

Biological Disease Survey of Open Stone Relics in Ningbo Area

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Abstract: Ningbo has many stone cultural relics. However, many of them have been preserved in the open air for a long time, and the disease situation should not be underestimated, among which biological damage is especially obvious. In order to reasonably protect the open-air stone relics in Ningbo, the article selects several open-air stone relics preservation units in Ningbo as the research object and tries to use new materials to remove and prevent biological diseases on the surface of stone carvings, trying to provide a reference for the prevention and control of biological diseases of open-air stone relics in the southern region.

Keywords: Heritage Conservation, Open-Air Relics, Stone Relics, Biological Damage

Ningbo is rich in stone cultural relics, consisting of temples, ancestral halls, inscriptions, burial groups, etc. They are valuable properties of Ningbo and carry cultural connotations of different eras. Currently, most of the stone relics in Ningbo are preserved in an open-air environment, subject to various factors such as precipitation, temperature and light, and the disease condition is not optimistic. Due to the geographical location of Ningbo, the biological damage to stone relics is undeniable. For example, the bodily harm of dinosaurs in the Qing'an Hall, Ashoka Temple, and the Southern Song Dynasty Stone Carving Garden in Dongqian Lake is serious, which will certainly shorten the life cycle of relics if any conservation measures are taken in line. Investigating and repairing is urgent in compliance with the principles of heritage conservation based on the necessary heritage disease.

1 Ningbo Open-Air Stone Cultural Relics Preservation Status

1.1 General Situation

Ningbo area is rich in humanities and has a large number of cultural relics, and was announced as a national historical and cultural city by the State Council in December 1986, and there are 31 national key cultural relics protection units in the territory. According to the data, in order to improve the management level of the record files of immovable cultural relics in Ningbo, Ningbo built a database of immovable cultural relics record files in Ningbo in 2005 with strict reference to the requirements of the "Instructions for Writing Record Files of National Key Cultural Relics Protection Units"[1].

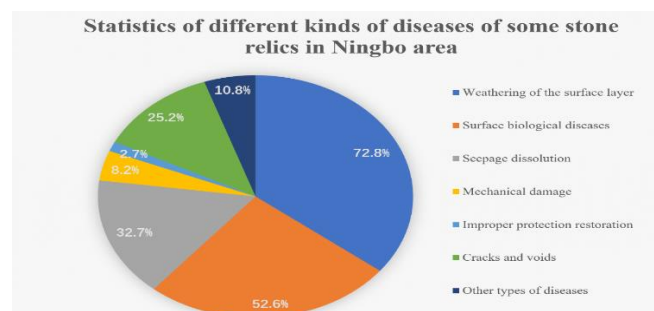


Figure 1: Statistics of different kinds of diseases of some stone relics in Ningbo area

Ningbo cultural relics census and protection of quality and quantity, the overall level of protection of immovable cultural relics to improve. In the third national census of cultural relics, the number of immovable cultural relics rose from 1399 to 8322, which contains a large number of open-air stone carvings as well as open-air stone buildings[2]. The various regulations for the protection of cultural

relics in Ningbo have been relatively complete, but there is a lack of professional institutions for the protection of stone carvings, and there is still room for improving the periodic repair and daily maintenance system for stone relics (Fig-1).

1.2 Overview and Problems of Stone Carvings

Ningbo stone cultural relics are mainly temples, ancestral shrines, ruins, burial groups and scattered stone inscriptions in immovable historical buildings; stone inscriptions are primarily types of monuments, various types of stone statues and stone buildings, among which the aesthetic value and immovability of the appearance of monument inscriptions and stone statue forms are difficult points to be improved in conservation work. Some museums or heritage conservation units will be some stone relics in the open air; due to the impact of the environment and climatic conditions, the stone carving group microbial disease is more serious, so the open-air stone relics disease problem is endless. Need to be resolved. Some of the stone relics in Ningbo area are preserved and listed with diseases (Table-1).

