WEATHERING RESISTANCE OF THE COLOUR OF WATER BASED COATINGS FOR ARCHITECTURAL USE

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Abstract

The decorative service life of architectural coatings for outdoor use is often determined by the onset of large colour shifts. Here, the author reports two-year natural compared with accelerated weathering results for a series of coloured coatings from five different producers with a palette of relatively similar colour shades – cream, salmon, pink, green, red, and blue.

This study was performed in order to serve as a base for the future development of a Portuguese standard with minimum requirements for the colour resistance of these type of coatings.

Many of the studied coatings showed minimal visible colour change after two years and 1000 hours accelerated weathering but others show much lower colour retention, both after few months of natural and after artificial weathering under three different accelerated weathering conditions using fluorescent UV (ISO 11507) and xenon arc lamps (ISO 11341- with and without water spray). As expected, paints with the same colour presented different tint retention due to their different constituents, justifying the need of laboratory testing and the better simulation was that obtained with the xenon arc test chamber.

1. Introduction

The change of appearance of organic coatings applied on exterior walls of buildings can affect their aesthetics and have a major influence on the customer's judgment of the quality of the building as a whole. The durability of the appearance of architectural coatings is mainly related with dirt pickup, presence of efflorescence with origin in cement-based substrates and colour retention. This last property is especially important in the case of coloured paints since an inadequate resistance of the pigmentation can lead to differences in the degradation level of the colour in a short time, according to the solar orientation of the walls.

Although the resistance of the colour can be assessed by accelerated laboratory tests, reliability of their results is sometimes inadequate giving rise to failure modes of the coatings that do not occur under outdoor exposure conditions. A review of several issues related with the use of natural and accelerated tests, their advantages and drawbacks, can be find on references by Johnson and McIntyre [1] and by Martin et al. [2].

In order to validate a methodology for the assessment of the potential durability of coloured coatings for exterior use in buildings in Portugal, a study was developed by LNEC consisting in the comparison of the degradation after exposure under natural conditions, of different colours of paints obtained from several portuguese producers, with the degradation obtained after submission to three artificial exposure conditions. The degradation of the colour was evaluated visually and by colour measurements according to ISO 7724.

As a base for the assessment, the criteria adopted by the European quality label Qualicoat [3] for the qualification of the durability of the colour of coated aluminium for architectural uses was investigated, in order to evaluate its applicability in the case of coloured coatings for exterior walls of buildings. The referred qualification label allows a certain colour difference after 1 year exposure in Florida, defining the maximum ΔE^* admissible for each RAL colour.

In the present study both ΔE^*values measured in each coloured coating after 1 and 2 years of natural ageing and 1000 h artificial weathering were compared with the maximum ΔE^* admissible for the more similar RAL colour indicated by Qualicoat [3].

2. Background

Exterior coatings are subject to UV radiation and high temperatures in the presence of humidity and oxygen for long periods or cycling conditions which can cause oxidation of the polymeric binder and discoloration and fading of coloured pigments [4]. Outdoor resistance of pigments is highly variable and depends not only on their chemical nature and colorant technology but also on the type of other constituents present in the paint, namely on the chemical characteristics of the binder. In addition, binders, pigments and colorants used in architectural coatings must withstand the alkaline and humidity intrinsic to cement-based substrates, especially when fresh, or when damp or wet from the intrusion of water.

The more reliable way of evaluate the durability of organic coatings for external applications would be to expose it in natural environmental conditions, ideally on their intended service environment [1] since it is well known that the results obtained in one exposure site cannot be extrapolated to others sites or different timing of exposures even at the same site [2].

Due to the long time necessary to this type of evaluation, some accelerated laboratory testing simulating environmental stresses like temperature, humidity and UV radiation but using higher intensity radiation or shorter wavelength radiation are usually adopted. In the area of organic coatings there are two standardized ISO methods developed for this purpose:

a) ISO 11341 in which chambers with xenon arc lamps and means to control the temperature, humidity and cycles of water aspersion or immersion are used.

b) ISO 11540 in which chamber with fluorescent tube lamps and means to control the temperature and cycles of water aspersion or condensation are used.

