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SCIENCE DIRECT®
Building and Environment 41 (2006) 223–234
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

Defects and moisture problems in buildings from historical city centres: a case study in Portugal

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Received 1 December 2004; received in revised form 7 December 2004; accepted 4 January 2005

Abstract

Conservation of ancient buildings is a major issue for modern societies, both from economical and cultural viewpoints. Information about the ancient built heritage is vital to plan adequate remedial measures. Taking a historic centre in Portugal as a case study, this paper presents an extensive survey of building typology and materials, damage in the building envelope, indoor survey of damage, and measurements in indoor air temperature and relative humidity. Water-related problems can be confirmed as the single most important defect combined with inadequate sun exposure, ventilation and heating, and excessive moisture indoor production. Extremely low temperatures, high humidity and presence of mould therefore, compromise the indoor quality of life of the inhabitants; and make urgent repair at many levels necessary.

Keywords: Ancient buildings; Building damage; Traditional building techniques; Indoor moisture; Indoor temperature

1. Introduction

After the second World War many ancient buildings and historical centres needed major repairs and rehabilitation. Nevertheless, due to the low income after the war and because of the need for new materials such as reinforced concrete and steel, masonry buildings were in many cases abandoned to the population with less financial resources i.e. to those who could not afford the costs of adequate repair and restoration. Only during the last decades, the idea that ancient buildings could be restored and reused became appealing for the market. The present policy is not only to preserve but also to make buildings and the whole historic part of the cities came alive, functioning and appealing to the inhabitants and to the tourists. It is the unique atmosphere of narrow streets and historic squares that provide a meaning to the cultural heritage, which must be the everyday reality for the local population.

Due to the combined effects of environment (earthquakes, soil settlements, traffic vibrations, air pollution, microclimate, etc.) and lack of maintenance, now most of this heritage is damaged. The issue of structural safety is, of course, a primary requirement, particularly in seismic zones, see [1,2]. But the adoption of appropriate remedial measures and the elaboration of plans for the rehabilitation of historical centres call for comprehensive surveys of the existing built heritage, details of materials, prevalent damage, building typology, living conditions, etc.

Humidity is a major source of problems in buildings worldwide. Moisture can damage the building structure, the finishing and furnishing materials, [3,4] and can increase the heat transfer through the envelope and thus the overall building energy consumption [5]. Besides being a direct cause of human discomfort, high indoor humidity promotes mould growth, which can have

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doi:10.1016/j.buildenv.2005.01.001

adverse health impacts on the occupants [6,7]. Moisture-related problems are generally more severe in residential buildings due to the absence of air conditioning and presence of more intensive moisture sources. Moisture problems are also intensified when there is a deficient (or even lack of) insulation of the envelope and when no heating is provided on a regular basis, which is the case of the historical centre considered as case study.

The present paper addresses both the issues of detailed characterizations of the urban composition of a Portuguese historical centre and hygrothermal indoor conditions. Damage survey in the building envelope and indoor is addressed, and, for a selected sample, measurements of the room temperature and relative humidity were made during the most grievous season (winter). An accurate characterization of the indoor building environment and of the construction characteristics of the building components, such as done here, are an essential step for the preservation of the built heritage and for the selection of adequate remedial measures.

2. Materials and methods

The investigation was carried out sequentially in consecutive steps and using three levels of refinement. The consecutive steps were: (a) building typology (Section 3.1), (b) building materials (Section 3.2), (c) damage survey in the building envelope (Section 3.3), (d) indoor survey of hygrothermal conditions and damage (Section 3.4).

The first level of refinement was the entire classified historical centre area, and the objective was to address the building typology (Section 3.1) and the building materials (Section 3.2). The investigation was carried out using the general plan of the area, available from the Municipality, and visual observation from the exterior. The historical centre possesses two clearly different distinguishable areas (inside and outside the walls) and the building typology and materials have been addressed independently for each area.

A second level of refinement had to be used for the subsequent step of damage survey in the building envelope (Section 3.3), due to the relatively large size of historical centre and the available resources. In this case, the complete area inside the walls and two main streets have been selected for further analysis in the building envelope. Again, only visual inspection from the exterior was carried out, using a classification of damage rooted in the literature and the defects found in the first level survey, previously carried out.

Finally, a third level of sample refinement was considered, aiming at analysing the indoor conditions of the building stock (Section 3.4). For this purpose, around 25% of the houses inside the walls have been selected with the aim of a deeper characterization, with a special focus on damage manifestation, sources of damage and hygrothermal measurements. A special form has been prepared and filled for this sample of sixteen houses, which required indoor observation and an interview with the inhabitants. The measurements of temperature and relative air humidity were carried out for three consecutive days during the coldest period (December to March, 2001), separately in the kitchens, living rooms and bedrooms. The equipment used is produced by Testo (Testostor 175-2) and includes an internal sensor to measure air temperature and air relative humidity, internal memory and a battery. The readings can be afterwards downloaded to a PC. The precision of the equipment is $\pm 0.5\,^{\circ}C$ for the air temperature and $\pm 3.0\%$ for the relative humidity. The readings have been registered every hour and the equipment has been always placed 1.0 m above the floor level, so that the different results can be compared.

2.1. Characterization of the historic centre of Bragança

The city of Bragança is located in the North-East of Portugal and old documents refer that Bragança was already inhabited in the first century BC, even though the first walls of the Castle date from the 12th century [8]. Being located far away from the large cities and the Atlantic coast, with difficult access through a mountainous region, the city was never wealthy and powerful. This fact resulted in ancient buildings being mostly simple and modest, even though some monumental buildings exist.

The classified historical centre area is a total of $0.33\,km^2$, 724 houses and 1087 inhabitants, see Fig. 1. Two areas are clearly distinguishable: one inside the walls (Citadel) and another outside the walls. The Citadel is the oldest part of the city, which later grew outside of the walls with more spacious and wealthier houses.

The climatic conditions are rather harsh with considerable rain (an annual average of 800 mm, mainly between October and May) and cold temperatures in the winter (the number of degrees-day, on a $20\,^{\circ}C$ base, is 2850 and the heating season duration is of eight months), see also Fig. 2.

3. Results and discussion

3.1. Building typology

Housing is always the result of a multiplicity of several interrelated constraints, reflecting natural and historical conditions, building techniques, economical and social structure, profession, family requirements, aesthetics and feelings, especially group feelings of the people that built the house and live there. These