Research on the Restoration Techniques and Prevention Strategies of Historic Buildings in Macao

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Abstract: For the protection of historical buildings, in addition to the policy and legal provisions for the protection of historical buildings, it is also necessary to consider the traditional architectural form, craftsmanship, materials and other factors for specific historical buildings, and adopt appropriate restoration techniques. The text analyzes the common causes of damage to historical buildings in Macau, provides corresponding repair techniques to deal with the causes of damage, provides references and functions for the restoration of historical buildings, and avoids secondary damage caused by improper repair.

1. Introduction
Due to changes in the environment and the decay of building materials, Macau’s historical buildings have begun to expose more and more problems, including human factors and natural factors, to explore the causes of these problems and adopt scientific building restoration measures. This is for historical buildings. The most effective method of protection.

2. Causes of damage to historic buildings
There are many reasons for the damage of historical buildings, which can be mainly divided into natural and man-made factors. If the repair work is carried out blindly without knowing the cause of the damage, it will lead to poor repair timeliness and repeated problems of damage, which makes the maintenance cycle frequent and aggravated The economic and human burden on the maintenance of historical buildings. The common causes of damage to historical buildings in Macau are as follows.

2.1. Vandalism damage
Vandalism damage is one of the important reasons for the repeated restoration of historical buildings. Rammed earth and blue bricks are commonly used as the main materials for the construction materials of historical buildings in Macao. The materials are easy to loosen and fall off after being washed or weathered by rain. However, as a tourist city in Macao, tourists are in a rush, and tourists touch the walls of historical buildings from time to time. The surface falls off and forms potholes, which aggravates the aging of traditional materials of historical buildings and reduces their physical properties and service life.

Residents' and tourists' graffiti on historic buildings can also cause damage to the facades of historic buildings (Figure 1). For example, graffiti on the walls of Travessa da Paixão, Macau, and its bad
behavior will have a negative demonstrative effect on the public, and it also reflects Individual residents and tourists need to strengthen their awareness of the protection of historical buildings.

Figure 1. Travessa da Paixão (Source: Self-photo).

The use of wrong maintenance methods is also one of the reasons for the damage of historical buildings. For example, the use of impermeable latex paint on the blue bricks or rammed earth walls of historical buildings or filling the walls with cement, etc., causes the moisture in the walls to be unable to In addition, strong acid substances such as liquid phase are used to clean the stone wall moss. Although the moss and mold on the stone wall can be used instead to make the black stone wall white, it also melts part of the marble and releases carbon dioxide, especially when the words are engraved. On the stone wall, the stone inscriptions will be blurred and the quality of the cultural relics will be damaged.

2.2. Sea breeze and groundwater
Located on the west bank of the Pearl River Estuary, Macau is surrounded by the sea on three sides. It has a maritime subtropical monsoon climate. In summer, there are often tropical cyclones, bringing severe weather such as squalls and rains. The seawater is rich in chlorides, such as sodium chloride and magnesium chloride, which volatilize under solar radiation to form granules, and are attached to the facades of historic buildings by the sea breeze, and pass through the water or rain in the sea breeze. Infiltrated into the traditional building materials of historical buildings, these materials are often porous materials, such as red bricks, blue bricks and rammed earth, etc., and the evaporation of solar radiation causes chlorides to form crystalline salts, which increase the internal volume of the building materials, Which makes the material generate internal pressure, which has a serious impact on the building material, causing it to crack or powder. Therefore, historical building materials are required to have certain corrosion resistance, air tightness and wind resistance.

At present, most of the soil in Macau contains sea salt (chloride), and the groundwater is relatively high. Under the action of the capillary tube, the chloride will accompany the groundwater to penetrate upwards along the wall through the foundation of the historic building, and the water in the wall also evaporates under solar radiation. The chloride in the groundwater will form crystalline salt and destroy the building walls (Figure 2). Especially when the surrounding plots of historical buildings are impervious and hard ground, under the principle of hydraulic pressure, the action of the capillary will increase, allowing groundwater to penetrate to a higher position of the wall and expand the scope of wall damage.
2.3. Urban pollution

There are few industries in Macau, mainly tourism and entertainment. According to statistics from the Bureau of Earth, Geography and Meteorology of Macau, the air index of Macau’s roadsides and high-density residential areas ranges from normal to good, with an air quality index of 22-75. [1], so there is less acid rain. However, the pollutants produced by transportation activities still have a certain impact on historical buildings. In the research of scholar Rovella N, they took samples from the walls of historical buildings and discovered by using electron probe microanalyzer and energy dispersive X-ray spectrometer. The black substances on the walls of historical buildings are metal compounds and carbon powder. These substances mainly come from automobile exhaust emissions, etc., which are deposited on the building facade through air pollution [2], destroying the visual effect of the building facade and affecting cleanliness. Degree, increasing the maintenance cost of the building facade.

