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Advances in *ETICS* Behaviour Analysis and Consequences for Planning Maintenance

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ABSTRACT

The efficiency of maintenance of ordinary buildings is quite relevant in what concern their durability and functionality and requires an accurate method for planning the different actions involved. This paper deals with some results of one of these models, developed at the University of Coimbra, oriented to the maintenance of school buildings where an External Thermal Insulation Composite System (ETICS) was adopted.

The first part is dedicated to the characterization of the behaviour of ETICS during its service life (reference state), based on a real time survey. The most relevant anomalies and their evolution are stated and analysed.

In a second time, a typical degradation curve is proposed and compared with traditional generic degradation evolution.

Keywords: Building Maintenance, Facades, External Finishing, *ETICS*.

1. INTRODUCTION

The maintenance of Portuguese buildings is mostly based on an empirical approach. There are three main reasons for this situation: insufficient budget for intensive and systematic maintenance; insufficient public knowledge of maintenance benefits, lack of technical models and support tools to help planning actions, in this domain, matching Portuguese reality.

Most of these facilities are ordinary buildings, in spite of their diversity of architectural solutions and construction options.

The increasing relevance of the durability of buildings – and sustainability challenges - is an important alert to the role of maintenance planning in all stages of the construction process (since the first steps of conception and design, to the end of buildings service life) and this is the main reason for the research work carried out on this domain at the University of Coimbra. This paper reports some results of a MsC Thesis that has proposed a model for planning inspection and maintenance in ordinary buildings, which Portuguese acronym is *PIMEC* (Falorca, 2004).

The proposed model of *PIMEC* is conceived for generic use, and needs to be customized for each kind of construction solution, for each construction member and, also, eventually, for each building material. In order to test and validate the proposed model, it was decided to analyse building facades covered with *ETICS* (thin and reinforced synthetic mortar over an external insulation layer). This solution is quite promising in Portugal, considering new energy code and its requirements. The University of Coimbra has adopted this insulation technique for a large number of buildings erected at the new Campus in the last ten years, which results in an amazing experimental sample for this research work.

Others approaches to maintenance of facades, based on degradation curves of their finishing, are known in Portugal (such as Flores, 2002) but they don't include *ETICS*. Furthermore, other approaches are hard to adapt to Portuguese climatic conditions and their influence on facades.

The evolution of facades finishing defects and the definition of its conventional curve were selected as guidelines for this paper, since it is a very important step to assure the practical relevance of the method.

2. REFERENCE STATE Characterization

2.1 PIMEC approach

After the general characterization of building *(stages A, B)*, planning maintenance with *PIMEC* (Falorca, 2004) includes a large number of procedures and actions, organized as follow: detailing of elements and materials *(C)*, knowing their performance under service conditions *(D)* (see Fig. 2.1) and establishing guidelines for technical actions and their specific schedule *(E)*.

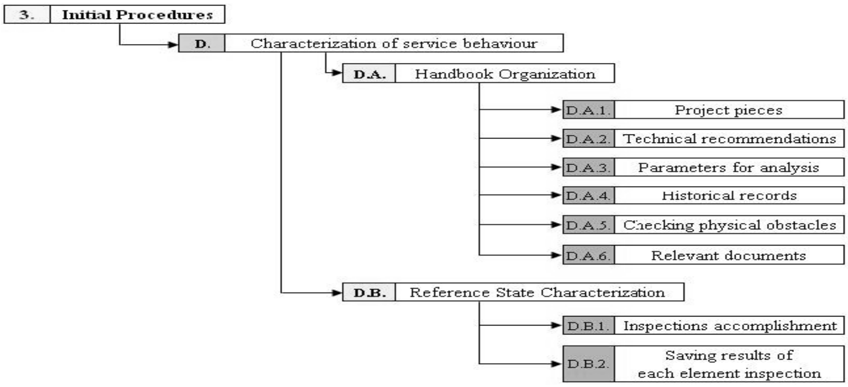

Figure 2.1 *PIMEC* - Initial procedures organizing scheme

This paper is focused on stage (D), particularly on the Reference State characterization (D.B. - Fig. 2.1), where the actual performance of building elements is observed and stated. This step is required to establish a maintenance plan, not only because it gives technical information about performance and degradation (including its prevention and rehabilitation), but also because it helps to adjust the theoretical degradation curves.

