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Experimental evaluation of plasters durability aimed at maintenance planning and scheduling

Giuseppe Alaimo [1]
Daniele Enea [2]

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ABSTRACT

Through the obligation to schedule maintenance during executive planning, a strategic importance is assumed by the phase of building management. Moreover, in order to obtain the greatest sustainability of the intervention, a reasonable duration of service life must be balanced with global quality-cost ratio. A contribution towards this objective is given by the reduction in the achievable resources and raw materials consumption through the improvement of the durability requirement of building and its parts. This is true even for the interventions on the existing public building stock, especially if lacking in maintenance planning and scheduling. This work, taking cues from a maintenance intervention "at happened breakdown" on an Engineering school building in Palermo, deals with the introduction of process innovations in the management phase, directed towards preventive intervention strategies. Beyond the collection of the informative data, the behaviour in the time of envelope surfaces, through a viewpoint system, is monitored. Particular attention has been given to the finishing plaster (rasante) layer and the relative colour, to be evaluated depending on the different technical solutions and exposure to the weather conditions. The study, following the methodology of ISO 15686, also foresees accelerated ageing tests on samples of different materials, in order to formulate hypothesis on the degradation evolution, from a maintenance planning and scheduling viewpoint.

KEYWORDS

Sustainability, maintenance, durability, finishing plasters (rasanti), colour

[1] Faculty of Engineering of the University of Palermo (DPCE), Palermo, ITALY, alaimo@unipa.it
[2] Faculty of Engineering of the University of Palermo (DPCE), Palermo, ITALY, daenea@unipa.it

1 INTRODUCTION

A specific attention to the issue of maintenance programming was codified in Italy with a 1994 law, which requires, for the new government intervention, the establishment of a proper maintenance plan work, in the stage of final design. The UNI 11257:2007 specifies further the ideas expressed by law and provides guidance to the real estate management. This programming is becoming increasingly necessary in view of the complex management of existing buildings, in a balanced global cost-performance ratio. With the established regulatory framework and increased sensitivity towards the sustainability of the whole building process, it is necessary to change management strategies of constructions, from a still widespread condition at happened breakdown into a preventive policy. For this reason, it is important to have knowledge of the durability of materials and building components, their ability to maintain acceptable performance characteristics over time. This paper reports the first results of a study inspired by a classic intervention at happened breakdown on a building of the Faculty of Engineering, University of Palermo. The study aims to introduce elements of innovation in the methodology of management process (design, planning, execution) and the maintenance activities, and on the other hand to monitor the time behaviour of the building envelope subject to intervention. Here we refer the studies, according to the methodology of ISO 15686, as implemented by the UNI 11156:2006, regarding the assessment of the durability of the colour of the plaster coatings. The colour, by the class of requirements for appearance, not only contributes to the definition of the technological quality of the building, but also the involved environment (relevant architectures, planning the colour of the facades in the old towns, etc.). Therefore the assessment of the durability of the colour (UNI 10838:1999) of the envelope surfaces is relevant in the implications related to the definition of reliability and durability, especially when related to microclimatic parameters, from a maintenance planning and scheduling point of view.

2 CASE STUDY: THE FACULTY OF ENGINEERING OF PALERMO

The Building 8 under study is located within the university campus, Orleans' Park, and is part of the Faculty of Engineering of Palermo. Its construction dates back to the years 1953-'63, by professors of Architecture and Building Science: S. Benfratello, S. Caronia and E. Castile [La Mantia, 2006]. The building in 'Fig. 1' has two main bodies: the body of classrooms that are spread over four floors, over a terrace almost completely open, and the body of the departments that is shaped like a comb that is spread over three floors and is characterized by a long porch on the ground floor, five amphitheatre classrooms, protruding from the edge of the building, and the various academic departments.

