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Conservation of cultural property — Test methods — Colour measurement of surfaces

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Erhaltung des kulturellen Erbes - Prüfmethoden - Farbmessung von matten Oberflächen

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Foreword

This document (EN 15886:2010) has been prepared by Technical Committee CEN/TC 346 “Conservation of cultural property”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2011, and conflicting national standards shall be withdrawn at the latest by March 2011.

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1 Scope

This European Standard describes a test method to measure the surface colour of porous inorganic materials, and their possible chromatic changes. No reference to the appearance of glossy surfaces is described. The method may be applied to porous inorganic materials either untreated or subjected to any treatment or ageing.

The method is suitable for the measurement of colour coordinates of:

— representative surfaces of specimens, see 3.11;

— representative surfaces of objects, indoors or outdoors.

2 Normative references

The following referenced documents are required for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced documents (including any amendments) apply.

prEN 15898:2010, *Conservation of cultural property — Main general terms and definitions concerning conservation of cultural property*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in prEN 15898:2010 and the following apply.

3.1
porous inorganic materials
natural stones as well as artificial materials such as mortar, plaster, brick and others

3.2
chroma
attribute of colour used to indicate the degree of departure of the colour from a grey of the same lightness

NOTE See ASTM E 284.

3.3
lightness
attribute by which a perceived colour is judged to be equivalent to one of a series of greys ranging from black to white

NOTE See ASTM E 284.

3.4
hue
attribute of a visual perception according to which an area appears to be similar to one of the colours, red, yellow, green, and blue, or to a combination of adjacent pairs of these colours considered in a closed ring

NOTE See the International Commission on Illumination CIE (1931)

3.5
reflectance factor
R%
percentage ratio of the reflected radiant power compared to incident radiant power

3.6
CIE standard illuminant D65
reference illuminant having approximately the same relative spectral power distribution of a phase of daylight with a correlated colour temperature of approximately 6 500 K

3.7
CIE XYZ trichromatic system
system for colour measurement established in 1931 by the International Commission on Illumination CIE (1931)

NOTE The interpretation of numerical data is connected directly to visual perception. It is based on the principle that colours are obtained by mixing together the three imaginary colour as primaries defined X, Y, Z. These primaries define the reference frame in the tristimulus space and any set (X,Y,Z) is a vector in this space. The principal property of the reference frame is that the Y component is the luminance factor, generally given on a percentage scale.

3.8
CIE 1931 standard colorimetric observer
average observer whose colour matching properties correspond to the CIE colour matching functions for the 2° field size

3.9
CIE 1964 standard colorimetric observer
average observer whose colour matching properties correspond to the CIE colour matching functions for the 10° field size

3.10
CIE L*a*b* colour space 1976
mathematical transformation of the CIE XYZ space into a metric space

NOTE 1 See Figure 1.

NOTE 2 The L*a*b* system is useful for calculations of colour differences because it allows them to be defined by numerical values.

NOTE 3 In the CIE L*a*b* colour space the colour coordinates in this rectangular coordinate system are:

— **L*** - the **lightness** coordinate. The scale for L* ranges from 0 (black) to 100 (white);

— **a*** - the **red/green** coordinate, with +a* indicating redness and -a* indicating greenness;

— **b*** - the **yellow/blue** coordinate with +b* indicating yellowness and -b* indicating blueness.

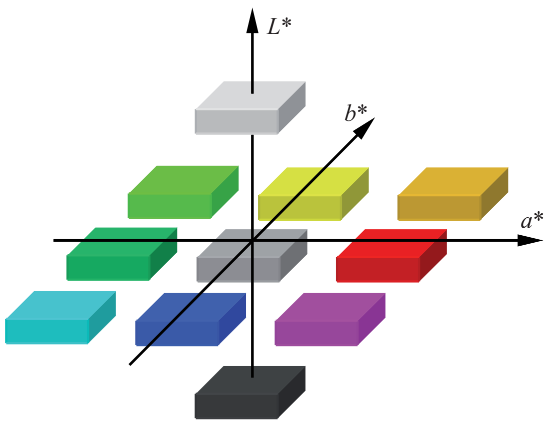

Figure 1 — L*a*b* colour space

3.11
specimen
part considered representative of the material constituting an object.