2.2 Selected buildings

The test of *PIMEC* was carried out on four selected recent buildings of common typology (concrete structure, concrete walls and masonry), in spite of their modern and outstanding design. These buildings (with different acronyms shown in Figure 2.2 – IPN, DEI, DEEC, DEC) are mainly engineering and research departments of the University of Coimbra, designed by international teams of architects. The facades of all these buildings (more than 35.000 m^2) are covered with *ETICS*, using synthetic insulation boards of 30-60 mm thick and synthetic thin mortar, painted with a light colour (white or light grey).

Figure 2.2 Selected buildings and their facades

2.3 Methodology

All the facades of these four buildings have been inspected twice until now, in order to obtain the essential data to approach the *Reference Characterization State, for ETICS,* as defined by *PIMEC*. Table 1.1 summarizes the main guidelines of this procedure. The first inspection occurred at 2004 and the second one at 2006; in both cases, the inspection action was based on visual identification of defects, according to a pre-defined list based not only on scientific publications, but also on previous Portuguese experience (Mendes Silva *et al*, 2003; Lucas, 1990).

In spite of the accuracy and detail of the defect collected data, only the existence or the non-existence of each defect, for each "module" of facade, is considered to establish the *Reference Characterization State*. The relevance of additional information - about materials, elements, constructive systems and the evolution of the defects - concerns, obviously, another layer of this process: the technical approach to maintenance actions and their scheduling.

Table 1.1 *ETICS* - Characterization of the reference state.

C.B.1	Facade Covering – *ETICS*
3.	Initial procedures
D.	Characterization of service behaviour
D.B.	Characterization of the reference state
D.B.1	Inspections accomplishment
	1.[st] Stage – preparation of field work, with selection of some aspects and defects to analysis, creating tables to note inspections results; 2.[nd] Stage – considering the big surface of all facades, it's made a small calendar of observation; 3.[th] Stage – to verify in field work the existence of anomalies identified before, make use of a simple inspection technique that essentially is an observation to the generality of building facades: - *System unstuck*; - *Perforation of the system*; - *System plan deficiency*; - *Covering fissures*; - *Visualization of plates joints*; - *Plates swell up*; - *Alteration of the surfaces colour*; - *Development of parasitic vegetation*; - *Re-cover deterioration of corner shelves reinforcement.* Note: Considering the behind mentioned tasks, it can come necessary the accomplishment of more complex inspections.
D.B.2	Element inspection file
	To organized the management archives, should be filled out a pre-accomplished model inspection report, which should always be filed in this sifter.

2.4 Type of defects

Three groups of defects have been observed during both inspections: (i) surface defects, (ii) cracks and (iii) local deterioration. Figure 2.3 illustrate some of these defects.

Surface defects – like parasitic vegetation, rain water dirty areas and irregular surfaces -, that affect a wide area of the facades, are particularly inconvenient in what concerns visual comfort and aesthetics, but there is no evidence of their consequences on physical performance of the wall (thermal insulation, waterproof, mechanical strength and cohesion).

Cracks occur in 60% of facades, but they affect only a small area. The more relevant are the cracks between insulation boards (due to inadequate materials or construction errors) and local cracks over metal reinforcements of *ETICS* system. Unlike surface defects, cracks promote a progressive deterioration of *ETICS* and of the facade physical performance.

Local defects result mainly of mechanical actions – unpredictable use or vandalism – that perforate the thin external mortar layer and the reinforcement mesh, leading to a progressive degradation of *ETICS.* These phenomena occur at confined areas but they can be responsible for a general degradation. It is important to remember that the most relevant function of the reinforced external mortar layer of *ETICS* is to protect the insulation boards against rain water, to prevent the migration of humidity to the wall, the deterioration of insulation material and the thermal conductivity increase. Local perforation often affects this basic function.

