Subject Review

METHODS FOR THE EVALUATION OF THE DEGRADATION OF COLORED COATING PRODUCTS SUBJECTED TO OUTDOOR ENVIRONMENTAL ACTIONS

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ABSTRACT

External environment can act on colored coating products used as construction finishing materials through climatic factors (UV radiation, moisture, temperature) causing photochemical degradation reactions at the structural level, with direct implications on the aesthetic character through loss of the colorimetric properties but also on the protective role by reducing physical and mechanical properties. From this perspective, accelerated test exposure to UV radiation under conditions that simulate the action of climatic factors from natural environment are of particular importance and evaluating methods for colored coating products degradation at the end of exposure offers the possibility to obtain the data about their behavior in service.
The article presents methods of visual evaluation on colored coating products degradation, which are based exclusively on qualitative evaluations influenced by the examiner, compared to the instrumental methods that allow to reduce the uncertainty induced by the human factor and to obtain accurate and quantifiable results to contribute in establishing the sustainability and the performances of the finishing coating materials.

Keywords: colored paint product; degradation; evaluation methods.

REZUMAT

Mediul exterior poate acționa asupra produselor peliculogene colorate utilizate ca materiale de finisaj în construcții prin intermediul factorilor climatici (radiație UV, umiditate, temperatură) determinând reacții de degradare fotochimică la nivel structural, cu implicații directe asupra caracterului estetic al acestora prin pierderea proprietăților colorimetrice dar şi asupra rolului de protecție prin diminuarea proprietăților fizico-mecanice. Din acest punct de vedere testele accelerate de expunere la radiație UV în laborator, în condiții ce simulează acțiunea factorilor climatici din mediul natural, pentru produsele peliculogene colorate au o importanță deosebită iar metodele de evaluare a degradării la încheierea perioadei de expunere oferă posibilitatea obținerii de date cu privire la comportarea în exploatare a acestora. Articolul prezintă metodele de evaluare vizuală a degradării produselor peliculogene colorate, ce se bazează exclusiv pe aprecieri calitative influențate de examinator, comparativ cu cele instrumentale care permit reducerea incertitudinii induse de factorul uman şi obținerea unor rezultate precise, cuantificabile care să contribuie la stabilirea durabilității şi performanțelor materialelor peliculogene de finisare.

Cuvinte cheie: produse peliculogene colorate; degradare; metode de evaluare.

1. INTRODUCTION

Coatings are currently the most widely used category of finishing construction products. Regarding this aspect, coating products are the subject of advanced research, performed to obtain performant products with different properties, designed to meet the various functional requirements. Over the time, besides improving the film strength properties (physical and mechanical), the producers tried to intervene also on the appearance of the final product, an important feature that provides information about the finishing material durability.

Thus, because of the studies conducted in the field of colorimetry, complemented by the development of new systems based on macromolecular compounds and pigments, as well as due to the improvements in manufacturing processes, it became possible to design coating products in a wide range of colors that meet the requirements concerning both physical and mechanical properties, as well as their appearance.

In the program of thermal rehabilitation of existing buildings, initiated by the Ministry of Regional Development and Public Administration in 2009, and which is still in progress, it is mentioned the necessity to reconstruct the facades that are in an advanced state of decay.

This program was intended to achieve two main goals: thermal rehabilitation and changing of the default appearance of buildings and cities, in the spirit of sustainable development concept.

Choosing facade finishes took into account the aesthetic criteria, which finally led to the use of colored coatings products.

In this context, the component, which refers on durability of these products, is extremely important, as well as maintaining performance issues in the specific climatic conditions of our country.

Climatic factors (UV radiation, moisture, temperature) can cause photochemical degradation reactions at structural level, with direct implications on their aesthetic character through the loss of colorimetric properties, but also of the protective role, by the degradation of physical and mechanical properties. The evaluation of the degradation of colored coating products provides the possibility to obtain data on their operational behavior.

Evaluation methods that underlie establishing the behavior in time of the colored coating products are divided in two categories: visual and instrumental methods, as in Figure 1.