NOTE 1 The specimen can have different origins and can be taken from:

— materials similar to those constituting the object under study (e.g. stone quarries);

— reference materials, for instance, specifically prepared comparative materials.

NOTE 2 The number and dimension of the specimens can be different depending on difficulties encountered in sampling the required amount of material.

4 Principle

The method is based on the determination of the colour of a surface with an instrumental quantification of colour, expressed numerically according to international methods defined by the International Commission on Illumination CIE. The colours are represented in a "colour space", where any colour in the visible range is defined by three coordinates.

5 Test equipment

5.1 General

Common instruments used for colour measurement are tristimulus colorimeters or reflectance spectrophotometers characterized by:

— spectral range: 380 nm to 780 nm;

— acquisition data at least every 10 nm;

— CIE standard illuminant: D65 (recommended), A, C;

— CIE standard colorimetric observer: 2° and 10° (recommended);

— reference system colour space: CIE x,y,Y and L*a*b*[1)].

It is recommended that the instrument geometry conforms to the d/8° illumination and viewing condition specified by the CIE, where the illumination is diffused with the specular component excluded. Use of other geometries, such as 0/d, is also allowed. The test report shall specify the geometry used.

5.2 White object colour stimulus

For the calculation of L* a* b* values, the white reference shall be constituted by a perfect reflecting diffuser illuminated by the same light source as the tested specimen and/or object.

1) Usually the instruments available on the market are equipped with a software, which calculates the colorimetric parameters CIE x,y,Y and L*,a*,b* from the reflectance values. Otherwise these parameters can be calculated using the CIE Tables.

6 Colour measurement of specimens

6.1 Test areas of specimens

The tested surface areas shall be representative of the colour of the material under investigation. On inhomogeneous materials, the number of measurement points shall be adapted to the specimen as to obtain statistically representative values. Specimens shall be large enough to extend beyond the measurement area of the instrument.

6.2 Number of specimens

A minimum of five representative specimens is considered suitable. However, if only a limited number of specimens are available, the most representative specimen(s) shall be used.

6.3 Preparation of specimens

The specimens shall be conditioned in equilibrium with the surrounding environment. Temperature (T) and Relative Humidity (RH) should be recorded.

The surface of the specimens to be measured shall, if strictly necessary, be smoothed with sand paper with grain size of 82 µm (corresponding to grit number P180 according to the FEPA[2)] classification) and wiped with a soft brush, bearing in mind that such action may alter the colour of the surface prior to measurement.

Measurements taken before and after treatment shall be performed under the same environmental conditions.

7 Colour measurement of indoor and outdoor objects

The area of measurement is the section of the surface of the object on which the colour measurements are carried out. The surface to be measured should, as far as practicable, be smooth and flat so as exclude external light from the area of measurement. Where no smooth, flat areas are available, this should be noted in the report.

Sand paper shall not be used to smooth the surface of an object.

Environmental parameters should, as far as is practicable, be reproduced when measurements are made. Relevant environmental conditions, including temperature and humidity should be recorded in the report. Colour measurements before and after treatment, and any subsequent measurement, should be carried out under the same environmental conditions.

8 Test method

8.1 General

The surface to be measured shall be representative of the specimen and the object as a whole. The number of measurement points shall be adapted to the specimen or the object as to obtain statistically representative values.

2) FEPA – Federation of European Producers of Abrasives.

8.2 Measuring area and number of measurements

The diameter of the measuring area and the equipment shall be appropriate to the type of material under investigation, and the size of the specimen or object. Heterogeneous surfaces may be measured using a measuring area with a diameter as large as possible, in order to compensate variations in colour and texture, and to even out structural unevenness on the surface of the specimen or object, thus imitating the human visual process. Uniform specimens or objects with or without well-defined areas of different appearance (such as dark veins on light marble) may be measured with a much smaller (1 mm) measuring field diameter to avoid (or define) any areas of in-homogeneity.

The necessary number of measurements varies according to the homogeneity of the measuring area, but shall be at least five to obtain a reliable average value per specimen or per object. The measurements are taken at arbitrary locations of the surface

In order to ensure precise repeated measurements, the selected measurement points shall be localised by either reference spatial coordinates or by annotated images. A grid delimiting the measurement area may be useful for this purpose, depending on the size of the specimen or the object.