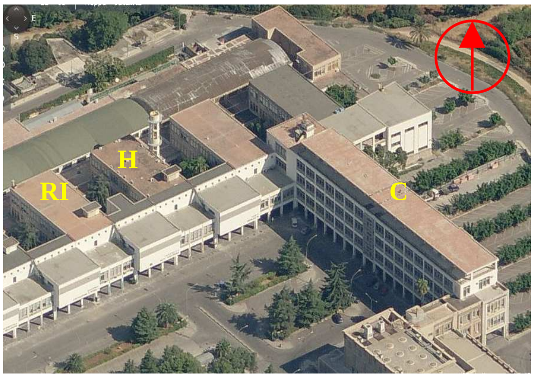

Figure 1. Isometric view of Building 8 (www.bing.com)

The three bodies are oriented in the north-west/south-east direction. The building as a whole, was built with a load-bearing reinforced concrete frame, divided into independent blocks, joined together, characterized by the presence on the facades of two or three levels of modular openings. The body of classrooms is characterized by the presence of a cantilevered reinforced concrete brise-soleil with geometric designs, as in 'Fig. 2'. The external walls are made of square blocks of yellow limestone. The maintenance intervention of the complex (the first since its construction), prepared by the Technical Department of the University, took place over the last five years and is the starting point of this study. Particularly, the surfaces of the body of Classrooms (C) and those of the Department of Hydraulics (H), as in 'Fig. 3', and the Department of Road Infrastructures (RI) were investigated.

Figures 2 e 3. The brise-soleil of the body of classrooms (left) the Department of Hydraulics (right)

2.1 Surfaces and pathology survey

The knowledge of the Building 8 and particularly the stratigraphy of the technical elements, object of the study, is based on a careful survey of the status quo, especially during the demolition of the degraded surface layers. The preliminary survey phase is, in fact, important to identify relationships between the different parts of the building, the boundary conditions (microclimate, exposure, etc..) and the used materials. As mentioned above, after more than fifty years from original, no maintenance had been applied on surfaces until May 2005. The evaluation of the degradation (UNI 11182:2006) showed:

- Dripping stains below the drips of the window modules;
- Lack of plaster and concrete cover, due to the degradation of reinforced concrete of the window modules, as in 'Fig. 4';
- Superficial deposits, characterized by yellowing of the plaster surface, due to loose material, as in 'Fig. 5'.

Figures 4 e 5. Lack of plaster (left) superficial deposits with yellow patina (right)

The causes of degradation can be attributed to:

- The weathering, in particular the action of wind, which is crucial for the transport of marine aerosol and loose material on the surface;
- The quality of raw materials making up the plaster and the concrete;

- The thick plaster (even more than 8 cm), misplacement of the window sills and consequent lack of appropriate slope.

2.2 The intervention and used materials

The intervention on the facades, after the consolidation of degraded reinforced concrete elements, provided for the restoration of the plaster base and the finishing with a plastic coating applied to continuous (RPAC), made of inorganic binder potassium silicate based, inorganic pigments and selected aggregates, at medium particle size, according to the classification of the UNI 8682:1984. The coating that has the nature of a smoothing product, which makes it akin to the class of plasters, was applied by stainless steel trowel, on plastered surfaces treated with an appropriate primer to enhance adhesion to the substrate. The nature of the RPAC provides thickness between 1 and 15 mm, depending on the size of the aggregates, that is between 1 and 7 mm, resulting in three classes of RPAC, known by the letters from G1 to G3, in ascending order of applied thickness. The product used in the case study has been classified as G3 and has a pasty consistency. In particular, the feature of silicate RPAC is to react with carbon dioxide present in the atmosphere, giving rise to colloidal silica fixing the coating components together and with the support, resulting in a structure similar to the plaster support. This ensures excellent breathability of the treated surface, as a consequence of the porosity to water vapour of the microcrystalline structure of thickness applied, arising from the crystallization of silica, while the treated surface is impermeable to weathering. In the application under study two different colours were used: white in the reinforced concrete structure and gray in the window modules.