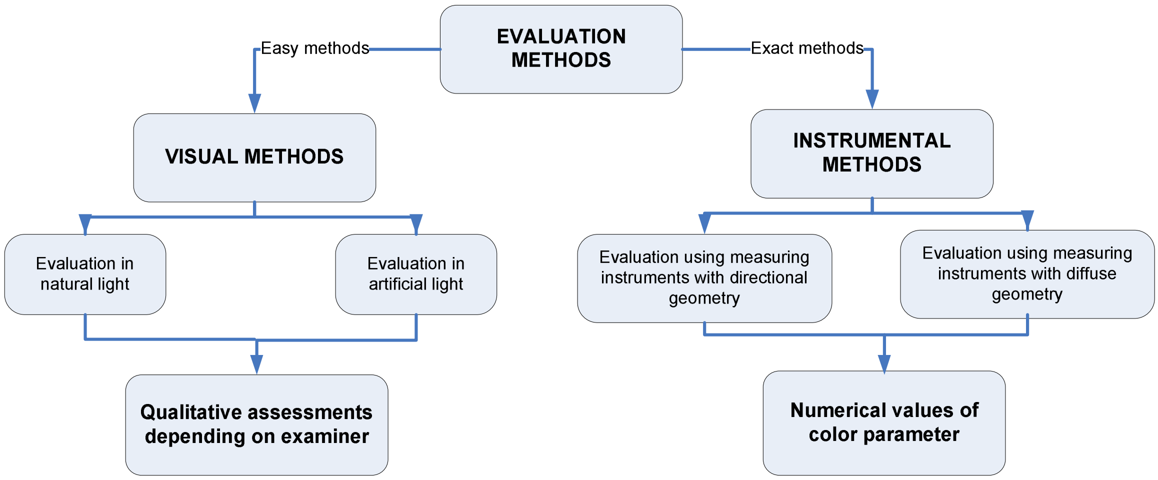

Fig. 1. Evaluation methods of degradation colored coating products

2. EVALUATION METHODS OF COLOURED COATING PRODUCTS DEGRADATION

Colored finishes are a complex chemical system that consists of a macromolecular matrix and a number of substances with well-defined roles: processing agents, filler agents, stabilizers, pigments. The external environment can affect these colored finishes, by producing changes due to the action of UV radiation, temperature, oxygen and moisture, all these factors initiating photochemical degradation processes. Evaluation methods of coating products degradation listed below follow the effects of the action of climatic factors in terms of maintenance of the colorimetric properties.

2.1. Visual evaluation methods

Color sensation assumes the existence of an electromagnetic radiation emitted by a source to the viewed object, this reflecting a part of the radiation in the direction of the human eye, that functions as a detector, transmitting to the brain a series of stimuli, which are interpreted as color.

To perceive the color of an object, two elements are needed: a light source and the presence of an observer (human eye). Color variation is the result of interaction of electromagnetic radiation (light) with the matter [1].

Visual methods for the evaluation of colored coatings subjected to the action of the external environment are influenced by the presence of several factors such as:

- the type of lighting under which the evaluation takes place;
- examiner who performs visual comparison of color;
- the way of preparation of the substrate and of the coating product application.

Colors of paint films that will be compared by visual methods should be examined under specified conditions of illumination and viewing, either daylight or artificial light, using in this last case a color comparison chamber.

To make the visual comparison of colors, it is important that the examiner distinguishes and differentiates normally the colors; the experience gained in this kind of evaluation also matters.

During the visual evaluation of color differences between coating products, the eye fatigue effects must be avoided, and in this respect, complementary or pastel colors will not be examined immediately after evaluating bright colors. The quality of visual assessment decreases drastically when the examiner is constantly working and several minutes of rest are necessary, during which it should do no color comparison.

Substrate preparation contributes significantly to color quality assessment for coating products. Both, the substrate on which the paint will be applied and the reference standards used for visual comparison of color differences must have flat surfaces with approximate size of (150 x 100) mm.

Sample size and distance of examination should be chosen so that between the sample and the examiner's eye a viewing angle of about 10˚ can be formed.

The reference standards according to which the assessment is carried out should be characterized by satisfactory stability of color and, as far as possible, they should have size, gloss and texture similar to the analyzed samples.

The application of the coating product is an important factor, similar to those previously presented, because the application method used and the film thickness can considerably affect the color. The film thickness should have an optimal value that can ensure a complete coverage of the substrate to eliminate its influence when the surface is evaluated in terms of colorimetric properties.

2.1.1. Visual evaluation of color in natural light

Visual evaluation of color in natural light is performed under diffuse daylight, which corresponds to partly cloudy sky. Lighting in this case should be uniformly distributed on the sample surface and on a level of at least 2000 lux, direct sunlight being avoided.

The evaluation method consists in the comparative examination of colored coating product samples in natural daylight, in relation with the reference standard, at a viewing angle that minimizes the differences given by the gloss.

