implement protective measures. Coordinated implementation of this strategy can greatly slow down the aging of buildings and ensure the sustainable protection of cultural heritage.[4]

6. Conclusion

The study identified the main reasons for the degradation of historical building materials, including environmental factors, biological erosion, human interference and chemical reaction, and the establishment of a multi-dimensional protection system. Through comprehensive strategies such as environmental control (temperature and humidity control/pollution), biological characteristics control (microbial inhibition), technical recovery (using compatible substances) and scientific maintenance (regular monitoring), a protection plan supporting theory and practice has been formed. This study especially emphasizes the necessity of microscopic monitoring of material decomposition and developing green repair materials. It is suggested that an interdisciplinary cooperation mechanism should be established to integrate innovations in materials science, environmental engineering, biotechnology and digital technology. The research shows that establishing a preventive protection system based on big data analysis, developing intelligent materials for self-repair and establishing a database of cultural relics protection standards will become the key means to improve protection efficiency. These developments provide a systematic solution for the protection of historical buildings in the whole life cycle, which is very important for the sustainable protection of cultural heritage.

References

[1] Li Yujia, Li Shaoxuan. Research on Building Materials and Technologies of Ancient Buildings[J]. China Building Decoration, 2024, (09): 117-119.

[2] Che Wen, Chen Yanru. The Optimization Effect of Nanotechnology on the Performance of Building Structural Materials and the Outlook for Future Applications[J]. China High-Tech, 2024(11): 121-123.

[3] Zhao Shanying. Exploration of the Construction Management Path of the Renovation Project of Ancient Buildings[J]. Real Estate World, 2024, (13): 95-97.

[4] Su Runzhou. Study on the Mechanism of Photochromism of the Decorative Materials for the Surface of Wooden Materials[D]. Northeast Forestry University, 2011.