Engineering Failure Analysis 90 (2018) 103–115

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Contribution of humidity to the degradation of façade claddings in current buildings

Clara Pereira[a], Jorge de Brito[b,*], José D. Silvestre[b]

[a] CERIS-ICIST, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
[b] CERIS-ICIST, Department of Civil Engineering, Architecture and Georresources, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

ARTICLE INFO

Keywords:
Coating failures
Defects
Building failures
Correlations

ABSTRACT

The effects of humidity on façade claddings are analysed based on the statistical results of six similar expert inspection systems focused on adhesive ceramic tiling, natural stone claddings, wall renderings, painted rendered walls, External Thermal Insulation Composite System (ETICS) and architectural concrete surfaces. The analysis compares the association within each system between defects and causes. ETICS have the highest incidence of humidity defects. However, painted rendered walls have more defects associated with humidity causes. Biological colonization and efflorescence are the defects most associated with humidity defects and causes. Incorrect detailing is a main cause of humidity defects.

1. Introduction

Humidity is one of the most recurrent causes of defects in buildings, both in claddings and structural elements. Some authors [1–3] even consider it as the main direct or indirect cause of defects in housing. It is also a relevant factor on the choice of materials for a given location, conditioning the use of some materials in moisture-prone environments [3,4]. From a different point a view, the presence of water in buildings, namely indoors, can be the cause of an increased risk of respiratory disorders, according to epidemiological evidence from studies on indoor air quality that shows higher risk for people living in damp or mould-ridden buildings [5]. This paper intends to compare the effects of humidity in different types of façade claddings in current buildings, based on the results of previous inspection programs [6–18].

This paper starts with a review of the main humidity issues in buildings. Then, in a second stage, humidity defects (leakage humidity and superficial humidity) are analysed, as well as the humidity-related causes of defects. In a third stage, the analysis focuses on the causes that originate humidity defects and other defects associated with humidity causes.

2. State of the art on humidity as a cause of defects in buildings

2.1. Degradation of façades

Façades are a complex system, part of the building envelope, which decisively affect the building's comfort level. They are typically composed of cladded walls and openings that define the building's appearance. Furthermore, façades work as a barrier against external aggressions, simultaneously establishing a means of communication between indoors and outdoors [19]. To evaluate

* Corresponding author.
E-mail addresses: jb@civil.ist.utl.pt (J. de Brito), jose.silvestre@tecnico.ulisboa.pt (J.D. Silvestre).

https://doi.org/10.1016/j.engfailanal.2018.03.028
Received 6 October 2017; Received in revised form 17 March 2018; Accepted 19 March 2018
Available online 20 March 2018
1350-6307/

Fig. 1. Example of an historic building with various protrusions intended to protect the façade from the water flow (left) and a contemporary building with a single protrusion that is effective in protecting the façade from humidity-related issues (right).

the performance of a façade, its components need to be identified, as well as the aggressions that will affect it. In this paper, six different types of façade claddings are analysed: adhesive ceramic tiling, natural stone claddings, wall renderings, painted rendered walls, External Thermal Insulation Composite System (ETICS), and architectural concrete surfaces. This analysis intends to understand how they are affected by one specific aggressive agent: humidity.

As stated by Mostafavi and Leatherbarrow [20], to some extent, humidity effects on claddings can be seen as a surface modification often classified as aesthetic deterioration, resulting in “sightly” (i.e. pleasant to look at) or “unsightly” buildings. This aesthetic deterioration on façades corresponds, essentially, to the effects of rainwater on materials, accentuated by the inadequate provision of projections to lead the downward flow of water, such as sills, copings or downpipes, unpopular in recent “flat” façades. The effects are more visible in more porous materials, as limestone and concrete, resulting in a dramatic change in the overall appearance of the building. In fact, historic buildings (Fig. 1, left) used to have abundant ornaments that protrude beyond the surface and function as drips, projecting the rainwater and preventing the deposition of water on the façade. As the architectural trends evolved, as seen in Fig. 1 (right), these dripping ornaments were removed, bringing the need of new sealants [20].

2.2. Humidity as an aggressive agent towards buildings

For the purpose of this paper, humidity includes two types of defects, namely leakage humidity and superficial humidity. Superficial humidity includes construction humidity, rising damp, rainwater, and condensation. On the other hand, leakage humidity refers to the penetration of rainwater and humidity due to accidental causes. Although some buildings may have been designed to endure the effects of humidity, all buildings need maintenance measures to prevent and correct such effects.

Rainwater can penetrate buildings through their envelope, humidifying the materials and frequently altering them [2]. The internal layer of external walls reflects the problems of external claddings, resulting in stains of various sizes and compromising the overall aesthetic appearance of a wall [3]. In the current area of the façade, leakage humidity is often related with the inadequate choice of materials or their deficient application. Nevertheless, most leakages occur in vulnerable areas, like discontinuities in walls and roofs. When leakage humidity is related with accidental causes, it may be due to a plumbing leakage, accidentally open taps, or the excessive use of water in inadequate cleaning methods. Humidity infiltrated in walls searches and finds all weak points, creating preferential paths. Through those paths, water dissolves soluble salts from mortars, altering the wall's structure. Water is the main cause of walls disaggregation in old buildings [21], in which leakage humidity is also pernicious if walls include timber elements, leading to rot fungi and thermite attacks. As for paintwork, moisture is also considered a key agent to the occurrence of efflorescence, rust, mould and splintering/blisters [22].

Humidity in buildings may have different expressions [2]. Construction humidity refers to the water that is associated with most binding materials or with the operations of application of materials on site, and which can affect the building within its first year. If a post-construction drying period does not occur before the occupation of the building, residual humidity may affect the performance of the insulation, favouring condensation. It may also be responsible for the deterioration of putrescible materials. Rising damp affects elements in contact with the ground. Groundwater is absorbed and rises by capillarity until it is stopped by a physical barrier or gravity. It may originate the deterioration of materials, their loss of adherence, and the crystallization of soluble salts forming a visible stain in claddings. These issues may be more severe in basements and ground floors. Rainwater can penetrate the building's envelope, humidifying the affected materials and altering them. It may result in water leakages and humidity stains, as well as efflorescence. Condensation is originated by water vapour in indoor air, which liquefies in surfaces cooler than the surrounding air and at temperatures below the dew point. It is highly related with the type of use of the building and with ventilation rates, originating mould, thermophoresis, and compromising thermal insulation. Condensation can be prevented by heating indoor air, increasing the insulation of external walls and improving natural ventilation [5].

Porous materials are hygroscopic, and they retain a given amount of the environment's humidity in their pores, according to a hygroscopic balance. However, generally, defects associated with hygroscopic humidity in the materials are not severe. They may lead to swelling and to a rising risk of biological degradation in timber elements, humidity stains, decrease of thermal insulation and efflorescence and cryptoflorescence occurrences. Humidity due to accidental causes occurs randomly due to leakages in plumbing, floods, and excessive use of water in inadequate cleaning/washing operations [2].

Furthermore, humidity-related issues are not isolated occurrences. Often, there is an interpenetration between causes and effects