The components that give color difference, known as chromatic attributes, are: hue difference (DH), the difference in saturation (chroma) (DC) and the difference in brightness (DL) and the result of evaluation consists in assessments on their prominence order.

Table 1 presents the visual evaluation criteria of color differences in natural daylight, for coating products subjected to the outdoor environment action.

Table 1 - Evaluation criteria for color differences components [2]

Level	Difference degree
0	There is no perceptible difference
1	Very small, barely perceptible difference
2	Small but clearly perceptible difference
3	Moderate difference
4	Considerable difference
5	Very big difference

Table 2 presents an example of scoring for assessments made on color differences between the sample and the reference standard.

Table 2 - *Ways of assessment of color difference. Examples*

Color difference components (Indicative)	Evaluation	Example of notation (explanation)
Hue difference (DH)	More yellow – ye,y More green – gr, g More red – re, r More blue – bl, b	DH5ye (test specimen corresponds to level 5 and is too yellow)
Difference in saturation (chroma) (DC)	More (+) Less (-)	DC:-2 (test specimen corresponds to level 2 and is less saturated color)
Difference in brightness (DL)	Brighter (+) Darker (-)	DL:-2 (test specimen corresponds to level 2 and is darker)

It should be noted that DH, DC and DL are not colorimetric values and that these values are used only for the classification of color difference. The result of the evaluation is based, in this case, on assessments made by the examiner.

2.1.2 Visual evaluation of color in artificial light

The method of color evaluation in artificial light assumes the existence of a chamber where no light penetrates from the outside, equipped with an artificial light source with high spectral distribution. Spectral energy of electromagnetic radiation produced by the artificial light source must correspond to the spectral energy distribution of CIE D65 and CIE A illuminants.

The level of illumination while visual comparison of color is performed must be between 1000 lux and 4000 lux, the higher end of the value range being desirable for evaluating dark colors.

The interior walls of the chamber must be painted in neutral matt grey color (the value for a^* and b^* must be smaller then 1,0) with a brightness, L^*, of approximately 45 to 55. When mainly light colors and colors close to white are compared, the inside of the chamber should be painted so that a luminosity, L^*, of about 65 or greater, is obtained, to give a contrast of brightness lower than the color under examination. When especially dark colors are compared, the inside of the chamber should be painted in matt black with a luminosity, L^*, of about 25.

Sample examination is done by visualization at an angle of 45˚, with a source light at an angle of 0˚, or vice versa. The total color difference or the color difference components described above (DH, DC, DL) are observed.

2.2. Instrumental evaluation methods

Because the visual evaluation of surface colored coating products is directly influenced by a number of factors, such as the method of determining color differences (evaluation in natural or artificial light), type of light source used, the examiner's experience and their ability to determine changes in color, the need emerged to develop a more precise method, that can lead to the quantification of obtained results and that will not be influenced by this factors. Thus, the colorimetry appeared, as a method of analysis for quantifying color perception.

In addition to chromatic attributes, the appearance of an object is given also by the geometric attributes relating to shape, gloss, texture and translucency. Complete characterization of colored coatings products in terms of maintaining colorimetric properties is achieved through chromatic and geometric attributes.

The instrumental method of analysis allows a numerical evaluation of colored coating products, unlike the visual method that performs a classification based only on the examiner perception. In this perspective, specific measuring instruments are used for color differences evaluation. The general principle of operation is based on the existence of three main color stimuli, characteristic to the human eye perception (red, green and blue).

Important parameters that must be specified when conducting color evaluation of coating products by instrumental analysis methods: source type, type of illuminant and geometric characteristics of the measuring instrument.

Optical geometry systems for measuring instruments define the constructive type of light source and detector in relation with the analyzed sample. Optical systems are divided in two categories:

– with directional geometry (45˚/0˚ or 0˚/45˚);
– with diffuse geometry (spherical).

2.2.1 Optical systems with directional geometry

These systems use a light source that transmits electromagnetic radiation to the sample at an angle of 45˚. Colorimetric property measurements are made at an angle of 0 ˚ - optical systems 45˚/ 0˚.

There may be optical systems 0˚/45˚ in which the light source is located at an angle of 0˚ from the sample and colorimetric property measurements are made at an angle of 45˚.

Principle schemes of measuring instruments based on geometry optics 45˚/0˚ and 0˚/45˚ are shown in Figure 2. Both geometries do not take into account the specular gloss of the analyzed surface.