8.3 Reproducibility of measurements

Reproducibility of measurements is assessed by comparing two series of measurements made on the same surface under the same conditions and at different times, defined as moving the measuring head/probe turning the instrument on and off, and recalibrating it. Repeat the measurements until the difference, expressed as ΔE, between the average L* a* b* values of two successive series of measurements is ΔE ≤ 1,5.

9 Calculation and interpretation of results

9.1 CIELAB values

Calculate the CIELAB (CIE L* a* b* 1976) values from the X, Y, Z values for each specimen. Daylight illuminant (D65) and 10° observer should be used.

9.2 Calculation of total colour differences

The total colour difference ΔE* between two measurements ($L^*_1a^*_1b^*_1$ and $L^*_2a^*_2b^*_2$) is the geometrical distance between their positions in the CIELAB colour space. It is calculated using the following equation:

$$\Delta E^*_{2,1} = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})}$$

where

$\Delta L^* = L^*_2 - L^*_1$; corresponds to the lightness difference;

$\Delta a^* = a^*_2 - a^*_1$; corresponds to the red/green difference;

$\Delta b^* = b^*_2 - b^*_1$; corresponds to the yellow/blue difference.

9.3 Recommended options

Because the L*a*b* colour space does not have exact equidistance between perceived colours (differences in the saturated colours are more difficult to perceive), the colour difference formula ΔE_{94} modifies the lightness, chroma and hue (L*C*H*) of L*a*b* colour space by incorporating factors that correct for variation in perceived colour difference magnitude. It is therefore recommended that the colour differences for each specimen are calculated from the equation ΔE^*_{94}.

The colour difference, or ΔE^*_{94}, between two colours is:

$$\Delta E^*_{94} = \left[\left(\frac{\Delta L^*}{k_L S_L}\right)^2 + \left(\frac{\Delta C^*_{2,1}}{k_C S_C}\right)^2 + \left(\frac{\Delta H^*_{2,1}}{k_H S_H}\right)^2\right]^{1/2}$$

where

$\Delta L^* = L^*_2 - L^*_1$;

$\Delta C^*_{2,1} = C^*_2 - C_1^*$;

$C^*_1 = (a_1^{*2} + b_1^{*2})^{1/2}$;

$C^*_2 = (a_2^{*2} + b_2^{*2})^{1/2}$;

$\Delta H^*_{2,1} = [(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*_{2,1})^2)^{1/2}]$.

and S_L, S_C and S_H are weighting factors for lightness, chroma and hue, respectively, and are given by the following formulas:

$S_L = 1$;

$S_C = 1 + 0,045\ C^*_{1,2}$;

$S_H = 1 + 0,015\ C^*_{1,2}$;

NOTE In S_C and S_H, $C^*_{1,2} = (C^*_1 \cdot C^*_2)^{1/2}$.

$k_L = k_C = k_H = 1$ (default).

The variables k_L, k_C and k_H are called "parametric factors". They are included in the formula to allow for adjustments to be made independently to each colour-difference term to account for any deviations from the reference viewing conditions, that cause component specific variations in the visual tolerances. Under reference conditions they are all set at 1.

10 Test report

The test report shall include the following information:

a) purpose of the measurements;

b) reference to this document (EN 15886);

c) description of the specimens;

d) number of specimens measured;

e) description of the object and of the details examined;

f) photographic and/or graphic documentation of the areas of measurement;

g) number of measurements;

h) technical characteristics of the instrument (colorimeter, spectrophotometer), measurement geometry, standard observer used (CIE 1931 2° standard observer, CIE 1964 10° supplemental observer), illuminant (recommended D65), and whether the specular component is excluded (as recommended). If a different reference illuminant is used (i.e. illuminant C or A), it shall be indicated;

i) results of the reproducibility of the test $\Delta L^*_{2,1}$, $\Delta a^*_{2,1}$, $\Delta b^*_{2,1}$ results;

j) $\Delta E^*_{2,1}$ results;

k) $\Delta E^*_{2,1}$ colour difference between two successive measurements;

l) ΔE^*_{94}, $\Delta C^*_{2,1}$, $\Delta H^*_{2,1}$ results (if used);

m) test environmental conditions: T and RH;

n) if there is/is not a significant difference between the two sets of results;

o) X, Y, Z values before and after treatment including standard deviation.

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