3 METHODOLOGY, TESTS AND SPECIMENS

The research, conducted as part of national and international studies to evaluate the durability of construction products and elements, following the methods of ISO 15686 and UNI 11156, is based on the evaluation of the Reference Service Life and the Estimated Service Life, through the correlation between accelerated laboratory ageing tests and field exposure. Starting from the identification of potential agents that may affect the duration of components, the effects of degradation which may cause changing in the considered characteristic properties, especially the surface colour, are determined. On the basis of tests carried out, it’s possible to proceed to the rescaling by comparison with the results of monitoring the field exposure. However, linking natural and laboratory ageing is not easy, especially because of the difficulty to reproduce in laboratory all the stresses that occur in reality (action of dust, hail, wind, vibration, etc.). The parameter that the research wants to investigate and monitor is the colour of the surface where measurements were made in accordance with the recommendations from Normal 43/93. Observations were taken with a spectrophotometer (CM-2600 Konica-Minolta) with control number of gloss that provides simultaneous data for each measurement with the specular component included (SCI) and excluded (SCE). The observations were made with the standard illuminant D_{65}, as defined by the CIE, with an inclination angle of 10°. The colour space chosen to represent the colour is CIELAB, as defined by CIE in 1976, based on lightness, L*, and two chromaticity coordinates a* and b*. The lightness L* indicates the achromatic stimulus from black (0%) to white (100%), used to determine whether a colour is lighter or darker[3]. The coordinates a* and b* are referred to colour schemes in opposition to one another: red-green for a* and yellow-blue for b*. Starting from the coordinate values measured at zero time, the colour difference, ΔE*ab, over time, was observed through the formula:

$$\Delta E^*_{ab} = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2}$$

[3] L* represents the lightness that is a feature associated with the visual perception of surface color due, relating to the white reference and represents the fraction of light widely reflected.

The measurements[4] carried out on the samples and on the external surfaces of buildings, provide for each point the average of five measures, on an area representing approximately one square meter.

4 NATURAL AGEING

The monitoring of the effects of natural ageing applied on the exterior coating of the investigated buildings was applied on a representative set of points on the facades in the four different exposures, as in 'Fig. 6'. Interventions were made at different times relative to periods of natural ageing. In particular:

- February 2005 (T_3): North-East façade, body of the Classrooms;
- April 2006 (T_2): South-West facade, body of the Classrooms;
- November 2008 (T_1): North-East and South-West facades, Department of Hydraulics;
- December 2009 (T_0): North-East and South-West facades, Department of Road Infrastructures.

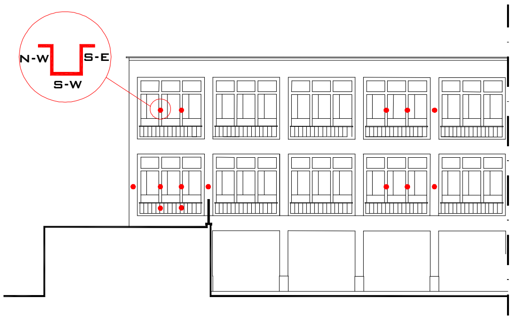

Figure 6. Department of Hydraulics South-West façade, with monitored points in red and the cross-section of a pillar, with different exposures

Therefore data cover the period between 2005 and 2010. The configuration of the buildings allows a favourable comparative investigation because of the presence of morphologically identical facades in different exposures, treated with the same materials and colours. On each facade, the representative elements to be monitored have been identified, particularly in the framed structure, covered with the white coating, the fronts and the perpendicular surfaces to the facade were measured; the same applies to reinforced concrete elements, part of prefabricated blocks, coated in gray. For each façade, measurements were derived from three different exposures.The results of the investigation on the N-E and S-W facades of the three bodies, show that the measurements with the spectrometer, under conditions specular component included (SCI) and excluded (SCE) do not ever differ by more than $\Delta E^*ab = 0.4$ (since opaque surfaces have a modest contribution of reflected specular light). Therefore, graphs and tables below refer to measures in specular component excluded, closest to that perceived by the eye. The colorimetric measures carried out on the fronts of the buildings showed for the white colour, a variation of the coordinate L* between 86.79 and 91.40 points; a variation between -0.06 and 1.09, for the coordinate a* and a range of values between 4.54 and 7.52, for b*. The gray ranges of values measured for the three colorimetric coordinates are as follows: L*= 60.15÷76.12, a*=0.12÷1.41 and b*=7.40÷12.75.

