XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

Condition-Based Maintenance Models for Stone Claddings

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Keywords: *Degradation, Service Life, Maintenance, Natural Stone Claddings, Petri Net.*

1 Introduction

The awareness of the building managers and/or owners about the need to maintain their assets more efficiently has increased over the last years (Silva and de Brito, 2019). The maintenance of buildings' envelope elements is not yet a first concern and is still reactive and sporadic based on subjective criteria (Forster and Kayan, 2009). Therefore, the development of more efficient methodologies for the implementation of strategic planning of maintenance actions is important (Aikivuori, 1999).

The main purpose of this study is the development and implementation of a condition-based maintenance model for Natural Stone Claddings (NSC). The proposed model is implemented using a stochastic Petri Nets (PN) framework. The case study selected is composed of 203 NSC, located in Portugal. The sample was established based on the diagnosis of the degradation condition of these claddings in-service performance, through *in situ* visual inspection. In the methodology proposed, three maintenance strategies are assessed: (i) major intervention only (MS1); (ii) combination of minor and major interventions (MS2); and (iii) combination of cleaning operations, minor and major interventions (MS3). The first one represents the most common solution adopted by buildings' owners. The other two are analysed in order to evaluate the impact of the different alternatives in the claddings' service life and in the whole-life maintenance costs, for the period under analysis.

2 Maintenance Model

PN are a mathematical and graphical modelling tool, suitable for description of systems whose dynamics are characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic (Murata, 1989).

In the maintenance model implemented, it is assumed that maintenance actions are planned after the condition has been assessed through inspections. In other words, the need for a maintenance action is assessed during inspection, and then, according the current observed degradation condition of the component under analysis, a decision on intervening is made. The model can be divided into several main parts: (i) degradation process; (ii) inspection process; (iii) maintenance process; (iv) modelling of the maintenance actions; and (v) periodicity of the cleaning operations (Ferreira *et al*., 2019).

3 Discussion of Results and Conclusions

In Figure 1, the degradation curves and cumulative costs obtained for the three maintenance strategies and for the situation without interventions are compared. In an overall analysis, the results reveal that:

- MS1 presents the lowest cumulative cost for a discount rate of 6%. In MS1, only replacement of the cladding is considered, which does not allow improving the condition over time, as well as its service life;
- MS3 shows the best degradation results, but leads to the highest cumulative costs over the claddings' lifetime;
- MS2 seems to be the most rational and adequate solution, according to the model's assumptions, since it allows increasing the service life and the cumulative costs are competitive when compared with those of MS1.

However, in the end, the choice of the best MS is always assumed by the building managers and/or owners and depends on their budgets and target condition for the cladding.

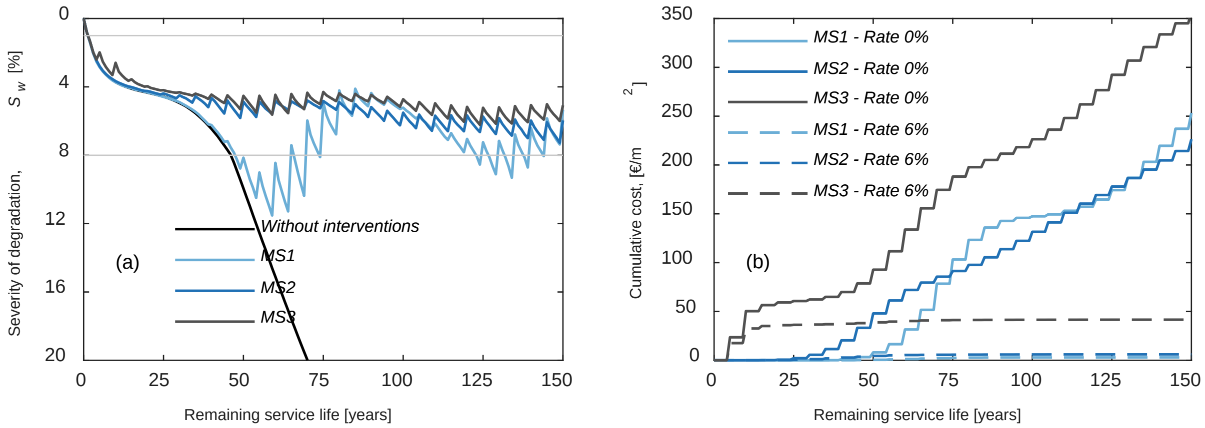

Figure 1. Comparison of the degradation curves over time for all maintenance strategies.

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References

Aikivuori, A.M. (1999). Critical loss of performance - What fails before durability. Performance Based Methods for Service Life Prediction Reports compiled, CIB W80.

Ferreira, C., Neves, L.C., Silva, A. and de Brito, J. (2019). Stochastic maintenance models for ceramic claddings. *Structure and Infrastructure Engineering*, *16*(2), 247-265.

Forster, A.M. and Kayan, B. (2009). Maintenance for historic buildings: a current perspective. *Structural Survey*, *27*(3), 210-229.

Murata, T. (1989). Petri nets: Properties analysis and applications. *Proceedings of the IEEE*, *77*(4), 541-580.

Silva, A. and de Brito, J. (2019). Do we need a buildings' inspection, diagnosis and service life prediction software?. *Journal of Building Engineering*, *22*, 335-348.