Table-1: List of some stone cultural relics preserved and diseases in Ningbo area

Heritage Preservation Unit	Stone artifacts	Main diseases and threats	Preservation Status
Baoguo Temple (Zhejiang Province Key Cultural Relics Protection Unit)	Baoguo Temple Prayer Building	Weathering disease, particulate matter, dust causing surface deposits, smoke damage, obvious biological disease on the lower surface of the column	Open-air storage
Qing'an Hall (the fifth batch of national key cultural relics protection units)	Stone carving	Weathering disease, water damage, microbial disease	Indoor storage
Stone pagoda after the temple ditch (the sixth batch of national key cultural relics protection units list)	Stone pagoda	Weathering caused by direct rainfall, biological diseases caused by open-air environment	Open-air storage
Dong Qian Lake stone carving group (the sixth batch of national key cultural relics protection units list)	Open-air stone carving groups	Obvious microbial disease	Open-air storage
Ashoka Temple (the sixth batch of national key cultural relics protection units list)	Ashoka Stone Pillar	Serious smoke damage, long-term open-air preservation caused by biological diseases, rain erosion, splash corrosion caused by mechanical damage	Open-air storage

2 Analysis of the Causes of Microbial Diseases

Ningbo has a long history and rich resources of stone carving relics. The stone relics are mainly pagodas, stone bridges, cliff stone carvings, tombstone carvings and stone carving components in historical buildings. The survey found that most cultural relics have been preserved in the open air for a long time. There have been different degrees of diseases on the surface of the stone carvings, among which biological diseases are especially obvious. Some of the stone carvings have many moss, lichen and other organisms attached to the surface, which severely threatens the safety of stone cultural relics.

2.1 Nature of Stone

The material of stone relics in the Ningbo area is mainly Plum Garden Stone, which belongs to tuffaceous sandstone, the size of mineral particles is mainly 0.1 to 0.5 mm. The rock's pore space and water absorption rate are ample, making Plum Garden Stone less resistant to weathering than siliceous colluvial sandstone. The rock's surface is easily damaged by factors such as light and temperature in the environment, which provides favourable conditions for the growth of microorganisms and mosses[3].

2.2 Natural Climate

The natural climate is one of the main reasons for the frequent occurrence of biological diseases on stone relics in Ningbo. Ningbo is located on the southeast coast of China and the south wing of the Yangtze River Delta; influenced by a subtropical monsoon climate, with high temperatures and rain in summer and mild and humid in winter; the average temperature is about 16.4°C throughout the year, an average temperature of the hottest month is 28°C and the average temperature of the coldest month is 5.4°C. In summer, Ningbo is strongly influenced by the southeast monsoon, with abundant precipitation, in addition to being susceptible to JAC quasi-stationary fronts and typhoons in spring and autumn, with continuous rains, annual average precipitation around 1480 mm, and relative humidity remaining at around 70% year-round [4]. Basic information of precipitation in Ningbo area in 2018~2022 [5-9] (Table-2).

Table 2: Statistics of basic information of precipitation in Ningbo area in 2018~2022

Year	2018	2019	2020	2021	2022
Average precipitation throughout the year	1503mm	2020mm	1528mm	2161mm	1555mm
Average number of precipitation days throughout the year	163 days	173 days	155 days	169 days	143 days
Average temperature	18°C	17.8°C	18.3°C	18.5°C	18.2°C

Mosses, lichens and other organisms quickly grow in warm and humid places. Due to the high humidity in the air from long-term precipitation, the surface of stone relics remains moist, and even if it does not rain for a long time, the lichen moss on the surface of stone relics has enough moisture to survive. Some of the stone relics in scenic spots such as Ningbo Tianyi Pavilion Museum, Southern Song Stone Carving Park and Xuedou Mountain are located near bushes or under tall trees, which are in a shady environment for a long time, and the biological diseases on the surface of stone carvings are especially obvious (Figure 2 and Figure 3).



Figure 2: Lichen growing on the surface of stone carvings next to Shi Jian's tomb path



Figure 3: Surface of mortise and tenon of No.6 on the south side of the top of Bai Goose Pavilion in Tianyi Pavilion

It should be noted that temperature-difference weathering is also conducive to the occurrence of biological diseases on the surface of stone carvings. Due to the high temperature in Ningbo in summer and the convective rain in the afternoon, some of the stone carvings were suddenly washed by heavy rain after exposure to the sun, which quickly caused the development of surface fissures. Because the local rocks were full of water for a long time, it intensified the rock crumbling. The increase of cracks on the surface of the rock carvings is favourable for the residence of water or other organic matter, which provides suitable conditions for the growth of moss or lichen [4].

2.3 Inadequate Protection Measures

The survey found that some scenic spots are lacking in the management of open-air stone relics against biological diseases. Most of the stone relics in the scenic spots are kept in the open air for a long time, and the protection of stone relics is limited to fire prevention, theft prevention, and prevention of mechanical damage, and the prevention and control of biological diseases is relatively lacking. Although some scenic spots have measures for biological damage, but the effect is not obvious, biological disease, especially microbial disease is prone to recurrence.