In terms of exposure time, EOTA Technical Report TR 010 [5] describes the calculation method that can be used to get the equivalence between 1 year of natural exposure and the correspondent time of exposure under artificial conditions, in terms of radiation dose. For this purpose, it is considered that the exposure in a weathering apparatus according to ISO 11341 corresponds to a UV irradiance of 60 $W.m^{-2}$ between 300-400nm and in a QUV apparatus using Type I (340) lamps according to ISO 11540 corresponds to a UV irradiance of 39 $W.m^{-2}$ between 300-400nm. If the radiation dose in one year for the same wavelength range is known for the exposure site ($X\ J.m^{-2}$), it can be calculated the number of days in the weathering apparatus that are equivalent to 1 year.

The average global (300-1100 nm) and UV radiation (300-400 nm) measured during the exposure period by LNEC meteorological station were, respectively, 6 615 MJ/m^2 and 241 MJ/m^2 [6, 7]. Comparing these values with the average data from the Atlas weathering station in Miami, Florida (global radiation 6 588 MJ/m^2 and UV radiation 280 MJ/m^2) [8], it is confirmed the high UV radiation level of the exposure site [9] and justifies the possible adoption of the previous referred Qualicoat criteria [3].

The evaluation of the degradation after ageing can be performed by visual check measurement of the changes in colour and gloss [1, 10, 11]. or by using physical-chemical [11, 12, 13, 14], mechanical [11] or electrochemical methods [13, 14]. In the present study, as the main effect to be assessed is the visual change of the colour, the ΔE^* value was used to evaluate the degradation process and to validate the methodology for the assessment of the coatings durability by using an accelerated test method.

3. Experimental

3.1 Materials

The study was performed on 29 paints from five producers - I, II, III, IV and V. Each producer has presented for testing five or six different colours of water based paints – cream, pink, salmon, green, red and blue. The chemical nature of the coloured pigments used in the paints was not revealed by the paint producers but it was agreed that the final colours should visually present, as far as possible, the same classification according to the Natural Colour System (NCS) [15]. The designation of the colours and their classification according to NCS and the absolute colour measurements in CIELAB units according to ISO 7724 are presented on Table 1 for identification purposes of the studied paints. The closest RAL colour as visually assessed by comparison with the colours of the RAL classic K5 colour collection is also indicated.

Table 1: Colours of the studied coatings

Colour name	NCS Colour	Producer	CIELAB colour coordinates			Closest RAL colour
			L*	a*	B*	
Cream	S 505Y30R	I	92,14	0,41	11,07	RAL 1014
		II	92,19	1,44	10,11	
		III	92,00	0,45	11,02	
		IV	92,05	0,18	11,33	
		V	93,41	0,84	12,44	
Pink	S 515Y80R	I	85,40	9,29	9,85	RAL 3015
		II	87,49	9,93	9,79	
		III	88,23	10,02	10,08	
		IV	87,99	8,41	10,48	
Salmon	S 030Y60R	I	76,56	16,95	22,58	RAL 2009
		II	77,60	18,65	21,01	
		III	76,24	20,62	24,72	
		IV	77,12	19,79	19,72	
		V	77,07	20,57	24,49	
Green	S 040G10Y	I	77,38	-24,98	17,18	RAL 6021
		II	78,19	-26,11	14,54	
		III	77,70	-28,15	17,85	
		IV	76,90	-25,59	13,09	
		V	76,19	-26,53	18,97	
Red	S 080Y90R	I	43,78	48,16	30,11	RAL 2002
		II	48,73	51,43	31,05	
		III	45,18	45,87	26,33	
		IV	46,45	49,92	28,58	
		V	46,08	48,63	30,51	
Blue	S 3050R80B	I	49,36	-2,14	-33,78	RAL 5017
		II	46,29	-2,70	-30,95	
		III	46,90	-2,25	-31,34	
		IV	47,10	-2,48	-30,66	
		V	48,29	-2,07	-34,50	

The paints were applied on fibre-cement 3 mm thickness flat panels and to Leneta plastic foils. The painted fibre-cement panels were used for the exposure to the natural conditions and to the two artificial conditions that include the influence of liquid water and radiation. The painted Leneta foils were used for the exposure to the artificial condition without the influence of liquid water.

