GLASS FOR · EUROPE

Code of Practice for in-situ Measurement and Evaluation of the Colour of Coated Glass used in Façades

1. Scope

This Code of Practice describes a method for allowing an objective evaluation of the colour of coated glass, as defined in EN 1096-1, when used in facades.

It provides a method for measuring colour differences within the same glass pane and between two adjacent panes in the same façade. Specific requirements are given for coated glass, dependent upon its light transmittance and reflectance.

Guidance is also provided on angle dependency, reflection from the interior and transmission.

2. Introduction

It is known that facades incorporating coated glass can present different shades of the same colour, an effect that may be amplified when observed under an angle. Possible causes of differences in colour include slight variations in the colour of the substrate onto which the coating is applied and slight variation in thickness of the coating itself. Furthermore, for highly selective coatings, a slight variation in thickness can create a difference in colour, visible due to the high sensitivity of the human eye.

The purpose of this document is to avoid any subjective approaches that may have been used in the past. The procedure for in-situ measurement of the colour of coated glass in facades is detailed in 3.

All measured values concern the finished glass product as installed in the façade and not the single components. Only products with the same configuration (e. g. thickness, coating type, etc.) shall be compared.

3. In-situ colour measurement

3.1 General

The following paragraphs explain the procedures used on site for measuring the colour of the glass product.

Information on the perception, quantification and measurement of colour is given in Annex A.

3.2 Colour differences within the same glass pane

For colour differences within the same glass pane, the parameters L*, a* and b* shall be measured with a portable colorimeter. The measurements shall be undertaken at a minimum of three points in each zone representing the colour difference. An example is illustrated in Figure 1.
For cut sizes and thermally toughened glass, measurements shall not be undertaken at any point within 10cm of an edge. This is due to the potential for the colour near to the edge to differ slightly from the colour in the centre. Furthermore, the measurements may be affected by the proximity of the frame and the edge of the insulating glass unit.

The ΔL*, Δa* and Δb* values shall be calculated based on the difference between the average values for each zone, in accordance with equations (1), (2) and (3), respectively.

$$\Delta L^* = L^*_{(zone2)} - L^*_{(zone\ 1)} \quad (1)$$
$$\Delta a^* = a^*_{(zone\ 2)} - a^*_{(zone\ 1)} \quad (2)$$
$$\Delta b^* = b^*_{(zone\ 2)} - b^*_{(zone\ 1)} \quad (3)$$

The values of ΔL*, Δa* and Δb* shall meet the requirements given in 3.4.

ΔE* shall not be determined (see A.2).

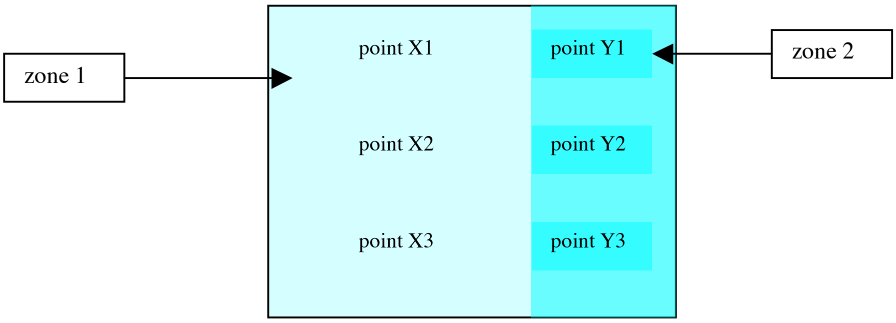

Figure 1. Example of measurements undertaken at a minimum of three points in each zone representing the colour difference.

3.3 Colour differences between two adjacent panes in the same façade

For colour differences between two adjacent panes, the parameters L*, a* and b* shall be measured with a portable colorimeter. For each pane representing the colour difference, the measurements shall be undertaken at a minimum of three points (i.e. along a diagonal). An example is illustrated in Figure 2.

Note 1. The reference pane may be compared with any of the four adjacent panes – above, below, to the left, or right.

Note 2. The comparison should only be undertaken for panes of the same glass type, composition and background conditions and situated on the same elevation.

The average values of L*, a* and b* shall be determined for each pane. An example is detailed in Table 1.

Pane Y Y= 1,2,3, …	L*	a*	b*
Measuring point 1	L^*_{Y1}	a^*_{Y1}	b^*_{Y1}
Measuring point 2	L^*_{Y2}	a^*_{Y2}	b^*_{Y2}
Measuring point 3	L^*_{Y3}	a^*_{Y3}	b^*_{Y3}
Average	$L^*_{glass\ Y} =$ $(L^*_{Y1} + L^*_{Y2} + L^*_{Y3})/3$	$a^*_{glass\ Y} =$ $(a^*_{Y1} + a^*_{Y2} + a^*_{Y3})/3$	$b^*_{glass\ Y} =$ $(b^*_{Y1} + b^*_{Y2} + b^*_{Y3})/3$

Table 1. Example of determining the average values of L*, a* and b* for one pane (e.g. Y)