2.4. Animal and plant damage

The excrement of birds has a wide range of effects on historic buildings, because their excrement releases acidic substances, dissolving traditional materials such as building materials, masonry and stone. In addition, bird excrement also promotes the growth of fungi, causing fungal hyphae to penetrate into porous building materials, causing building materials to become black and moldy. At the same time, they release acidic substances and convert masonry materials into soluble salts. The soluble salt penetrates into the porous building material and evaporates under the high temperature in summer to form crystals, causing the material to crack and fall off. Bird excrement can cause irreversible damage to the building surface, causing "scars" on the facade of historical buildings, destroying the appearance, and causing damage to the physical properties and visual effects of the building. Studies have shown that even if the scale is removed, the corrosive effect of bird excrement will continue for a long time after the traditional materials are contaminated [3].

Termites are also one of the main reasons for destroying historical buildings, especially in historical buildings that use wood for indoor floors, ceilings, and stairs as the main materials. Termites are mainly divided into underground termites and wood termites. The termites in historical buildings in Macau are mainly wood termites. Wood termites like a dark and humid environment. They use the humidity in the air to absorb water and secrete formic acid to melt wood and stone to feed. At the same time, termites are afraid of sunlight. In buildings that are severely damaged by termites, termites will retain the outer skin of the wood, making the building unable to judge the existence of termites through the surface, which is extremely confusing.

Saplings, ivy, lichen, moss and other plants can greatly damage building materials in historic buildings. Plants produce acidic substances in the process of respiration. These acids dissolve masonry
and the minerals that make up masonry into specific elements through chelation, which leads to
deterioration of the masonry surface, thereby softening the wall material and providing plants with In
the growing environment, the rhizome is inserted into the masonry as an anchor point. As the plant
grows, the masonry wall will be cracked by the plant’s rhizome until it is completely disintegrated. In
addition, plants have a water-retaining effect. Their branches and leaves can collect part of the rainwater,
allowing the outer wall of the building to preserve a moist environment, attracting fungi and insects to
survive. The branches and leaves will also restrict light radiation from reaching the building wall,
affecting its natural drying. In Macau, this phenomenon often occurs in places where the water content
of the walls is high and the downpipes are blocked.

3. Historic building restoration technology

3.1. Dirt removal technology

The water cleaning method is one of the milder methods, which can be divided into four methods:

- The spray cleaning method, which can melt the dirt, sulfate crystals and contaminants
  condensed on the surface of limestone and marble, so as to clean with water.
- The flushing method is the most common method to remove dirt. First, use low-pressure water
  flow to rinse, gradually increase to medium-pressure water flow according to the degree of
  cleanliness, and finally use a soft brush for scrubbing.
- Detergent cleaning method, add a certain amount of detergent to the water to remove oil stains,
  such as the walls of Macao temples blackened by incense candles, and finally scrub with a soft
  brush.
- The steam cleaning method, using low-pressure hot water washing or hot towel hot compress,
  using water vapor to clean the wall of dirt, oil and plant residues, is a gentle and effective method,
  which can reduce the use of liquid [4].

Chemical cleaners can remove paint, paint and other dirt, especially graffiti on the wall. Before using
chemical cleaners, you need to know the building materials of the wall, especially the historic masonry
walls, and choose appropriate chemical cleaners according to their material properties. Specifically, it
can be divided into two methods:

- Alkaline cleaners, which mainly contain potassium hydroxide, ammonium hydroxide or
  trisodium phosphate, can clean multi-layer paints such as oil stains, latex and acrylic. After paint
  stripping, acidic liquids are used for acid-base Neutralize and rinse with water at the end.
- Organic solvents, using one or a combination of organic solvents, such as dichloromethane,
  methanol, acetone, xylene and toluene, have the same paint stripping effect.

The grinding method is not suitable for historical buildings with cultural relics value. It will remove part
of the exterior surface of the building while cleaning the dirt, thereby causing permanent damage to the
masonry, especially on the stone carvings and brick carvings on the walls. Make the polished stone lose
the polished surface. Grinding methods can be divided into:

- Sandblasting method, using silica, glass, garnet or nutshells, grains, dried corn, baking soda and
  other finely ground powders to clean the building surface by sandblasting, or Clean materials
  that are not easily damaged by sandblasting, such as bronze sculptures.
- Polishing method, using mechanical grinders and sanding discs to polish masonry is currently
  the most efficient and commonly used method, but like the shortcomings of sandblasting, it will
damage the masonry itself and is not suitable for historical buildings with cultural relics.

