



# Microclimatic analysis of historic buildings: A new methodology for temperate climates



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## ABSTRACT

Old buildings frequently present specific microclimates that do not always match the ideal conditions for the safe conservation of their materials, but that have been stable and consistent for a long time.

In the last years several methodologies have been defined and the search by ideal values of temperature and relative humidity was intense, as is example of the UNI 10829. Presently the dynamic approaches are predominant, especially the methodologies presented in EN 15757 and in the ASHRAE specification (Museums, Galleries, Archives and Libraries).

Despite the standardization and the numerous case-studies, the literature on the buildings in temperate climates is still scarce and the standard EN 15757 does not seem adequate to be used in all types of climates.

This paper analyses the indoor climate of a thirteenth century church in Lisbon (Portugal) using the standard EN 15757, compares the data with other European case-studies and proposes a new method of analysis for temperate climates based on EN 15757 and influenced by the UNI 10829 and the ASHRAE specification.

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## 1. Introduction

Churches are an important part of the world's cultural heritage. Some of them have endured climate changes over the centuries, with their materials undergoing adjustments in order to adapt to the local climate. It is important to study the microclimate inside these buildings and set the values for which the materials themselves have been adapting, aiming to raise awareness and to contribute to a proper conservation. However, there is often a conflict between the needs for thermal comfort of the occupants and the requirements for a proper conservation of cultural property, which requires a reasonable compromise to be achieved [1,2].

Even when the studies are focused on the needs of materials and artefacts, a general analysis based on ideal values for each material is often taken. These values, although theoretically correct, may not express the microclimate conditions in which the artefacts were conserved and can increase the risk of degradation of the storage conditions.

For a long period the definition of ideal temperatures was related to the comfort of visitors [3], while for RH the values were

defined based on studies performed on museums and historic buildings, assuming that the combination of both would create adequate environments for conservation, no matter the type or location of the building [4,5].

Later the concerns turned towards the needs of various materials and laboratory studies were performed to provide optimal values of temperature and relative humidity for the proper conservation of each material [2,6] or artefacts composed for various materials [7]. During the last decade the trend of change was higher, the dynamic approach replaced the earlier methods and the search for ideal values was abandoned [8]. It was assumed that if a particular material or artefact is exposed for a long period (over 1 year) to the influence of certain conditions, it can experienced cracks and irreversible deformations resulting from the new achieved equilibrium. This process is known as acclimatization [9–12]. Changes in historic microclimate for which the objects were acclimatized can cause a catastrophic response, because the materials may have exceeded its capacity of deformation, which can ultimately lead to total losses [3]. Also based in the past conditions, but with slightly differences, Michalski defined the concept of “proofed fluctuations” as the fluctuations experienced by the object in the past as a target, assuming that if the largest past fluctuations are not exceeded in the future the risk of new mechanical damage will be extremely low [13].

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Quite often the authors of the existing studies adopt different analysis methodologies, making it difficult to compare results and decide on their applicability. The emergence of new standards – such as EN 15757 [9] in Europe (examples of application: [14–17]) and ASHRAE specification [18] (Museums, galleries, archives and libraries) in North America (examples of application: [19,20]) – led to a greater standardization of methodologies.

The European standard is based, among other references, on laboratory tests [7] and on the behaviour of several objects located in the church of Santa Maria Maddalena [21]. It is also possible to find some case-studies based on similar methodologies performed by the same authors [15].

However, the European standard is still recent and there is not an exhaustive study on its application in all types of climates. That is why it is necessary to evaluate this methodology in temperate climates and eventually propose changes, if required. To achieve this objective, data obtained from the monitoring of the church of St. Christopher in Lisbon (Portugal) was used, with records from November 2011 to August 2013.

## 2. Methodology

### 2.1. Site description

The thirteenth century St. Christopher church (Fig. 1) was built during the Arab occupation and later converted to Christianity. It features thick walls lined with limestone, which high thermal inertia. The roof is made with ceramic tiles and a wooden structure [22]. Inside there is a rectangular room with an area of 144 m<sup>2</sup> and a height of 13 m in the centre, with a funeral home at south and the sacristy at north.