5 ARTIFICIAL AGEING

The samples reproduce the solution applied on the buildings surfaces, on a base of brick, and final dimensions are 250x250x70 mm, with the RPAC applied according to a thickness of about 15 mm, on a suitable primer of about 10 mm thickness. The edges of the samples were protected by applying a

[4] Experimental activity was carried out in the Laboratory of Construction of the Department of Project and Building Constructions, University of Palermo.

layer of waterproof cement mortar to prevent water absorption. For the tests of artificial ageing in the climatic chamber, an ageing cycle was developed and calibrated [Alaimo, 2006], from weather data of the climatic context of Palermo[5] [Table 1].

Table 1. The final artificial ageing cycle

Phase	Hour	T (C°)	RH (%)
Rain (autumn season)	3.0	-	-
Cold (winter season)	1.5	2	-
Hot-humid (spring season)	5.0	60	87
Hot-dry (summer season)	2.5	50	56
TOTAL	**12.0**		

Three steps of artificial ageing were set both for the white samples and the gray ones, repeating the cycle 28, 56 and 84 times, corresponding to 336, 672 and 1008 hours of stressing action in the climatic chamber. The samples were placed in the climatic chamber inclined at 60° as in 'Fig. 7'. Measures were taken at zero time (S_0 corresponds to T_0 of the natural ageing), and after every step (S_1, S_2 and S_3). For each step, the colour measurement was taken on a couple of samples. The recorded values for the colorimetric coordinates were variable: for the white samples, the colour coordinate L* showed values between 89.21 and 90.64 points, the coordinate a* a variation between 0.14 and 0.37 and the coordinate b*, a range of values between 5.18 and 7.25. For the gray samples, ranges of values measured for the three colorimetric coordinates are: L*=65.92÷72.23, a*=0.43÷0.73, b*=11.75÷12.47.

Figure 7. The samples inside the climatic chamber

6 RESULTS AND CONCLUSIONS

The collected data on colour changing, related to laboratory samples, were compared with colorimetric measures made on the surfaces of buildings in terms of colour difference ΔE*ab, as in 'Figs 8 and 9'.

[5] Data processed by Ing. Tiziana Basiricò related to the research "Collecting and processing data related the framework of climatic agents of Palermo for the development of accelerated ageing cycles", funded by the PRIN 2003

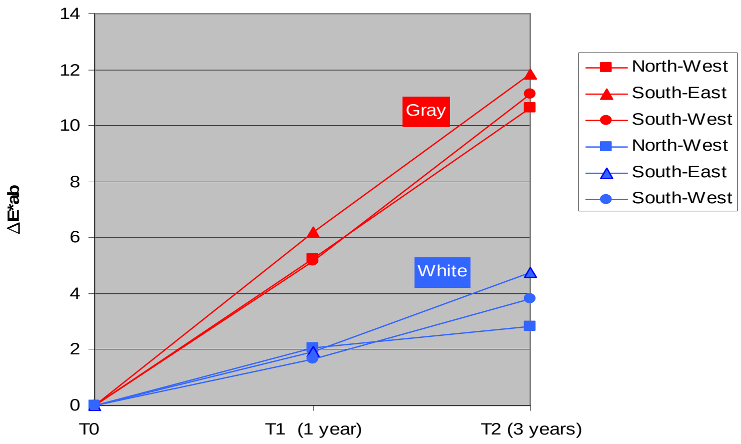

Figure 8. Colour changing on the North-East facades (natural ageing)

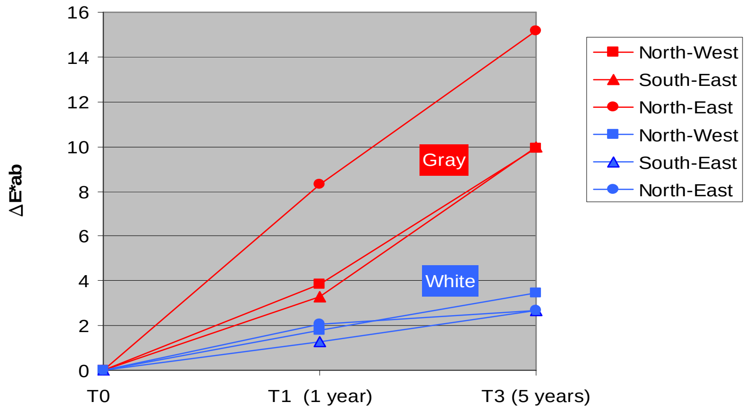

Figure 9. Colour changing on the South-West facades (natural ageing)