Laser removal can clean masonry walls without damage. Compared with chemical cleaners that are
harmful to human health and grinding methods damage masonry walls, laser removal can remove dirt
that is difficult to remove by water cleaning. However, the laser removal method has a high technical
level and is difficult to operate. It is necessary to adjust the laser beam to accurately focus on the
pollutants and adjust the appropriate wavelength to evaporate and burn the pollutants to achieve a
cleaning effect.
The bacterial cleaning method uses live bacterial cells and specific enzymes to non-destructively clean masonry materials, stone monuments and sculptures, especially masonry that has been penetrated by microorganisms and fungi, which cannot be deep cleaned by conventional methods. Bacteria can be used for cleaning. However, the bacteria cleaning method has certain risks. In addition to eroding the dirt, the bacteria will also erode the masonry and release sediments such as sulfide salts. Therefore, accurate bacteria equipment is required to ensure that the bacteria lose their activity in time after cleaning the dirt[5].

3.2. Building reinforcement and water interception technology

The wall grouting method is to inject natural hydraulic lime mortar into the wall to optimize the masonry voids of the masonry wall and strengthen the physical properties of the wall. The technology has great intervention and risk on building walls. Material tests and gas injection tests are required to check the compatibility of grouting materials and wall materials and the fluidity of grouting in the walls. At the same time, it accurately determines the grouting pressure, the depth of the wall hole and the conditions for wetting the internal wall. At the same time, it is necessary to consider the influence of traditional materials on the absorption of grouting materials, and adjust the material and ratio of grouting [6]. In addition, wall grouting technology is not a universal method, and the actual conditions of historical buildings must be fully considered.

The steel bar insertion method is an effective method to strengthen the safety of historical building structures by using mortar or epoxy resin combined with steel bars. The main steps are:

- Drill holes, drill holes with a diameter of 30mm in the wall to fill and insert steel bars, and use a dry drilling machine to avoid moisture damage to the original materials.
- Clean the holes and use special equipment to clean them thoroughly to ensure the effectiveness of the filling and the wall.
- Inject the filler of mortar or epoxy resin to 2/3 of the hole.
- For inserting steel bars, stainless steel threaded steel bars are suitable.

In addition, because the curing time of epoxy resin is short, the length of the anchored wall should not be greater than 1.5 meters, but epoxy resin has the advantage of not being easy to expand, it is easy to insert steel bars after injection, and has a better fixing effect. The mortar has strong fluidity and is easy to overflow in the wall joints, which hinders the filling of the wall and cannot guarantee the stability of the anchoring. Therefore, it is necessary to extract samples at the construction site to test the drilling of the original material, the cleaning of the holes, the curing time of the injected filler, and the drawing test of the steel bar.

Waterproofing agent injection method is a method of injecting waterproofing materials into building walls, which is suitable for brick walls with water seepage conditions. There are two injection methods in this method:

- Brick joint injection, drill holes in the brick joints of the brick wall, set appropriate holes, after cleaning the drill cuttings, insert the syringe into the hole for injection, when the waterproof material hardens, remove the syringe and use it Fill the holes with a suitable material.
- Inject into the brick, drill the brick body at a level of 45°. After cleaning the drill chips, insert the syringe and fix and inject the appropriate waterproof material. When the brick body fully absorbs the waterproof material or hardens, remove the register and fill the drill hole (Figure 3).
3.3. **Wall desalination technology**

The spray diffusion method is a method of spraying water on the surface of the wall to free the salt in the wall to the outside, thereby reducing or removing the salt in the wall. The amount of spray water can be set according to the salt content of the wall, and then the depth of water penetration into the wall can be adjusted. When the moisture on the surface of the wall dries, the salt crystallizes on the surface of the material, clean up the crystalline salt, and then repeat the whole process.

The electromobility method is based on the spray diffusion method, applying a smaller voltage to make the salt migration through the current to reach the outside of the wall. Although this method can efficiently remove salt, it has some shortcomings:

- If metal substances are contained in the wall, oxidation reactions may occur.
- The electrotransfer method has a better effect on alkaline metal ions and chloride ions, but has a poor effect on magnesium ions and sulfates, which aggravates its precipitation in porous materials.

