UNDERSTANDING AND CONTROLLING COLOR: Maintaining Your Product's Image

Gary Kennamer, Boral Bricks, Augusta, Georgia, and Jim Frederic, The National Brick Research Center at Clemson University

The Appeal of Color

With the increasing diversity of products, product recognition is becoming more important. Along with product design, color is one of the major factors in creating a product image. It has a great effect on market appeal and sales.

The average consumer will not accept the color ranges that were the industry standard ten years ago. They are always searching for a better product – one that gives them the desired properties with a minimum of variation. Because of these requirements, companies are becoming more concerned about color, and color control is becoming increasingly popular.

The Definition of Color and the Basics of Color Systems

Webster defines color as "a phenomenon of light or visual perception that enables one to differentiate otherwise identical objects". While the role of light in color development can be discussed in very scientific terms, the idea of "visual perception" can be very vague and very opinionated. For this reason, it is difficult for people to discuss and agree on color. A basic understanding of the components of a color system might help to clarify these communication problems.

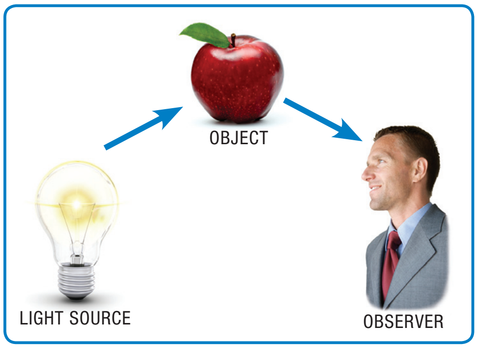

Figure 1: Components of a Color System

There are three components necessary for the perception of color. They are LIGHT, OBJECT, and OBSERVER (Figure 1). Light supplies all the spectral energy. Without a light source, there is no perception of color. The object reflects or absorbs the spectral energy from the light source. Each object has its own reflectance pattern. For example, a red object reflects and absorbs light differently than a green one. Finally, without an observer, no color can be perceived. The defining characteristics of color cannot be formed until they are in the mind of the observer. While the brain is very good at detecting color, it is not very good at remembering or comparing color. We deal with an infinite variety of colors every day, but verbal expression of color is difficult and often confusing.

Table 1: What conditions affect how a color looks?

CONDITION	AFFECTS
Light sources	sunlight, fluorescent, tungsten, etc.
Observer differences	sensitivity, vision, age, colorblindness, eye shape
Size differences	colors covering larger areas appear brighter and more vivid
Background differences	contrast to background may brighten or dull object
Directional differences	angle of observer can appear to change color

Our individual perception of color is influenced by many factors. These are LIGHT SOURCES, OBSERVER DIFFERENCES, SIZE DIFFERENCES, BACKGROUND DIFFERENCES, and DIRECTIONAL DIFFERENCES (Table 1). Examples of light sources are sunlight, fluorescent light, and tungsten light (regular light bulbs). Each source emits light of a different wavelength, and each can make the same object look different. A paint sample in a store with fluorescent lights might look different at home under

Case Study

tungsten lights. There are also many cases where two colors will match under one light source and be noticeably different under another light source. There is no doubt that light source makes a tremendous difference in perceived appearance.

Observer differences are also very important. The sensitivity of each individual's eyes is not the same. This may be related to the shape of our eye. One person may see blue colors, for example, more vividly than another person. Observer A may see shade changes in blue objects while Observer B may think that they are all the same. The extreme case of sensitivity (or lack thereof) is called color blindness. Here, the individual is not able to see certain colors at all. Age of the observer can also be a factor. Our vision changes as we age, and so does our color perception. Colors are not as sharp and as vivid as they once were.

Size differences can affect how we see colors. Colors covering a large area tend to appear brighter and more vivid than colors covering a small area. This is referred to as "area effect". For example, after looking at small paint samples in a store, many people find that the selected color is too bright when applied to a wall at home. Another example might be the color of coatings on oversized bricks. A multi-color range on standard size brick might be very pleasing to the eye, but the same range on larger units might appear too drastic, like a checkerboard effect. Muting these colors could help to make the range more appealing and lessen the influence of the "area effect".

