Information Note

Colour Tolerance for paints and coatings

Introduction

Coatings are used for the protection and decoration of buildings, structures, vehicles and articles. Coatings are applied to various substrates including wood, plastic, metal, and building materials. Colour accuracy, consistency, and ensuring the correct specification and colour shade is selected, are of prime importance to coatings manufacturers, coatings applicators and end customers.

It is possible for colour differences to be perceived on the final coated substrate for a number of reasons, some of which may be unavoidable due to the coating and application technology. Colour variations can be caused by a number of factors including different substrate, film thickness, gloss level, angle of viewing, smoothness of film, application and drying method, application and paint conditions, and lighting type.

Applied coatings may differ in colour from an agreed standard; in addition, there may be batch to batch variations. The magnitude of any perceptible difference between two colour tones may or may not be acceptable to the customer. A colour tolerance value nominally acceptable on paper can give rise to a distinctly appreciable colour deviation due to how humans visually perceive colour.

It should be noted that coatings are industrially-manufactured products and, as such, are subject to inherent deviations owing to their industrially-manufactured raw materials and their preparation processes.

Metallic and effect shades (e.g. aluminised or pearlescent finishes) are very complex with regard to colour and so are not included in this guidance document.

Colour appearance

Colour appearance can be influenced by a number of variables. One of the most important of these is the light source. Apparently similar colours formulated using different colourants can appear very different when viewed under different lighting conditions. This is known as metamerism . Certain colours can be more prone to metamerism than others. To minimise the potential for metamerism, the aim should be to use, where possible, the same choice and combination of colourants to those used in the original colour, and no more than four colorants. Coating manufacturers rely on light boxes with specified lighting sources included, to standardise the colour comparison procedure e.g. D65 (artificial daylight), CIE Illuminant A (tungsten filament light), TL84 (fluorescent light). It is vital to ensure these are well maintained.

Colour matching

Due to the variations for finished coated objects and building components, it is important for any two coatings to be compared under the same circumstances, i.e. samples must be applied on test panels under stated standardised laboratory conditions.

It is normal practice during batch quality control, to apply two samples side-by-side at the same time, one being the Standard to match and the other being the new batch under preparation. Note that wet coatings will often look different to their final dried/cured state. and that the quality of a wet paint sample can deteriorate on storage, so colour matching should also be done against an agreed coated Standard panel, that has been stored correctly (away from sunlight and heat).

When comparing two colours, the following requirements should be met:

- The finish must be opaque, with no substrate showing through;
- The assessment area must be flat and uninterrupted;
- The size must be sufficient for a reliable assessment of the colour. Ideal size for standards is between A6 and A5;
- The surface texture should be as close as possible to each other;
- The two samples should be of similar gloss, film thickness and substrate type & colour.

Other key parameters that need to be standardised when comparing coated panels are:

- the substrates used (the coatings will perform differently if there is a difference in the degree of absorbency into a substrate or substrate colour;
- the degree of reflectivity of the substrate and;
- the conditions under which the coating is applied (filmweight, booth conditions, application method and drying conditions).

Colour cards

It should be noted that commercially-available colour cards (e.g. RAL and BS 4800 and BS 381C) may be pigmented differently from the actual coatings that are manufactured, and can therefore show marked colour deviation at any given time from the manufacturer's original standards, i.e. the actual colour of a coating may not be identical to that shown on shade cards, brochures or in photographs.

As mentioned above, note that the gloss level of a coating can affect its perceived colour, for example, matt colour cards appear both perceptibly and to instrumental measurement as lighter and less saturated than the same shades of the gloss version. A visible and measurable colour difference can therefore occur between two samples, even of the same name or standard number. Because of this, where necessary a special card should be agreed upon between the interested parties as a standard; this should be rotated between the parties as required. The use of standard (e.g. BS or RAL) colour cards has not proved successful in practice and this is not generally recommended for sales agreement, but only as an indicator of colour for discussion. In case of doubt, for a coating manufacturer's stock products, the supplier's own colour card should be referred to as the correct standard.

Since commercial colour cards have only a finite lifespan as defined by the manufacturer, these cards must be replaced regularly. In order, however, to avoid a change in the colour of the coating over time, the measurement data in any colour measurement instrument/system should not be altered, but the deviation of the new colour card recorded.