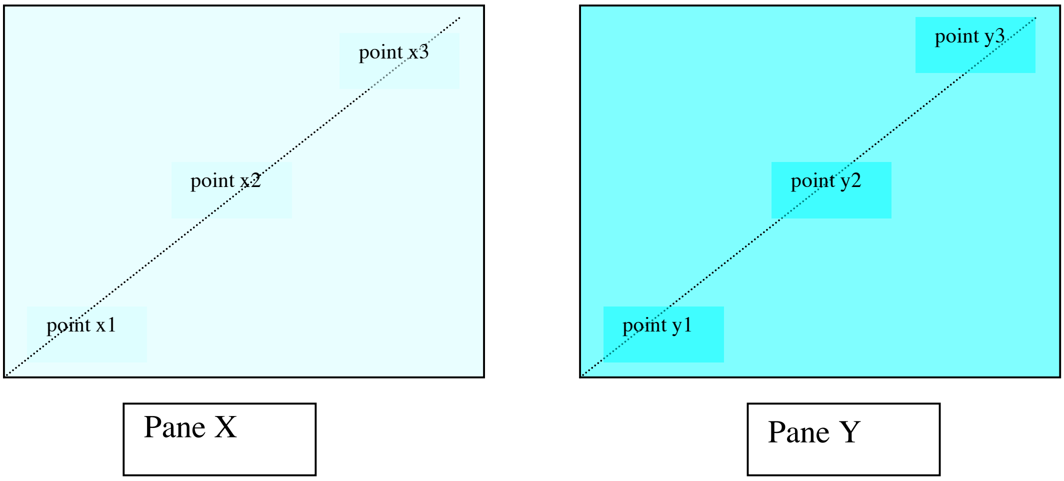

Figure 2. Example of measurements undertaken at a minimum of three points for each pane representing the colour difference.

The ΔL*, Δa* and Δb* values shall be calculated based on the difference between the average values for each pane, in accordance with equations (4), (5) and (6), respectively.

$$\Delta L^* = L^*_{(pane\ Y)} - L^*_{(pane\ X)} \qquad (4)$$
$$\Delta a^* = a^*_{(pane\ Y)} - a^*_{(pane\ X)} \qquad (5)$$
$$\Delta b^* = b^*_{(pane\ Y)} - b^*_{(pane\ X)} \qquad (6)$$

where X is the reference pane

The values of ΔL*, Δa* and Δb* shall meet the requirements given in 3.4.

ΔE* shall not be determined (see A.2).

3.4 Requirements for colour

The values of ΔL*, Δa* and Δb* determined in accordance with 3.2 and 3.3 shall meet the requirements given in Table 2.

ΔL*	4,0
Δa*	3,0
Δb*	3,0

Table 2. Requirements for colour

4 Other considerations

4.1 Angle dependency of colour

The colour of solar control glass, particularly those with a high selectivity, varies with the angle of observation. These variations can only be measured in a laboratory on small samples and should not be undertaken in-situ.

Consequently, the homogeneity of the colour of the façade under an angle shall only be assessed by visual observation and limited to a maximum angle of 45°. This is illustrated in Figure 3.

