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Original Article

A Comprehensive Analysis of Moisture as an Agent of Deterioration in Heritage Buildings.

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ABSTRACT

Moisture is widely regarded as the most pervasive agent of deterioration in heritage buildings because it acts directly, through dissolution, swelling and freeze–thaw damage, and indirectly, by transporting soluble salts and sustaining biological growth. This paper presents a narrative review of scholarly and technical literature on moisture-related decay in historic masonry. It first outlines the principal sources of moisture, namely rising damp, rain penetration, condensation, hygroscopic uptake and leakage from defective services. It then examines the main decay mechanisms, including salt crystallization, freeze–thaw cycling, biological colonization and the loss of mechanical and thermal performance in damp materials. Finally, it considers diagnostic approaches and conservation strategies, with emphasis on the compatibility of repair materials and the value of routine maintenance. The review argues that effective conservation depends on identifying the source of moisture before treating its visible symptoms, and that climate change and inappropriate modern interventions are increasing the vulnerability of historic fabric, particularly in monsoon-influenced regions such as northern India.

Keywords: moisture, heritage buildings, deterioration, rising damp, salt crystallization, historic masonry, conservation

INTRODUCTION

Heritage buildings are repositories of cultural memory, craftsmanship and local building knowledge. Their survival, however, depends on the physical condition of the materials from which they are made, and those materials are continuously exposed to environmental stress. Among the many agents of deterioration recognized in conservation practice, including pollution, vibration, biological attack and human intervention, moisture holds a special position. It is present in almost every building, it enters through many routes, and it participates in nearly every other decay process (Camuffo, 2014; Torraca, 2009).

Historic structures are typically built of porous materials such as brick, lime mortar, lime plaster, sandstone and timber. Such materials are hygroscopic and permeable, which means that they absorb, store and release water in response to changes in the surrounding environment (Hall & Hoff, 2012). Traditional buildings were designed to function as "breathing" structures, allowing moisture that entered the wall to evaporate again. When this balance is disturbed by altered drainage, impermeable cement renders, changed ground levels or poor maintenance, water accumulates in the fabric and begins to cause damage (Oliver et al., 1997; Young, 2008).

The problem is especially relevant in South Asia, where the monsoon brings prolonged periods of high rainfall and humidity, and where many historic buildings, such as lime-plastered brick palaces, mosques, imambaras and havelis, remain in use or in partial use without systematic conservation. Understanding how moisture behaves in historic fabric is therefore a prerequisite for sound conservation decisions. The Venice Charter, one of the foundational documents of the conservation movement, stresses that the conservation of monuments requires permanent maintenance (ICOMOS, 1964), and controlling moisture is arguably the most important part of that maintenance.

The aim of this paper is to review how moisture acts as an agent of deterioration in heritage buildings. It has three objectives: (a) to identify the principal sources and pathways of moisture in historic masonry; (b) to explain the main mechanisms through which moisture causes physical, chemical and biological

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damage; and (c) to discuss diagnostic and conservation approaches that address the cause of damage rather than its symptoms.

METHODOLOGY

Case examples are included to support the synthesis of existing knowledge on moisture-related deterioration and to demonstrate its practical implications for heritage building conservation.

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2. SOURCE SELECTION

Peer-reviewed journals (construction materials, heritage science)	**Books & edited volumes** (masonry, stone, moisture transport)	**Technical guidance** from conservation bodies	**International charters** Venice Charter (1964)

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3. LITERATURE SEARCH
Keyword combinations:
"Rising damp" • "salt crystallization" • "historic masonry"
"Moisture and cultural heritage" • "climate change and heritage"

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4. SELECTION CRITERIA
Priority to widely cited works and publications that explain mechanisms, not only individual cases

▼

5. THEMATIC ANALYSIS
Organised under three headings, following a conservator's logical sequence

▼

A. Sources and pathways of moisture
Where does the water come from?

▼

B. Mechanisms of moisture-related deterioration
What is it doing to the fabric?

▼

C. Diagnosis and conservation strategies
What can be done about it?

▼

CONCLUSION
Effective conservation of heritage buildings requires accurate identification of moisture sources, appropriate diagnostic methods, compatible repair materials, and regular maintenance to prevent further deterioration.

Sources and Pathways of Moisture in Historic Buildings

Moisture enters heritage buildings in liquid and vapour form, and the first task in any diagnosis is to distinguish between the possible sources. Five are commonly identified in the literature.

The first is rising damp, in which groundwater is drawn upward through the pores of masonry by capillary action. The height reached depends on the pore structure of the brick, stone and mortar and on the rate of evaporation at the wall surface, and the process is governed by the balance between water supply and drying (Hall & Hoff, 2012; Rirsch & Zhang, 2010). Rirsch and Zhang demonstrated that the properties of the mortar strongly influence this process, which

shows that wall behaviour cannot be understood from the masonry units alone (Rirsch & Zhang, 2010). Rising damp is nevertheless often over-diagnosed, and other sources are frequently mistaken for it (Oliver et al., 1997).

The second source is rain penetration. Driven rain wets exposed façades, and defects such as open joints, cracked renders, blocked gutters, failed flashings and damaged roofs allow water to move deep into the structure. In monsoon climates, repeated wetting and incomplete drying between rainfall events can keep walls damp for much of the year (Camuffo, 2014).