Colour measurement

Whilst the human eye cannot quantify colours accurately, and verbal description of a colour is subjective, there are no such issues when measuring colour instrumentally. Various types of instrument are available:

Colorimeters

Colorimeters make use of red, green, and blue filters that emulate the response of the human eye to light and colour. They are primarily used for quality control applications to check whether colours are within tolerance. One of their disadvantages is their inability to predict or compensate for metamerism. This is because they use a single type of light and do not record the spectral reflectance of the media.

Spectrophotometers

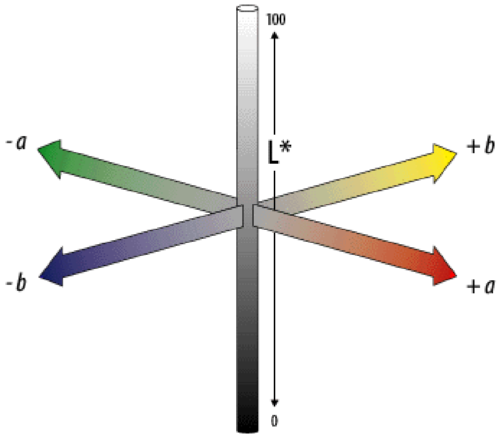
Spectrophotometers are more commonly used. They measure reflected or transmitted light at many points which results in a spectral curve. Since the spectral curve of each colour is unique, it is an ideal tool for identifying and matching colour. Spectrophotometers have sensitivities corresponding to those of the human eye and take measurements using a consistent light source and illumination method. This makes accurate colour measurement relatively simple as well as providing an opportunity to set and communicate both a Standard and any deviations.

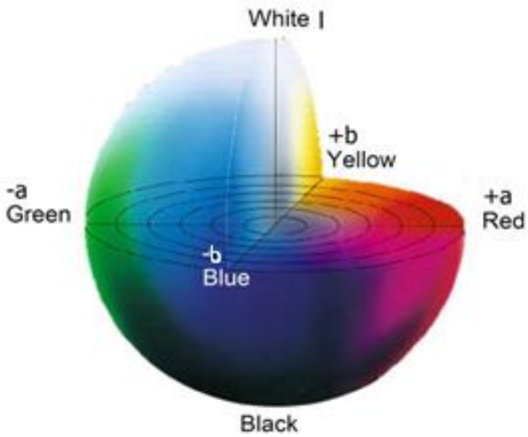
Even if colours look the same to the human eye, measurements with a colour spectrophotometer can identify slight differences, and express these differences numerically.

Classification of colours

Colour is expressed in terms of hue (colour), lightness (brightness), and saturation (vividness). Numerical scales for hue, lightness, and saturation, enable colour to be measured objectively.

The L*a*b* colour space (often referred to as CIELAB) is one of the most popular spaces for measuring object colour, where L* indicates lightness and a* and b* are the chromaticity coordinates. On the vertical line below, a lightness value of L* = 0 represents the darkest black whilst a value of L* = 100 is equivalent to the brightest white.





The red/green opponent colours are represented along the a* axis, with green at negative a* values and red at positive a* values. Similarly, the yellow/blue opponent colours are represented along the b* axis, with blue at negative b* values and yellow at positive b* values. The centre is achromatic i.e. neutral grey. As a* and b* values increase, the point moves out from the centre and the vividness of the colour increases.

The CMC colour difference formula is based on hue, lightness and saturation measurements and provides a single numerical number ΔE (Delta E). The ΔE value is calculated from a combination of the LAB or LCH variations, and provides a single "Headline" number that represents the 'distance' between two colours and can be used for pass/fail decisions.

ΔE calculations are based on colorimetry and are illuminant-dependent. A ΔE value of zero may indicate a perfect match to the standard, but as the ΔE value increases, the colour moves further away. A ΔE value of 1.00 is commonly used as a tolerance value as this typically represents the point at which colour differences become apparent using the naked eye. However there are three points worth noting:

1) Whilst the ΔE value provides a Headline colour deviation, as it is made up of an average or combination of LAB or LCH, and so the individual components need to be reviewed when assessing colour;
2) Whilst the ΔE value might be above 1.00, for certain colour shades the difference might not be perceptible to the human eye.
3) With some colours, for example bright Pantone or RAL shades used in graphic design, it might not be possible to achieve a ΔE of < 1.00 because the required pigments aren't available for use in paint. In such cases it might be necessary to increase the tolerance figure based on what is achievable, and/or visually acceptable.