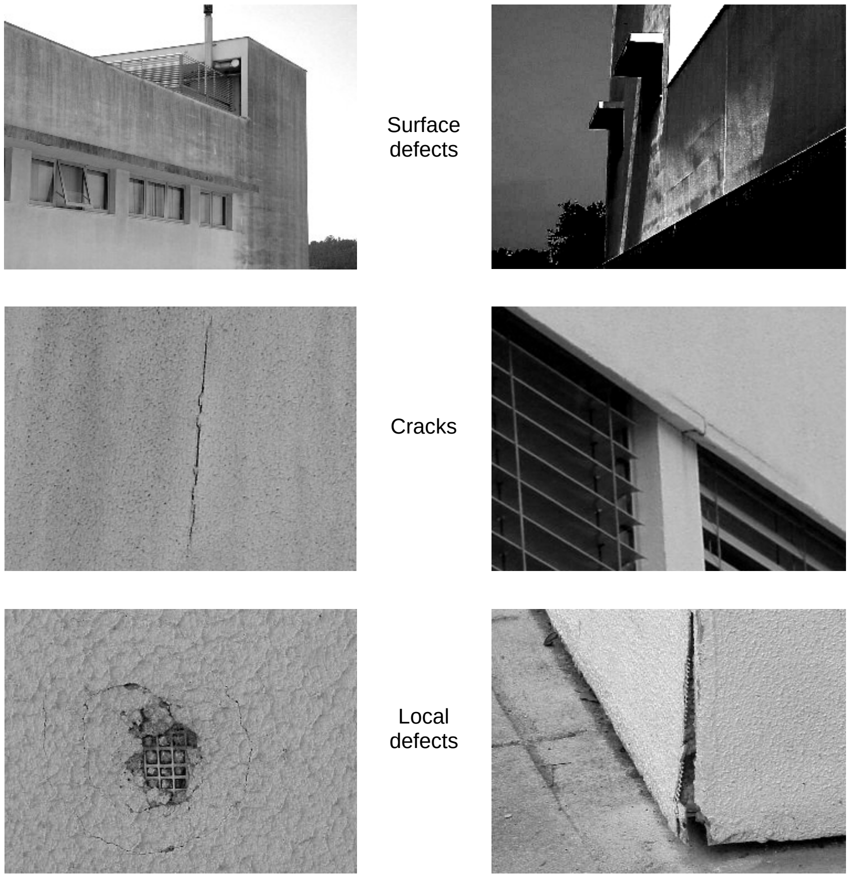

Figure 2.3 Examples of different groups of defects

3. INSPECTION RESULTS

Figure 3.1 presents the general results of the first inspection (2004) and the evolution of the main defects (2006) for all the facades of the selected buildings. Three types of defects affect more than 50% of facades: colour degradation, irregular surface and cracks. Loss of adhesion between insulation boards and the masonry wall is the less observed defect.

The number of facades newly affected by each defect in the last two years is between 1% (for visual defects at the insulation board interfaces) and 23% (for parasitic vegetation) with a mean value of 11%. Also important is the colour change and dirtiness (due to rain water and contamination of atmosphere) that reach almost all the facades after this period of time.

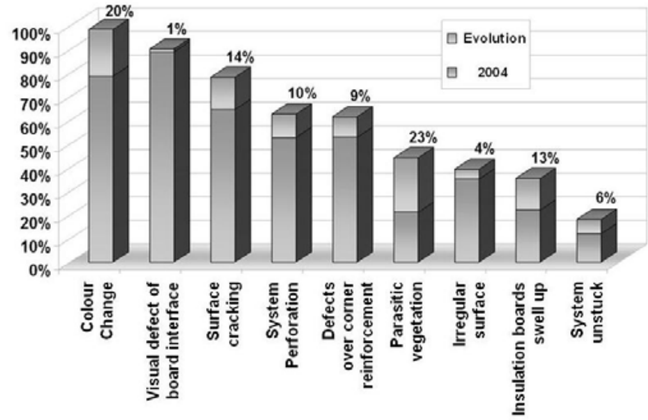

Figure 3.1 General evolution of affected facades by each main defect - case study.

The harmful effect of these anomalies is not proportional to the percentage of affected facades, since their evolution and their predictable contribution to reduce wall physical performance is quite variable. Based on Gaspar (2002), it was created a graphical scale of anomalies (see Figure 3.2), with four levels of degradation, where each kind of defect is considered.