Background differences are also a source of variation in color perception. This is referred to as "contrast effect". An apple viewed in front of a bright background will appear much duller than if it were viewed in front of a dark background. Another example of this effect would be using different colored mortars with the same brick. Here, the contrast can be used to create different appearances. It should be avoided, however when judging or comparing colors.

Directional difference refers to the angle at which an object is viewed. Looking at an object from a slightly different angle can make it appear brighter or darker. This can be due to texture or grain differences on the surface or to the glossiness of the surface. The angle from which the object is viewed and the angle from which it is illuminated must both remain constant for accurate color measurement and communication.

The conditions discussed in the previous paragraphs are external factors that influence color. There are also some properties of the color itself that we must understand for accurate color measurement and expression. These properties are HUE, LIGHTNESS, and SATURATION, and they are referred to as the attributes of color (Table 2). Hue is commonly related to the tint of an object. It is the quality that lets us describe a color as red, yellow, blue, green, etc. It is how we think of colors in every-day language. Lightness is the term used for the brightness or darkness of a particular hue. It is a separate and identifiable factor and can be measured independently of hue. Colors can be separated into light and dark categories when their lightness measurements are compared. Saturation is the term used to describe the vividness or dullness of a particular hue. Technically, it is the difference in saturation between the color in question and a gray of the exact same lightness. We tend to think of this attribute in everyday language as "how much color is present".

Table 2: Attributes of Color

ATTRIBUTE	DESCRIPTION
HUE	term used for the classification of red, yellow, blue, green (tint)
Lightness	term used for the brightness or darkness of a particular hue
Saturation	term to describe the vividness or dullness of a particular hue

Color Systems and Color Measurement

Considering all the previous factors explains why verbal expression of color is complicated and difficult. Color is a matter of perception and individual interpretation. To overcome these problems, various systems have been developed in the past in an attempt to quantify color and express it numerically. The first of these was the Munsell System developed in 1905 by an American artist, A. H. Munsell. His method utilized a large number of paper color chips of various hues, lightness, and saturations. A specimen color was visually compared to these standards, and the color was described in terms of the standards. This method was later updated to give the current Munsell

Table 3: CIE-LAB-1976

Most popular color measuring system in industry

AXIS	DESCRIPTION
L	Lightness axis
A	Red to Green axis
B	Yellow to Blue axis

System, where any given color is expressed as a letter/number combination after a visual comparison using the Munsell Color Charts.

The International Color Commission (CIE) in 1931 developed a color system based on the tristimulus concept. This concept is based on the XYZ tristimulus values which describe all colors as mixtures of the three primary colors, red, green, and blue. While these XYZ values are useful for defining color, they are not easily related to what we see in the real world. For this reason, the CIE revised its system into two dimensions, independent of lightness. This system still exists and is known as the Yxy System.

In 1976, the CIE developed the Lab System, which is the most used system in the world and the most popular system in the industry. It is a three-dimensional system where the L-axis indicates lightness, and the a and b axes indicate chromaticity or color. The a-axis refers to red in the positive x direction and green in the negative x direction. The b-axis refers to yellow in the positive y direction and blue in the negative y direction. Lightness (L) is on the z-axis and ranges from 0 (black) to 100 (white) (Table 3). Thus, we have a three-dimensional sphere within which all colors will fall. Also, changes in the coordinates of the colors will correspond to those changes that we visually perceive.

The simplicity of the Lab System and its uniformity over the entire color spectrum has made it easy to develop instruments for measuring color. Over the past two decades, both the triaxial colorimeter and the spectrophotometer has become commonplace. The colorimeter measures red, green, and blue light that is reflected by an object while the spectrophotometer measures reflected light over all the wavelengths. In many industries (like the brick industry), the smaller, cheaper, and more portable colorimeter will meet the needs of in-plant quality programs. The instruments have a built-in programmable light source and a measuring head for capturing the reflected light. In effect, they eliminate two of the three variables in a color system and leave only the object as an unknown. Numerical and statistical values can thus be assigned to colors, and the dependence on an individual's eyes for accurate color perception can be eliminated.