The adsorption method uses mortar with smaller holes than the original material, such as lime mortar, to adsorb the salt of the original material through the capillary effect, so as to achieve the effect of salt removal. This method needs to check the hole size of the original material in advance to prepare suitable plaster, otherwise it will have the negative effect and aggravate the salinization of the wall. After the plaster is saturated with adsorption, the plaster should be replaced in time to prevent the salt deterioration of the wall tiles.

Pasting desalination method is the use of compound chemical solutions to non-destructively desalt the brick wall. The specific steps are as follows:

- Prepare an aqueous solution of sodium hexametaphosphate (or potassium hexametaphosphate) with a content of 5%-15%, at 20- Stir thoroughly at 50°C, use a towel or absorbent paper to fully wet the solution, and then apply it to the surface of the masonry cultural relic wall for desalination.
- After desalting is completed, mix and stir dodecyltrimethoxysilane and ethanol at a ratio of 5:100 at 50-70°C to make a solution, and brush the solution to the wall to form a protective layer.

The humidity difference desalination method uses the principle of osmotic pressure of air humidity for desalination. The specific steps are:

- Detect and evaluate the actual situation of the water content and salinity of the brick body.
- Adjust indoor air humidity and salinity so that the air humidity and salinity are the same as the humidity and salinity in the bricks. After a few days of rest, due to the principle of osmotic pressure, the salt in the brick body will be discharged naturally.
- Clean the surface of the brick body with clean water and repeat the above steps until the salt content of the brick wall reaches the desired level.

3.4. Termite and plant cleaning

Due to the concealment of termites, it is necessary to check the existence of termites before removing termites. There are several ways to identify termites:

- Percussion method. If you can hear a slight or harsh sound when you hit the wood, this is because the termites have detected a warning threatening to hit the wood with their head and shake their body. The occurrence of this phenomenon indicates the presence of termites in the wood.
- Observation method. A large number of termites shed wings on the site, wood chips in the corners of the room, plastering off the wall and traces of termites moving, and direct sighting of termites, etc., all indicate the existence of termites.

Common drugs to eliminate and prevent termites are:

- hexaflumuron is a benzyluron insecticide, is a chitin synthesis inhibitor, can quickly kill termites and eggs, and prevent re-invagination of termites.
- Fipronil is a neurotoxin of termites. After poisoning, termites will bring chemical poisons back to their colonies. After death, their bodies will be touched by the same species, causing the termite colony to die. But because the termite colony dies in an unobservable corner, it will Causes the growth of fungi, so it is not recommended.
- Boric acid can shut down the nervous system of termites, causing them to become dehydrated and die instantly. Spraying in the gaps between floors, walls and ceilings can effectively remove and prevent termites.
- Diatomaceous earth can penetrate the exoskeleton of termites. Because the exoskeleton of termites is mainly composed of silicon dioxide, diatomaceous earth has strong water absorption and can penetrate the exoskeleton of termites to make them dehydrated and die.
- Some plant essential oils have the effect of repelling and killing insects, such as marigold, catnip, nepeta, etc., spraying them on wood or other materials eroded by termites can inhibit the ability of termites to molt and lay eggs. Thereby killing termites, and less harmful to the human body.

Cleaning plants cannot be directly removed. Under normal circumstances, the roots of plants have penetrated into the building walls. Direct removal will cause additional damage to the building, especially the building walls that have been softened by the plants. The roots of the plants need to be cut off first, and herbicides are applied to the cut surface to make the plants lose toughness and wither quickly, and remove the plants in a gentle way [7]. Use soft brushes and fungicides for moss and fungi to clean the surface of the building after it is fully moistened to prevent strong cleaning from damaging the wall and forming streak marks. After the cleaning is completed, the potholes and cracks in the building wall should be filled in time, the building components that cannot be repaired should be replaced, and regular cleaning and maintenance should be performed to prevent plants from growing in the historic building again.

4. Conclusion

There are many factors that cause damage to historical buildings. Corresponding countermeasures should be formulated according to the actual conditions of historical buildings. There is no universal repair method in the protection of historical buildings. At the same time, it should be realized that the prevention of historical building damage is more economical than repairing. Most of the damage to historical building materials is irreversible, and the damage to historical buildings caused by natural factors can be prevented and controlled to a certain extent. Secondly, the research on the original materials of historical buildings is important. It is necessary to fully consider the compatibility between
the new materials used in the restoration and the original materials to avoid secondary damage to them. The protection of historical buildings lies not only in the preservation of physical objects, but also in respect for human history and civilization. Historical buildings can truly reflect the history and events of a certain period of time, condense the collective memory and homesickness of the public, and are the material of human spiritual civilization.

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