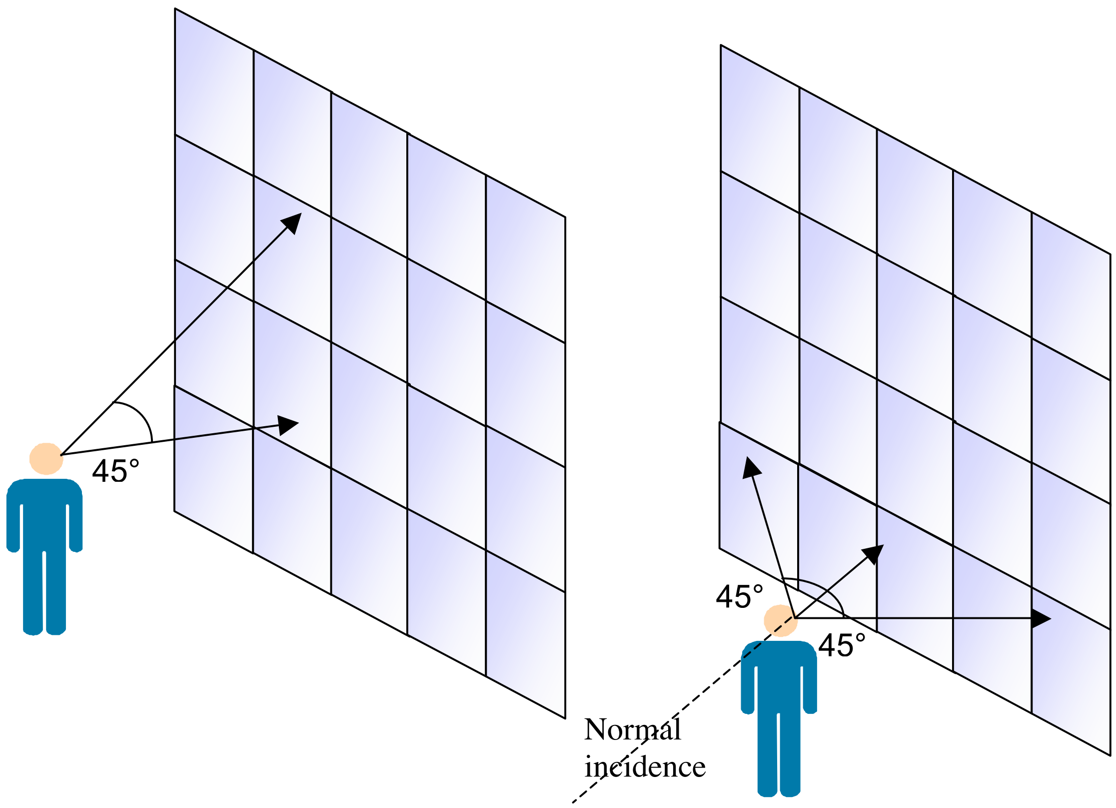

Figure 3. Diagram illustrating the restrictions on angle for assessing the homogeneity of the colour.

4.2 Colour in reflection from the interior

Differences in colour when viewed from the interior are not considered as a defect.

4.3 Colour in transmission

Although differences transmission colour may be also observed, they cannot be measured in-situ as no device is available. This colour can only be assessed by visual observation.

Annex A (Informative): Perception, quantification and measurement of colour

A.1Perception of colour

The perception of colour can be very subjective and linked to the impression and perception of the individual, as the sensitivity of the eye being a very personal characteristic.

Furthermore, a variety of conditions affect how a colour looks, for instance when observing the façade of a building from the outside, including:

- luminosity (e.g. a dark overcast sky might reveal colour differences not observed under direct sunlight)
- distance and angle of observation
- type and colour of mullions and transoms used in the facade
- distance between two adjacent glass panes
- the eye of the observer
- internal conditions (e.g. the absence of lighting in the building (dark background, may increase the perception of colour differences)
- external conditions (e.g. presence of other buildings that may be reflected by the glass)

Care should be taken to avoid observing the façade under conditions which are not representative for a building 'in use', or else due account taken of these factors during the assessment.

A.2 Quantification of colour

As noted in A.1, a visual observation of colour invariably has a subjective element. Therefore, it is very important to be able to quantify the colour of a façade in order to develop an approach independent of this subjectivity. Various methods have been devised in the past for quantifying colour and expressing it numerically with the aim of making it more easily and more accurately.

The method used by GEPVP is the L*a*b* colour-space, defined by the CIE in 1976. As the colour of an object is dependent upon the light source, the standard illuminant adopted by GEPVP is D65 (representing average daylight) and the angle of observation is 10°.

The L*a*b* colour space (also referred to as CIELAB) is one of the most popular colour spaces for measuring object colour and is widely used in a variety of fields. It provides a procedure for evaluating uniform colour differences in relation to visual differences and, moreover, it enables colour to be quantified.

This colorimetric system can be visualised by a three-dimensional colour space (see fig.1), where every colour can be represented by a set of 3 co-ordinates: L*, a* and b*,
where L* indicates the lightness and a* and b* the chromaticity coordinates. Positive values of a* show the red direction, and negative values the green direction, whereas positive values of b* show the yellow direction and negative values the blue direction. The centre is achromatic (i.e. neutral).

Note. The parameters L*, a* and b* can be used for quantifying the aesthetics of a façade, observed from the outside (in reflection), or to characterise the properties of transmission of light through a glass pane.

The differences of colour can be quantified using tolerances on the parameters L*, a* and b*, which are noted as ΔL*, Δa* and Δb*, respectively, and calculated as in following equations:

$$\Delta L^* = L^*_{object\ 2} - L^*_{object\ 1}$$
$$\Delta a^* = a^*_{object\ 2} - a^*_{object\ 1}$$
$$\Delta b^* = b^*_{object\ 2} - b^*_{object\ 1}$$

In the field of colour measurement, it is common to refer to a ΔE* value, combining ΔL*, Δa* and Δb* values. It is the GEPVP position that this ΔE* value is not accurate enough in terms of glass colour evaluation. Therefore, only ΔL*, Δa* and Δb* values shall be considered.

Figure 4. Representation of three-dimensional colour-space

<u>A.3Measurement of colour</u>

The parameters L*, a* and b* can be measured not only by spectrophotometers used in the laboratory but also by using colorimeters or spectro-colorimeters. These colorimeters can be portable instruments, suitable for use on site and as instructed by the manufacturer. Whether used in a laboratory or on site, these devices have a similar sensitivity to that of the human eye. The measurements should always be undertaken with the same light source and illumination method to ensure that the measurement conditions are the same, regardless of whether it is day or night, indoors or outdoors. This ensures that simple and accurate measurements are undertaken to provide numerical values that are independent of external factors (as listed in A.1).

Note. Portable colorimeters currently used on site are limited to the measurement of colour in reflection, with an angle of observation corresponding to the vertical. Laboratory instruments can measure the characteristics of glass panes in transmission and reflection under different angles of observation.

Normative References

EN 1096-1: Glass in building – Coated glass – Part 1: Definitions and classification

CIE Publication N° 15 : 2004 – Colorimetry