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Deterioration of European apartment buildings

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Abstract

A total of 349 residential building audits were performed in seven European countries to collect data on the degradation of building elements (architectural and installations). The buildings cover typical architectural typologies, sizes, constructions and installations, at different states of deterioration. The data was collected based on a standardized methodology for building audits. Follow up analysis revealed the most important influencing factors on the deterioration of existing residential buildings throughout Europe and estimated service lives of various building architectural elements and electromechanical installations.

Keywords: Residential buildings; Audits; Degradation; Influencing factors; Service life; INVESTIMMO

1. Introduction

The building sector uses about one third of all the raw materials and energy produced in Europe and over half of the electricity. Buildings are also a major pollution source. They account for about half of sulphur dioxide emissions, a quarter of nitrous oxide emissions, about 10% of particulate emissions and about 35% of carbon dioxide emissions which are closely related to climate change, while construction wastes have a major impact on landfills. Building practices in the past have not properly addressed the current concerns about the optimum use of energy in buildings or the minimization of the environmental effects. In addition, ageing installations and facilities result in an even grimmer scenario. Existing buildings are often energy costly to operate, with serious indoor environmental quality problems. However, they constitute a huge investment in natural and human resources, and the building stock is an enormous pool of private and public investment. According to studies carried out by the European Cooperation in the field of Scientific and Technical Research (COST), the estimated value of our European Urban Heritage amounts to about 40 trillion Euro for the housing stock alone.

The existing building stock in Europe is estimated at 150 million dwellings [1], whereas only around 2 million are built every year. About 70% of the residential building stock is over 30 years old and about 35% are more than 50 years old. This is an important observation also in relation to energy consumption of existing buildings, given that most national building regulations that mandate thermal insulation of building envelopes were introduced after the 1970s following the energy crisis. Technical installations are also becoming obsolete and consequently may fail to properly serve the occupants or in case of the energy related equipment, they consume more thermal or electrical energy compared to new equipment. For example, it is estimated that about 10 million residential boilers are more than 20 years old, thus having a significantly lower thermal performance than the currently available units.

The deterioration of building components and installations is an anticipated consequence of the ageing process. However, a number of parameters like the quality of construction and materials, the local weather conditions or the lack of maintenance, can greatly influence this process. The degree and rate of degradation of the built environment in Europe is of enormous economic and technical importance, since the value of the built environment

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represents approximately 50% of the national wealth of most countries [2]. About half of the expenditure in the construction industry in Europe is spent on repair, maintenance and remediation. Premature deterioration of concrete structures is becoming a major problem in many countries and especially in urban environments due to adverse environmental conditions.

Air pollution can damage building materials because of their long life [3]. Man-made pollutants have greatly increased the degradation rate of buildings. Of particular importance are corrosion caused by acid rain (especially due to SO_2) and soiling caused by particles (especially soot). Corrosion or erosion of construction materials and of coatings, are mainly due to acidity, especially from SO_2, air humidity and rain, O_3, NO_x, dust and soot. Numerous studies have quantified the effects of air pollution on corrosion and erosion on different building materials like natural stone decay [4,5], wood [6], finishing surface coats [7,8], and various other building materials [9]. Soiling is generally due to the deposition of airborne particulate matter, especially soot, onto the building surface.

Exterior building surface degradation is one of the major concerns for building owners that tend to decide on exterior renovation actions on the basis of the general appearance of a building. Air pollution damage to buildings [3] includes expenditures to restore the original condition of the damaged object (i.e. cleaning), preventive measures (i.e. the extra cost of paint with enhanced resistance to pollution), and loss of amenity (i.e. aesthetic loss as a building becomes dirty). In a study for calculating the damage cost of French buildings caused by individual sources of pollution, it was found that the amenity loss is approximately equal to the renovation cost.

Numerical models describing the deterioration process of masonry subjected to an aggressive environment, in order to predict time taken to reach a given damage level have been presented by [10]. Efforts have also been made to describe the deterioration process of building materials and components and to predict the future degradation state of a building, for example, the probable date of repair/replacement, since this is directly connected to higher refurbishment costs [11].

The service life of a building element is defined as the period of time, measured in years, after installation during which all properties meet or exceed the minimum acceptable values when routinely maintained. Service life prediction or demand for durability has been treated in several national standards and building codes [12]. Similar efforts are also underway by several international organizations [13,14].

Reference Service Life (RSL) and Estimated Service Life (ESL) methods are classified in one of the following categories: factor method (also referred to as ‘deterministic’); probabilistic (also referred to as ‘theoretical’ and ‘stochastic’) method and engineering approach. The factor method [14] is simple and needs few input data, but it may underestimate the actual complexity of degradation process of building materials and components. The probabilistic methods consider degradation as a stochastic process, and are more difficult to apply, since they require more detailed inputs in the form of probabilities. Engineering methods [15] relate structural engineering approaches or other common design analysis and service life prediction, using probabilistic inputs, which are linked by simple, determinate equations. Instead of using constant values as modifying factors, stochastic distributions of the influence of the different factors can be used instead, thus an ESL is given as a stochastic distribution [12].

Whatever method is used to assess it, the predicted service life is unlikely to be a precise figure because the effect of an action in any building is not likely to be accurately predictable. More reliable predictions can be made when there is a correlation between the results of different assessments. Among major factors contributing to uncertainties in service life predictions are lack of knowledge about service conditions, defects and flaws in materials, degradation mechanisms and the kinetics of degradation under likely service conditions, the appropriate failure criteria and the variability in the knowledge and insights of persons responsible for making the predictions [16].

For the current work, data on the degradation of building elements and installations comes from 349 residential building audits that were performed in seven European countries (Denmark, France, Germany, Hellas, Italy, Poland and Switzerland). The buildings cover typical architectural typologies, sizes, constructions, and installations, at different states of deterioration. Follow up analysis revealed the most important influencing factors on the building deterioration and the correlation between these factors and the deterioration process. The following sections present a brief overview of the apartment building audits, followed by the findings on the actual condition and the factors influencing their deterioration process. Information on actual and estimated service life of building elements is also included.

2. Methodology overview

The current work was performed in the frame of a European project, INVESTIMMO, which is a new method and software to assess residential building renovation and refurbishment processes, for selecting long-term financial investment strategies and setting priorities for a large building stock. The user can create and evaluate several retrofit scenarios and perform a cost analysis, taking into account building physical and functional state of deterioration, future deterioration of building elements, occupants’ quality of life, energy and water consumption as well as the environmental impact from building’s operation and retrofit actions, reduction of operating costs and the overall time effectiveness of the investment. The building’s physical and