The third source is condensation, which occurs when warm, humid air meets a surface cooler than its dew point. It is common in heavy masonry buildings, which respond slowly to changes in air temperature, and it can be aggravated by closing ventilation openings or by introducing new heating or air-conditioning without considering the building's moisture balance (Camuffo, 2014).

The fourth source is hygroscopic moisture. Salts present within the wall absorb water vapour from the air when relative humidity exceeds a critical value, so that the material remains damp even when no liquid water is entering it (Charola, 2000). This is why walls may feel damp in humid weather long after a leak or a rising-damp problem has apparently been solved.

The fifth source is leakage from defective services, including drains, water supply pipes and sanitary fittings, together with poorly designed ground drainage and changes in surrounding levels. These sources are often the easiest to correct, yet they are frequently overlooked because they originate away from the visibly damaged area (Young, 2008).

Once water is present in the pore system, it can damage historic fabric through several linked mechanisms.

Mechanisms of Moisture-Related Deterioration

Salt crystallization is widely regarded as the most destructive. Soluble salts, derived from groundwater, building materials, previous repairs, de-icing, atmospheric deposition or biological activity, are carried in solution through the wall and deposited where water evaporates. When crystals grow within confined pores, they exert pressure on the pore walls, and repeated cycles of dissolution and crystallization can cause powdering, flaking, scaling and loss of surface detail (Charola, 2000; Scherer, 1999). Lubelli et al. showed that the type of salt influences both the damage mechanism and the resulting decay pattern in brick masonry, which explains why similar-looking buildings can deteriorate very differently (Lubelli et al., 2004).

Freeze–thaw action is a second mechanism, although its relevance depends on climate. Where water in saturated pores freezes, the associated expansion and the movement of unfrozen water can generate stresses that exceed the tensile strength of the material (Doehne & Price, 2010). In much of the plains of northern India this is a limited concern, but in Himalayan and upland heritage settings it is significant. In warm climates, the equivalent damage is more often caused by wetting–drying cycles, which produce repeated swelling and shrinkage, particularly in clay-bearing stones and earthen materials.

Chemical and biological processes form a third group. Water dissolves calcium carbonate in lime mortars and plasters and carries the products of dissolution out of the wall, gradually weakening the binder. Dissolved pollutants add to this effect, and the interaction between moisture and atmospheric pollutants is well documented for the built environment (Brimblecombe, 2003). Persistently damp surfaces are also colonized by algae, fungi, lichens and higher plants, whose roots and acidic metabolic products further disrupt the fabric. In timber, sustained high moisture content promotes fungal decay and insect attack, which can compromise roofs, floors and decorative elements (Camuffo, 2014).

Finally, damp materials lose performance. Wet masonry conducts heat more readily, reducing thermal comfort, and wet plaster loses adhesion, which leads to detachment of painted surfaces and murals. Moisture therefore threatens not only structural integrity but also the aesthetic and documentary value of heritage, which is often the reason for protection in the first place. Fitzner and Heinrichs emphasize that weathering forms should be recorded systematically so that the severity of damage can be assessed and compared (Fitzner & Heinrichs, 2002).

Diagnosis and Conservation Strategies

Because moisture damage has many possible causes, conservation guidance consistently recommends that diagnosis precede treatment. A sound investigation begins with careful visual survey and documentation

of the pattern of damp, its height, its seasonality and its association with features such as gutters, drains or recent alterations (Oliver et al., 1997; Young, 2008). This is supported where necessary by measurement of moisture content, salt analysis and monitoring of temperature and relative humidity, which together allow conservators to distinguish between rising damp, hygroscopic salts, condensation and leakage (Camuffo, 2014).

Once the source is identified, the preferred strategy is to remove or reduce it using the least intrusive means. This usually involves repairing roofs and rainwater goods, restoring effective drainage, lowering excessive ground levels, repairing leaking services and improving ventilation. Such measures are low in cost, reversible and consistent with the principle of minimum intervention, and in many cases they allow the wall to dry naturally (Torraca, 2009; Young, 2008).

Where repairs to the fabric are needed, compatibility of materials is critical. Cement-based mortars and renders, and impermeable paints and coatings, are less permeable than historic lime-based materials. They can trap moisture and drive evaporation, along with the associated salt crystallization, into the adjacent historic brick or stone, which then decays instead of the sacrificial repair material (Doehne & Price, 2010; Torraca, 2009). Lime-based mortars and plasters, applied with an understanding of local traditions, are therefore generally preferred. Where salts are already established, sacrificial renders or poultices may be used to draw them out, and salt-laden material should be monitored rather than repeatedly patched (Charola, 2000).

Finally, long-term protection depends on routine maintenance and monitoring. Regular inspection and cleaning of drainage routes before the monsoon, prompt repair of small defects and records of condition over time are more effective and economical than large-scale intervention after serious damage has occurred. Maintenance is also the approach most closely aligned with the philosophy of the international conservation charters (ICOMOS, 1964).

CONCLUSION

Moisture is a primary agent of deterioration in heritage buildings because it enters through many pathways and drives a wide range of physical, chemical and biological decay processes. Rising damp, rain penetration, condensation, hygroscopic salts and leaking services each require different responses, and salt crystallization in particular links many of these sources to visible damage. The literature reviewed here shows that successful conservation begins with accurate diagnosis, favours simple measures that remove the cause of dampness, and uses repair materials that are compatible with historic fabric. Regular maintenance remains the most reliable defence. Treating the symptoms of damp, for example by applying impermeable coatings, without addressing its source often accelerates the loss of heritage value.

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