Before de application of the paints, one layer of primer was applied on the fibre-cement substrate. This primer was compatible with all the coloured paints from all producers and the purpose of its use was to eliminate the influence of the substrate alkalinity on the colour resistance and have a common base to study the effect of the age on the colour of the paints without the eventual influence of the performance of the primer, if different for each producer.

For the third artificial ageing test not including the influence of water in which the substrate was a plastic foil (Leneta), the paints were directly applied to the plastic (no primer).

3.2. Exposure conditions

Outdoor exposure

The coatings were exposed on the terrace of LNEC at Lisbon, a city with an environment considered to have a high UV radiation level [9] for two years. The samples were exposed facing 45°S and were periodically evaluated after a light cleaning with running water and a soft brush in order to eliminate the loose dirt accumulated on the surface. After each evaluation they were returned to the exposure site where they remained for future assessments.

Accelerated conditions

The samples were exposed for 1000 h under three standardized weathering cycles, two including the influence of liquid water and radiation and one including only the influence of the radiation in dry conditions. Duration and sequences of all tests are listed in Table 2.

Table 2: Accelerated weathering conditions: total exposure time – 1000 h

Weathering code	Procedure
QUV	According to ISO 15507: 4 h UV-A at 60°C + 4 h continuous condensation at 50°C
Xenotest	According to ISO 11341 –Method 1, cycle B 18 min radiation 0,51 W/m^2 at 340 nm + 102 min radiation and water aspersion; during dry period – T=38°C; RH=50%; Black Standard Temp. 65°C
Suntest	According to ISO 11341 –Method 1, cycle A Continuous radiation 0,51 W/m^2 at 340 nm T=38°C; RH≈50%;Black Standard Temp. 65°C

The calculation method previously described [5] leads to the conclusion that 1 year exposure is approximately equivalent to about 1100 h of Xenotest and Suntest and about 1700 h of QUV.

3.3. Evaluation of the coatings performance

Absolute and difference colour measurements in CIELAB units according to ISO 7724 were performed on the samples submitted to the accelerated and natural conditions, after several exposure periods, by using an Hunterlab portable spectrocolorimeter with d/8 geometry, D65 illuminant and 10° observer angle, gloss included.

4. Results and discussion

The maximum colour differences ΔE* allowed for each similar RAL colour by Qualicoat [3], after 1 year of exposure on Florida, are the following:

Cream (RAL 1014) - ΔE*=3; Pink (RAL 3015) - ΔE*=3; Salmon (RAL 2009) - ΔE*=4; Green (RAL 6021) - ΔE* = 4; Red (RAL 2002) - ΔE* = 8; Blue (RAL 5017) - ΔE* = 5.

The colour differences (ΔE*) of the coatings, relatively to the initial L*a*b* values, after exposure under natural conditions and the three artificial weathering conditions, are presented on Figs. 1, 2 and 3. The limit values of ΔE* allowed by Qualicoat [3] for those RAL colour are represented by the horizontal lines on the graphics.

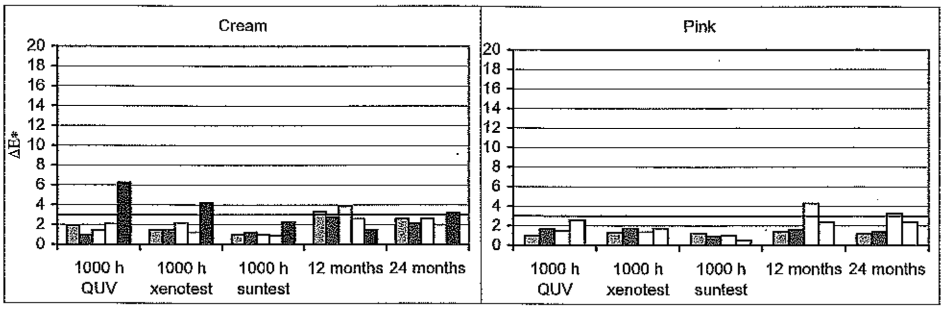

Fig. 1 - Cream and pink colour changes of paints from producers I, II, III, IV and V after natural and artificial weathering.