3. Open-Air Stone Cultural Relics of Biological Disease Prevention Measures

Microorganisms such as fungi and lichens growing on the surface of stone carvings may metabolize organic or inorganic acids while carrying out life activities, accelerating the weathering of the surface of stone carvings [10]. The root cleavage of mosses and climbing plants may also accelerate the weathering of rock surfaces. Therefore, the timely removal and prevention of biological diseases on the surface of stone relics is particularly important.

3.1 Stone Cultural Relics Biological Disease Management Measures

Mechanical and chemical cleaning are two methods for stone heritage biological disease management.

Mechanical cleaning usually uses brushes, skimmer swabs and other tools on the stone artefacts' light surface brush is mainly used to remove stone artefacts combined with the more flimsy moss microorganisms, according to the analysis of the current state of stone artefacts, can be used containing cleaning agent skimmer swabs for the wet brush.

For aged and stubborn moss and difficult-to-remove lichen, more chemical cleaning method, through chemical reagents to kill microorganisms. In some areas, $\text{Cu}(\text{OH})_2$ is used as the chemical reagent's main component to spray the stone carvings' surface. After some time, $\text{Cu}(\text{OH})_2$ will make the surface organisms yellow and wither and then use mechanical cleaning methods to clean the residue. This traditional method is time-consuming and laborious, so it is improved (Figure 4).



Figure 4: Comparison of chemical material before and after application of dodecyl dimethyl benzyl ammonium chloride

Dodecyl dimethyl benzyl ammonium chloride (BKC) is the main component of the chemical material sprayed on the surface of biological diseases. It combines with the negative charge on the cell wall of microorganisms, destroys the microorganism activity, and finally kills them. The main component is a neutral substance, which will not damage the stone carving. After killing the organisms, the remaining residue is slight and requires minimal mechanical cleaning. For the long-term growth of microorganisms on stone artefacts produced by organic acid, it is necessary to de-acidify them to reduce the corrosion of stone artefacts damage.

3.2. Prevention of Regeneration of Biological Diseases of Stone Artifacts

3.2.1 Improve Storage Conditions

Ningbo stone cultural relics are mostly stored in the open air, vulnerable to the interference of external natural environmental factors. Ningbo area is hot and rainy at the same time, and the air humidity is high, providing a suitable environment for microbial growth. Small stone relics can be stored indoors, and the temperature and humidity, light, etc. can be controlled in a scientific way to provide a suitable environment for storage. For the protection of large stone cultural relics, based on the reality of in situ conservation requirements, can be built to protect the scaffolding, control the flow of visitors, long-term monitoring, etc. to reduce the occurrence of microbial diseases.

3.2.2 Chemical Protection

Chemical agents can be applied to the surface of stone cultural relics, thus reducing the regeneration of stone cultural relics' disease. The material obtained from the proportional distribution of bactericidal ingredients such as dodecyl dimethyl benzyl ammonium chloride (BKC) and Trichloroisocyanuric acid (TCCA), Sodium metaborate ($\text{NaBO}_2 \cdot 4\text{H}_2\text{O}$) is regularly sprayed on the surface of stone relics for cleaning to prevent the growth of moss and microorganisms.

The cracks on the stone's surface are prone to the growth of microbial mycelium, which can cause damage to stone carvings [11]. The organic fluorine compound material with sure adhesive and ageing resistance was selected to treat small crack grouting and reinforcement treatment technology. After the restoration, a new material with hydroxyapatite as the main component is used for surface reinforcement to reduce the surface of stone artefacts broken off to cause new cracks and reduce microbial growth.

3.2.3 Improve the Protection Measures According to the Pavilion

Ningbo area is rich in stone types, and biological diseases on different stones are different. Each museum and garden need to establish perfect protection and restoration measures for the stone characteristics of this park. Improve the monitoring management system, regular inspection of stone cultural relics.

4. Summary and Outlook

Stone cultural relics are an essential part of China's cultural heritage. With high historical, artistic, and scientific values, it is an essential historical carrier presenting the historical changes in China and the social landscape of different periods. The stone relics represent an era and a period of history and are the sum of our precious material and spiritual wealth. Ningbo-wide research on stone relics found that stone relics suffer from disease problems, especially biological diseases. Lichens, algae, moulds and other organisms grow on the surface of stone artefacts and in their fissures, causing their metabolites and secretions to dissolve and corrode the stone artefacts, leading to surface discolouration and surface weathering. The final experimental results show that Dodecyl dimethyl benzyl ammonium chloride can effectively remove moss from the surface of stone carvings and inhibit moss regeneration, which hopefully can provide a reference for the prevention and control of biological diseases of open-air stone relics in southern regions.

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