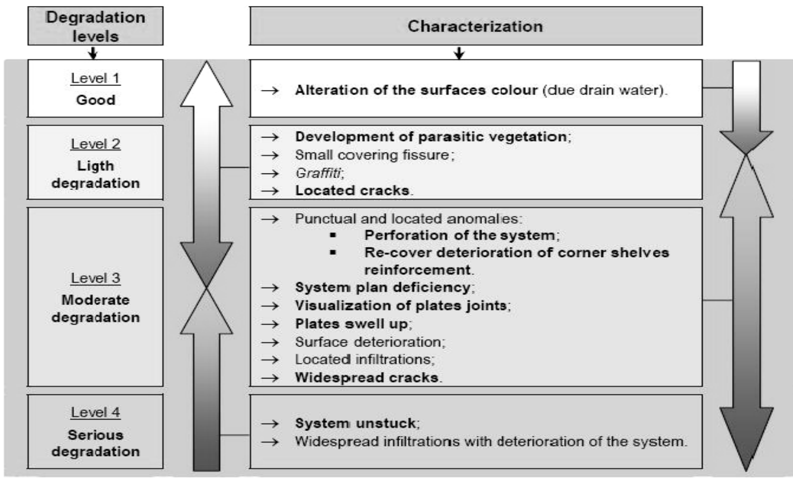

Figure 3.2 Degradation levels, according observed defects (Falorca, 2004).

Figure 3.3 represents the proportion between all nine different main defects, grouped according these conventional graphical scale of anomalies. In spite of the different evolution for each defect, the general layout is the same for this period of time and it clearly shows that degradation level 4 is quite insignificant, while level 3 groups 46% of detected anomalies.

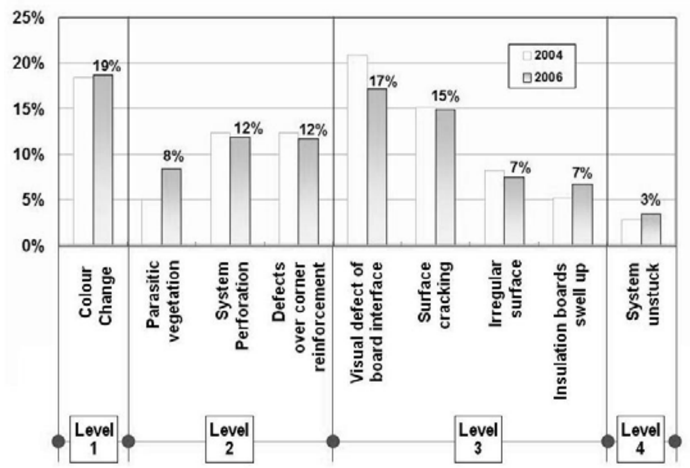

Figure 3.3 Evolution of relative importance of each defect distributed by degradation levels

4. PLANNING MAINTENANCE

At a first stage, *PIMEC* suggests a theoretical approach to maintenance planning, based on conventional life time curves and minimum quality levels for buildings. Then, *PIMEC* encourages the use of "case to case" approach, based on inspection and analysis, as shown for *ETICS* in the previous sections and Table 1.2.

n Portugal it is still hard to predict "life time" for *ETICS*, since this system is being used only for 15 years - in a few buildings - and case studies are rare. Also, its multilayer constitution represents an additional difficulty when it is necessary to know the global durability of the facade.

However, if we accept a conventional homogeneity of the system, some assessment tools (ISO 15686-1,2000; Sjotrom *et al., 2002;* Architectural Institute of Japan*,*1993) are available and, in conjunction we the reference state behaviour, it is possible to suggest a theoretical degradation curve of *ETICS*. Figure 4.1 represents the degradation curve of the system, without any maintenance action - also based on similar models (Flores, 2004) – what leads to a Life Time of 24 years for a minimum performance of 20%, with total failure at 28 years.

Several maintenance strategies and the consequent temporary maps of intervention have been simulated. The decision criterion to select the more favourable strategy was supported by *Life Cycle Cost* (*LCC*) method.

Table 1.2 *ETICS* characterization of the reference state (Falorca, 2004).