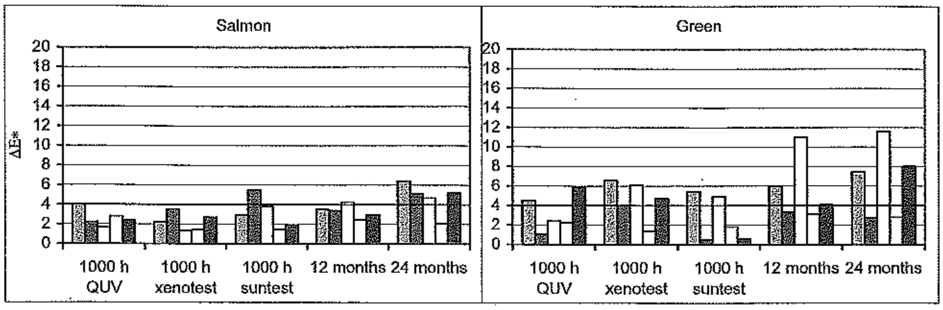

Fig. 2 – Salmon and green colour changes of paints from producers I, II, III, IV and V after natural and artificial weathering.

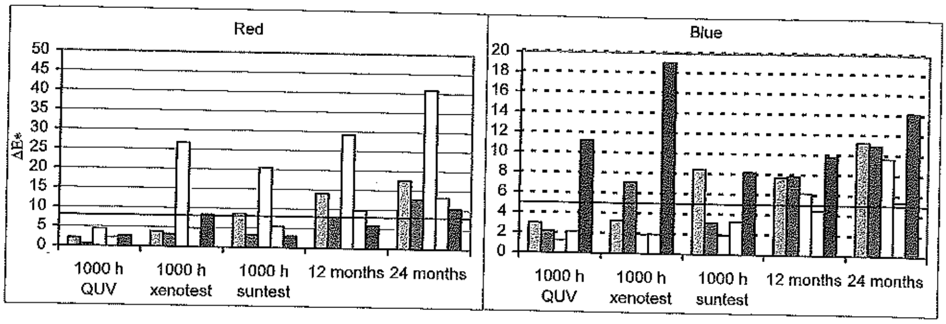

Fig. 3– Red and blue colour changes of paints from producers I, II, III, IV and V after natural and artificial weathering.

Cream and pink coatings (Fig. 1)

After 1 year of natural weathering, all the cream paints were showing similar alterations lower or next to the value 3 allowed by Qualicoat, except the paint from producer III that presented an higher value and the paint from the producer V that presented a slight better result (ΔE*=1,5). After 2 years all the cream paints presented ΔE*lower the limit value 3, except the paint from producer V (the better after 1 year) that had already a higher value – next to 4.

As to the pink colours, after 1 year ΔE* values are between 1 and 2 except the paint from producer III that presented a value higher than the value 3 allowed by Qualicoat. After 2 years all the pink colours presented ΔE* lower or next to the limit value 3.

All the artificial weathering conditions conducted to the higher alteration on the cream colour of the producer V, QUV seeming to be too drastic for this paint. The other cream coatings and all the pink coatings showed ΔE* lower than the limit value 3 after the three artificial ageing conditions.

Xenotest seems to have the better correlation with natural conditions for the cream colours. For the pink colours, QUV and Xenotest conditions allow higher alterations and more approximated to the alterations on natural conditions than Suntest.

The results of the accelerated tests allow concluding that all the pink coatings pass the criteria as well the cream coatings of producers I to IV. The cream colour of producer V presented a ΔE* higher than the limit value 3.

Salmon and green coatings (Fig. 2)

After 1 year exposure of the salmon colours, they presented a slight higher colour difference than the pink ones but with values lower or next to the value 4 allowed by

Qualicoat. On the contrary, not all the green colours presented a value lower than the limit value 4 after 1 year natural exposure - green colours of producers III (ΔE*=11) and I (ΔE*=6). After 2 years also the green paint from producer V showed a high alteration (ΔE*=8).

After the three artificial exposure conditions, the ΔE* values of salmon colours were of the same order than after 1 year natural exposure, except in the case of producer II under Suntest which presented a ΔE*=5,5. The better correlation with the results obtained on natural conditions seems to be that from Xenotest, since Suntest degraded too much coating II and QUV didn't alter significantly coating III, the worst after 1 year exposure.