On the base of these comparisons, it is possible to make the following conclusions, for natural ageing:

- After one year of natural ageing, white colour shows a medium colour change of almost 2 points, becoming lighter, for all facades; after three years, on the South-West facade, the trend is increasing and the medium value is 3,5 points, with a maximum recorded of 4,5 points in the S-E front.
- After five years of natural ageing, North-East facades show a medium white colour change equal to 2,5 points, with a maximum on the N-W front of over 3 points.
- For the gray colour, after one year of natural ageing, colour change is between 5 and 6 points in the South-West facades; the North-East facades show higher colour difference equal to 3,5 points in the S-E e N-W exposures, while the difference is more evident on the N-E fronts, over 8 points.
- After three years, South-West facades have a medium gray colour change equal to 11 points and after five years, the North-East ones show a strong difference between the main NE front, over 15 points, and the other two orthogonal, 10 points, remaining the trend to become lighter gray.
- The environmental conditions and microclimate produce after three years, on the South-West oriented facades, a greater degradation than the North-East ones after five years, for both colours, white and gray, with the exception of the N-E, for gray, that is more faded after five years.
- On all the facades, the front surfaces do not suffer the greatest colour change, but those orthogonal to them.

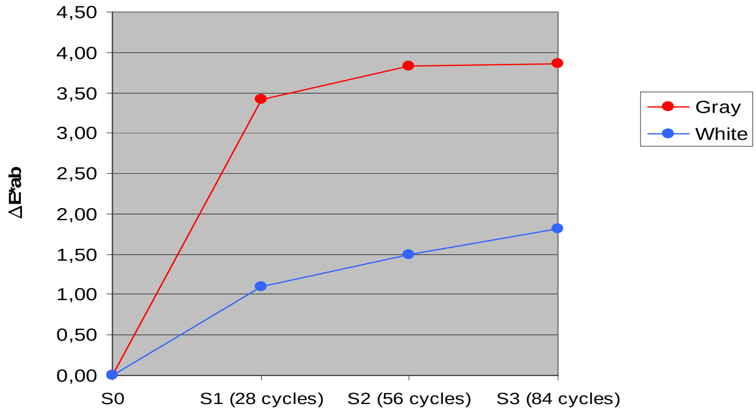

Figure 10. Colour changing on the laboratiry samples (artificial ageing)

And for artificial ageing:

- The first attempt at rescaling, for white colour, shows that the degradation produced artificially in laboratory, after application of 84 cycles of ageing (S3), is equal to the natural degradation measured on surfaces naturally aged after a year, so it is appropriate to proceed with further steps to reach ΔE*ab values comparable to natural ageing after a year. Regarding the gray colour, the application of three cycles of ageing involves a colour difference measured comparable to the North-East one after a year of natural ageing.

In conclusion, after about five years, the colour difference of the white plaster in different exposures, even if in different ways, remains below 5 points[6], with a progressive trend of surfaces to become lighter and yellow, even if the Just Noticeable Difference, perceptible by human eye, around the value of 2.3, is exceeded [Sharma, 2003]. The gray-coloured surfaces showed a greater tendency to degradation over a short period of time, in both natural and artificial ageing conditions. The stability of colour, compared to the original, is an often neglected aspect, despite contributes to characterize the quality of the envelope. We believe this issue deserves a healthy weight among the parameters to be monitored and a specific legislation would certainly give further important contribution to the maintenance of service quality of building structures, being necessary to establish functional limits of the colour of building surfaces.

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[6] The ASTM D-2244 imposes for pre-painted coils, after 5 years of external exposure, ΔE*ab less than 5 units Cielab

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