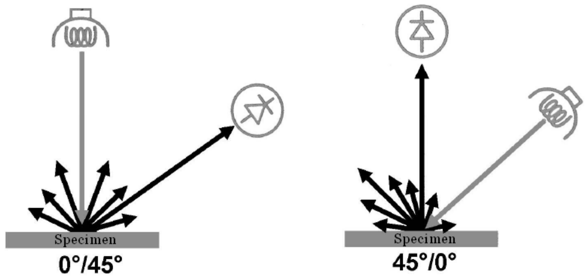

Fig. 2. Geometry optics systems 45˚/0˚ and 0˚/45˚

There may also measuring instrument with circumferential or bidirectional light sources, shown schematically in Figure 3 [3].

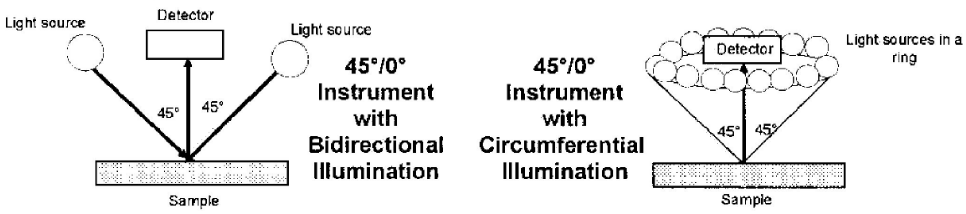

Fig. 3 - Optical systems with circumferential or bidirectional light sources [1]

Bidirectional geometry instruments 45˚/0˚ consist of two light sources positioned opposite from the sample at an angle of 45˚ while the circumferential geometry, have light sources positioned in the form of a ring.

2.2.2 Optical systems with diffuse geometry

They consist of a sphere with white surface to diffuse the light from the source to sample. In this case, measurements are made at an angle of 8˚ (d/8˚) than normal and these instruments have the ability to exclude the specular gloss of surface (direct reflection). The advantage of measuring instruments is their ability to achieve measurements that take into account the specular gloss or to exclude this phenomenon, as shown in Figure 4 [2].

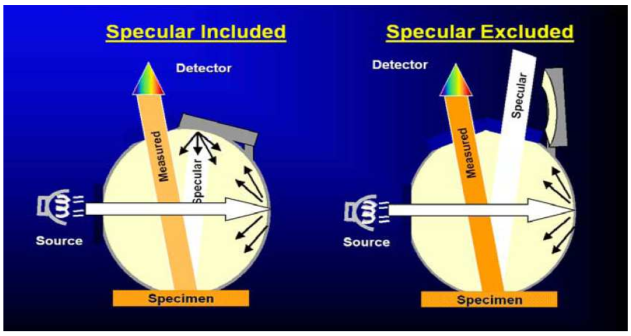

Fig. 4 - Optical systems with spherical geometry d/8˚; a) measurements that take into account the specular gloss; b) measurements do not take into account the specular gloss [4]

The peculiarities of measuring instruments whose optical system is based on the existence of an integrating sphere minimize the effects due to differences in gloss, texture and directionality. The colorimetric properties are measured independently of them, making these instruments suitable for measurements on all types of surfaces.

Measuring instruments used to evaluate surface color coating products subject to outdoor environmental action in terms of colorimetric properties variations can determine chromaticity coordinates for a well-defined observer and a light source, allowing the unique characterization of samples. Therefore, the hue difference, the difference in saturation and brightness and the difference in relation to the standard colorimetric space CIE (L^*, a^*, b^*) can be measured, based on a specific system of equations [5].

3. CONCLUSIONS

The evaluation of degradation coating colored products through the colorimetric properties offers the possibility of obtaining data on their operational behavior.

Currently, the most commonly used evaluation methods of degradation colored coating products are the visual methods in detriment of the instrumental method which requiring additional investment for specific equipment acquisitions. Instrumental evaluation methods of degradation colored coating products subjected to the external environment action, compared to visual methods, can detect structural changes via colorimetric variation parameters in their surface in relation with a standard reference, allowing to analyze the occurrence of the degradation processes when such changes can not be perceived by visual methods. The analysis of degradation processes for colored coating products provides information on the decrease of physical and mechanical properties and, therefore, on the loss of functional characteristics for which they have been designed.

The importance of instrumental methods used for the evaluation of colored coating products in terms of maintaining colorimetric properties is given by the reduction the uncertainty due to the human factor and to the lighting under which is made the evaluation, leading to precise and quantifiable results.

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