Color Control in the Brick Industry

Boral Bricks in Augusta, Georgia, has had great success in reducing color variation and in matching colors using the Lab System and a colorimeter. Plant #3, at this location, makes 13 different bodies ranging in color from red to gray to buff. Their old grading system involved a layout of 2 straps of brick twice a day, visual comparison to a master panel, and the assigning of a shading number to that run (a scale of 1-10 with 1 being the lightest, 10 being the darkest, and 5 being the target). This method involved the Plant Manager, the Sales Manager, and the Inventory Manager. It was time-consuming and often led to inconsistency.

The first step in setting up the new program several years ago was to purchase a Minolta CR-310 colorimeter. This model was chosen as it has a slightly larger measuring head and provides uniform lighting over a 50mm diameter area. This is especially helpful in measuring color on textured samples where measurement errors might occur if a smaller area were used.

Figure 2: Reading the Color of a Production Run

The next step for consistent color control was to develop targets for the various product shades. Using current production runs, old master panels, and existing runs from the inventory yard, targets were established using Minolta Spectra QC software for the 13 product colors, with 3 to 4 shades per product. This process proved to be very tedious and took over 6 months to complete. Once acceptable standards were developed, values were recorded daily from production runs and downloaded into the software to find the best shade match for that run (Figure 2). The best shade match was defined as the target that 50% or more of the individual brick values fell into. The color values for the current production runs were taken from specially selected samples to best represent the range of a given day's production. To select these samples, multiple kiln cars were used as well as multiple locations from each kiln car. About 50 daily samples are collected and taken to a color room for analysis (Figure 3). In addition to the color layout, 100 bricks are selected daily for defect analysis including chippage, cracks, and texture consistency. The color software generates a statistical report for the Plant Manager (Figure 4). A quick daily review can determine trends or problems. This grading process has worked extremely well and has achieved all goals set for accuracy and consistency.

Figure 3: Color Room Layout (Note: Master Display Rack in Background)

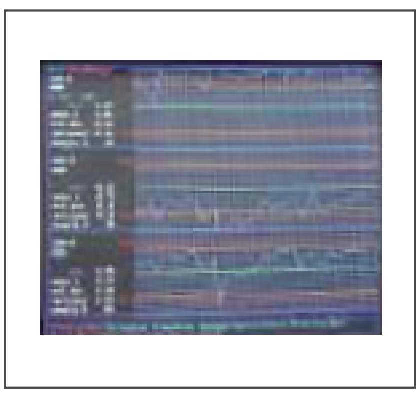

Figure 4: Daily Report on Color

Other areas of use for the colorimeter have been in the color evaluation of both incoming body raw materials and granular surface coatings. Extensive research has been done to develop control charts for the fired colors of kaolins, fireclays, shales, and alluvial clays. As these materials are delivered to the preparation area, samples are taken for laboratory testing. Hydrometer tests are done to check particle size distribution, and extruded bars are made for color and shrinkage evaluation. The color numbers are taken from each of the sample bars and plotted on a control chart (Figure 5). Using a statistically based software package, Statsoft, upper and lower control limits were set using + or – 3 times the standard deviation for the control population. As color control was applied to the incoming raw materials, less color variation was immediately seen in the composite bodies being produced in the plant. The colorimeter has also been used for color evaluation of surface coatings on residential products produced at the other Augusta plants. While inconsistencies in coating application densities in the plants have limited them in recording surface readings from the brick, they have been able to check lab-fired, pre-applied samples with success. They have tested and established color control charts for 35 different sand coatings. This has allowed quality control personnel to stop production on potentially off-color coatings before they are used. About 18 months ago, a program was started in which the colorimeter is used to check incoming bulk coloring agents such as manganese dioxide and red iron oxide (Figure 6). Color control charts were established and used to accept or reject incoming shipments. This procedure has greatly reduced the testing time necessary to evaluate t h e s e materials.