C.B.1	**Facade Covering – *ETICS***	
4.	Current inspection and maintenance procedures	
E.	Planning maintenance	
E.A.	Preventive maintenance	
E.A.1	Characterization of parameters	
	LT	Proceeded to a *Life Time* (*LT*) analysis based in an *Evaluation* (*Av*) by *Estimate* (*Es*) and using as *Alternative* (*Al*) some *Available Information* (*Ai*). The representative values estimated for life time are: • For an inexistent maintenance level: **28 years**; • For a normal maintenance level, including visual inspections, cleanings and periodic repairing: **35 years**; • For a good maintenance level, with maintenance operations with reduced periodicity: **42 years**.
	NQ	The minimum quality level (NQ) should be established in technical specifications of building project, for instance, like an *Initial Register* (*Ri*). In this case, we need to create *Criteria Definition* (*Cd*): it is supposed that the minimum quality level should around **20%** for an incidence of anomalies that corresponds any circumstances no longer accepted in the point of view of performance demands. The perspective value of the life time, for this performance and without maintenance, is **24 years**. For the minimum quality level defined, theoretically is supposed been reached serious degradation states, such as: • General *perforation of the system*; • General *covering fissures* or *deep fissures*; • *Support adherence loss* and/or between layers with eventual detachment; • *Deep deterioration in the reinforcement corner shelves areas*; • *Deep alteration of the surfaces colour*; From where implicate or result above all: • Accentuated infiltrations and waterproof losses; • Considerable alteration of the term-higrometric demands initially extolled; • Significant visual degradation that reaches the minimum requirements of aesthetics; • Other, in the verification of the performance level.

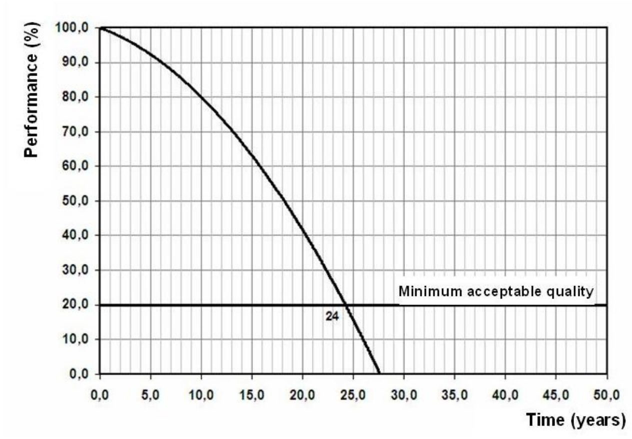

Figure 4.1 Degradation curve proposed for *ETICS* without maintenance (Falorca,2004).

Figure 4.2 shows the degradation curve for one of the simulated scenarios of maintenance for *ETICS*, according *PIMEC*. In this specific case, a global cleaning action is considered at the 14th year (half of the predictable minimum life time), followed by a light rehabilitation at the 28th year, resulting on 70% increase of predictable life time (reaching, here, 48 years).

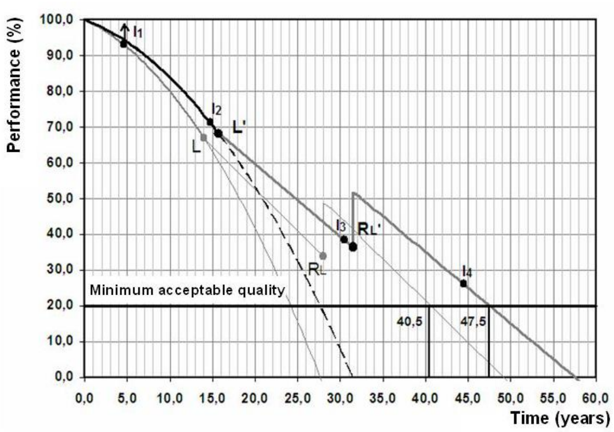

Figure 4.2 Example of degradation curve proposed for *ETICS* under a specific maintenance scenario - (Falorca,2004)

5. CONCLUSIONS

The use of External Thermal Insulation Composite System (*ETIC*S) began in Portugal, only in the 90's, which leads to an insufficient knowledge of the system durability. Its performance has been, however, quite promising.

A survey of more than 35.000m^2 was presented and its results analysed under the scope of a new proposed method for planning maintenance of Portuguese ordinary buildings (*PIMEC*). Through this specific case study it is intended to show, not only the potential of *PIMEC*, but also the extraordinary advantage of slight accurate maintenance actions, over expectable life time of *ETICS.*

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