As well as providing a ΔE value, the spectrophotometer will give an indication of how the colour deviates from the standard. This gives an indication of where the actual colour lies within the CIE Color Space compared to the standard e.g. redder, greener, bluer, yellow, stronger or weaker. This is useful because one batch of a particular colour could be passed with a ΔE of 1.00, lighter, redder and yellower to the digital standard, with the next batch also showing a ΔE of 1.00 but darker, greener and bluer. Whilst both are within the required tolerance, the colours are at the opposite extremes of the CIE color space. This colour difference would most likely be visible to the naked eye. A visual check against a physical standard, and the last batch, should therefore be included as part of the final decision making.

Visual assessment using the naked eye

Advantages:

- Provides information on how the colour is perceived, which is the most important.
- Using a light cabinet with standardised illuminants D65 (artificial daylight), CIE Illuminant A (tungsten filament light) and TL84 (fluorescent light). Can highlight effects such as metamerism.

Disadvantages:

- Without a light cabinet it is difficult to obtain control over the viewing conditions, particularly light source and interference from background and surroundings.
- Eye fatigue, age and other physiological factors can influence colour perception.
- The opinion of one observer might be different to that of another.
- Each person also verbally defines an object's colour differently.

Instrumental assessment using a spectrophotometer

Advantages:

- Can provide reproducible data to indicate the closeness of a colour match
- Minute colour differences can be expressed numerically and easily understood.
- Colour master standards can be stored digitally

Disadvantages:

- Measurement data is dependent on the type of instrument and its calibration.
- Colour tolerances need to be reviewed to ensure they are appropriate for the colour, and that Pass/Fail criteria align with the visual assessment

It is recommended that, ideally, comparison of colours is best carried out using a combination of both visual and instrument, rather than relying solely on a spectrophotometer. The tolerances used on an instrument should be regularly assessed to the visual assessment, to ensure that colour tolerances are appropriate for each product. Also, as part of the visual assessment, consideration should also be given to comparing against the previous batch history.

Colour tolerances

It may be useful for a coating manufacturer and customer to set a tolerance value, either to an agreed standard colour or batch to batch variations, so as to provide a means of establishing whether a colour is acceptable or not. There are various colour tolerance systems, such as the CMC system or Qualicoat system for powder coatings.

For a given colour shade, the generally permissible colour deviation of a coating under the stated laboratory conditions can be defined in relation to the standard from the following "colour footprint" on basis of x and y values (see ISO 7724-1). The x and y values describe the current colour and its saturation. Note that a ΔE value may be perceived visually in different ways for samples in different colour regions i.e. a ΔE value of one in the deep red region may be an acceptable match, whereas in the light grey region may not .

Customers and suppliers may like to set colour tolerances accordingly.

Note: CEPE has made available a guidance document on colour tolerances of powder coatings[1]

Advice to applicators

This guidance document refers exclusively to the control of coatings at point of supply, on test panels applied under standardized laboratory conditions. The applicator is advised to carry out any tests under the same criteria.

Since colour differences can arise as a result of the coating and curing process, the coated parts must be subjected to a quality control by the coating company, especially during a product's development phase with clients, and thereafter through Quality Control activities on each batch, to ensure it is able to perform in a range of process variation.

In particular the following parameters, which lie outside the control of the coating supplier, can have a large influence on the colour of the coated parts, e.g.:

- differences in film thickness;
- differences in substrate material, colour, gloss, smoothness or quality;
- differences in drying/curing conditions for example, for stoving finishes, the cure temperature of the parts and duration in the oven (such as in plant stoppages, breaks, plant start-up, alteration of plant parameters such as line speeds etc.);
- differences in application method and paint booth variation i.e. temp & humidity.

To avoid unacceptable colour differences and metamerism, it is recommended to avoid samples which have been coated under different application conditions, or come from different suppliers or product ranges. In subsequent supplies for existing objects the applicator must warn the supplier of special requirements for colour consistency.

[1] *'Permitted color tolerances of unicolor powder coatings for architectural applications', available website;* http://www.cepe.org/efede/public.htm#!HTML/15483