The building has retained its original configuration until the sixteenth century, when it was severely damaged by a fire and suffered major reconstruction works. Later, in 1755, when a major earthquake in Lisbon destroyed much of the historic district, the church resisted with little damage. In the twentieth century it was recognized as a national monument by the Portuguese government in recognition of its historical and cultural significance to the country [22].

The Church, located on the slope of the São Jorge Castle, in Lisbon, is under the influence of a Mediterranean climate with mild temperatures. Lisbon has about 260 days of sunshine per year, an average annual temperature of 17 °C, annual precipitation of 725.8 mm and north prevailing winds [23].

This building no has artificial heating systems and the number of visitors is reduced, limited to the celebrations periods, which occurred normally for 2 h per day.

Although Portugal presents a Mediterranean climate, it has important differences in relation to the other countries in southern Europe due to the proximity to the Atlantic Ocean. This fact contributes to a particular climate with winters less cold and summers less warm, leading to the reduction of the extreme cycles that are very dangerous for the conservation of materials and buildings [24].

### 2.2. Microclimatic measurements

The environmental monitoring was conducted to understand the natural microclimate of a historic building in a temperate climate. For this purpose, a set of sensors for automatic and manual records was used and the measurements were taken from November 2011 to August 2013, with automatic records every 10 min.

Outdoor, the temperature and relative humidity were measured automatically with a portable sensor (H1-HOBO U12-013; uncertainty:  $\pm 0.35$  °C for temperature and  $\pm 2.5\%$  for relative humidity – below the required values defined by the standards EN 15758 [25] and EN 16242 [26], respectively), while for the indoor the basis measurements were conducted at the northern pulpit of the main room using a probe (Delta T RHT2nl – denominated as D1) composed by a relative humidity sensor (uncertainty:  $\pm 2\%$  – below the required value of EN 16242 [26]) and a thermistor for the temperature (uncertainty:  $\pm 0.1$  °C – below the desirable value defined by EN 15758 [25]). A portable sensor (H2) was also used for comparison purposes. In the rest of the room the temperatures were measured using thermocouples type T (uncertainty:  $\pm 0.5$  °C – equal to the required value for the air temperature and below for the surface temperature, according to EN 15758 [25]) and the relative humidity was calculated assuming that the concentration of water vapour was constant in the entire room (due to the lack of sources of variation) using the probe values as reference. The

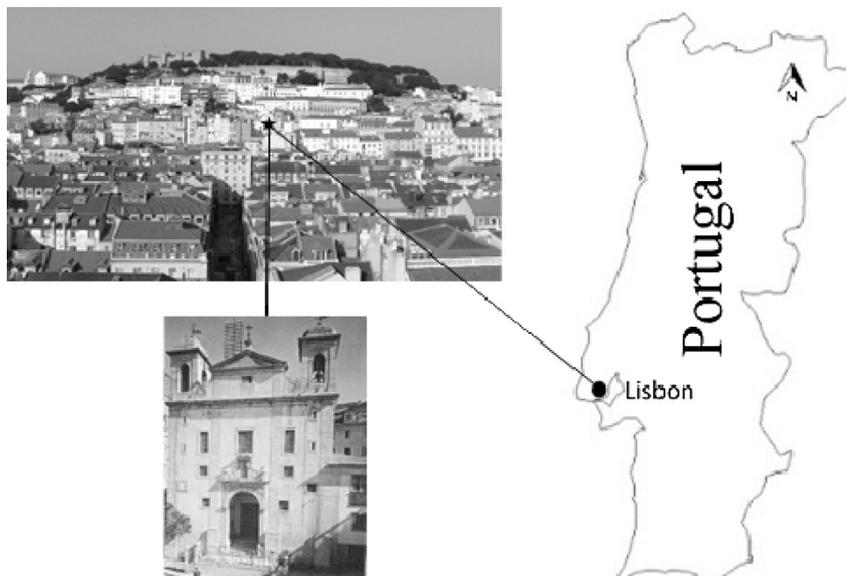


Fig. 1. St. Christopher church, Lisbon (Portugal).

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