The three worst performing 1 year green coatings (from producers III, I and V) presented also the worst performances after 1000 h Xenotest (ΔE* values from 5 to 7). Suntest ageing conditions conducted to the worst and similar results only for green coatings from producers I and III (ΔE* values near 5). QUV conditions only altered significantly the green coatings from producers I and V (ΔE* values of 4,5 and 6, respectively) and didn't alter significantly the coating III, the worst after 1 year exposure. The better correlation with the result obtained after natural exposure seems to be that from Xenotest (the three worst coatings are the same that presented higher colour difference after 1 year).

Xenotest results allow concluding that all de salmon coatings pass the criteria, that only the green colours from producers II and IV pass the criteria and the coating from V is just in the limit.

Red and blue coatings (Fig. 3)

After 1 year natural exposure the most intense alteration of the red colour was that from the producer III (ΔE*=29), followed by that from I (ΔE*=14) and IV (ΔE*=10), all above the value 8 allowed by Qualicoat.

The most intense alteration of the blue colour after 1 year was that from producer V (ΔE*=10), followed by the blue coatings from I and II (ΔE*=8) and III (ΔE*=6). Only one blue paint had a ΔE* value lower than the limit value 5 allowed by Qualicoat (blue paint from producer IV).

The red coating from III presented also the worst performances after 1000 h Xenotest (ΔE*=27) and Suntest (ΔE*=21). QUV did´nt significantly change any of the studied red colours, although the red coating from III was also the most altered (ΔE*=4,5). The best correlation with the result obtained after natural exposure seems to be that from Suntest. Suntest results allow concluding that only the red colour from producer III do not pass the criteria and coating from I is just in the limit. Xenotest only eliminates coating III.

After artificial weathering, the blue coating from V (the worst after 1 year) showed also the higher colour difference (QUV $\Delta E^*=11$, Xenotest $\Delta E^*=19$, Suntest $\Delta E^*=8$). Blue coating from II showed a significant alteration after 1000 h Xenotest ($\Delta E^*=7$), but not the blue coating from I ($\Delta E^*=3$). The reverse happened after 1000 h of Suntest: the blue coating from I presented $\Delta E^*=8$ and the blue coating from II presented $\Delta E^*=3$. QUV altered significantly the blue colour from V but not the others. Xenotest seems to have the best correlation with the result obtained after natural exposure since it could distinguish the worst blue coatings (V and II) and the two better blue coatings (III and IV) in a similar way that natural exposure did, eliminating coatings II and V.

5. Conclusions

The colours that presented the higher changes, both under natural and artificial conditions of exposure, where the green, the red and the blue.

QUV and Suntest conditions of artificial ageing resulted in colour alterations of some green, red and blue coatings that were not confirmed by natural exposure conditions: the green coatings from producers III, I and also V (Fig. 2), had the worst performance after 1 and 2 years (the coating from III being the worst) but QUV didn't alter appreciably the green paint from III and Suntest didn't change the green coating from V.

Red colour from III (Fig. 3) presented a very bad performance after a few months of outside exposure but QUV conditions didn't change this coating very much, in opposite to what happened with Xenotest and Suntest conditions.

Suntest altered the blue coatings from producers I and V (Fig. 3) significantly but not the coating III that after two years under natural exposure presented also an alteration similar to the coating I. Xenotest could show that both coatings I and II were potentially more degradable than III and IV.

Although the rating of the colours after artificial weathering was not generally the same as that occurring under natural exposure for the colours that presented the higher alterations (green, red and blue), Xenotest allowed to distinguish the worst performing coatings of these colours, correlating in general better with the natural exposure results.

It is possible to formulate coloured coatings for exterior walls of buildings fulfilling the limits proposed by Qualicoat [3] for the maximum allowed colour difference for different RAL colours after 1 year of exposure.

In general, 1 year of natural exposure originated higher colour differences than 1000 h of artificial weathering, but on a similar scale of values. In this way it can be accepted that the artificial exposure Xenotest for 1000 h being used to evaluate the potential durability of the colours of architectural coatings for external walls.

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