Figure 5: Quality Control of Raw Material

With all of the success using the colorimeter in plant and lab applications, one great challenge still existed. Could it be used in field applications to determine color values from existing structures so that matching brick could be produced? An opportunity presented itself as the First Baptist Church of Augusta prepared for a sanctuary addition in 1999. The original building was built between 1979 and 1984 using Plant 3 modular wire cut 10-828 dark pink body. In the last 20 years, nearly all of this plant's raw materials had changed significantly. The first step was to go to the job site and gather information about where and how the addition would be made. Many colorimeter readings were taken from existing brick in and around this area (Figure 7). These readings were then downloaded into the software for statistical breakdown. This information provided the target with which to match the building. Comparisons were made between this target and the current 828 production runs to see how close the colors matched. The current formula was found to be lighter and less red than the brick on the existing building. Using this data as a starting point, lab bars were made and fired in an electric furnace. Through testing, a formula was chosen to proceed to the next step. Slabs were made on the lab extruder and cut to simulate modular face brick dimensions. These slabs were face set and placed at various locations on a kiln car at Plant 3. They were fired, and the colors evaluated for depth and hue, along with overall range. Several trials were made using similar procedures until a color match was made.

Figure 6: Color Check of a Red Iron Oxide

The new formula was then given to clay preparation for grinding and mixing of a four-car test. These brick were produced at Plant 3 and panels were made to take to the job site for visual inspection. After verifying a match, a ten-car plant run was made using the same formula. A 100-brick job sample was submitted to the contractor. This sample was accepted, and the main production run was made. These brick have since been laid and cleaned, and the addition is slated for dedication this summer (Figure 8). Responses from this match job have been very positive. A similar procedure will be used for an addition to the Radisson Riverfront Hotel and Conference Center on Augusta's River Walk. This job will use Plant 3's modular wire cut 10-935 gray, and trial runs suggest that this project will also be a success.

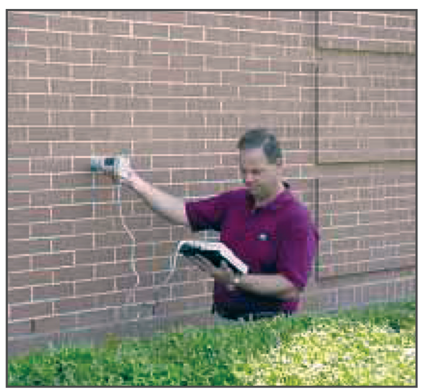

Figure 7: Collecting Data for a Match Job

Other Uses for the Colorimeter

Other applications for the colorimeter in the brick industry have been documented. The colors of slurries and engobes can be monitored by putting a sample of the liquid in a test tube. This tube then slides down into a fixture, and the color is read through an opening in the side of the fixture. This procedure has been used for many years to check the consistency of liquids such as orange juice. With color data and specific gravity readings, control of wet coatings can also be achieved.

The NBRC has used color measurement in both research projects and field complaints. In the study of capture (body) additives to possibly reduce emissions, the maximum addition rates of the additives were established based on color. Decisions could then be made as to whether the additive might be effective without changing the color. Body additions of fluxes, bottom ash, fly ash, etc., can be evaluated in the same way. Also, the addition of recycled process water or effluent water can be tested for effect on color. Color monitoring in these cases can establish standards which can help solve environmental problems without sacrificing product quality and integrity.

The Center has also used color measurement as a tool for helping to explain discolorations or stains on brick. In one particular case, the instrument helped to determine that a

Case Study

clear liquid was the likely source of a problem rather than variation in body additions or faulty cleaning procedures. The list of possible uses for color measurement is as endless in the brick industry as it is in many of the decorative ceramic fields.

Conclusion

With the emergence of new technology in our industry, great strides are being made in the quality of brick produced, from durability to color control. Outsiders often look at the brick industry as being antiquated and virtually unchanged since the early days of time, but through innovative thinking, aggressive plant automation, and strategically planned research programs, the industry is moving into the 21st century by leaps and bounds. We still possess the premier building product, and with the aid of technology like the colorimeter, we can offer the consumer the consistency that they desire.

Figure 8: The Completd Addition with Successful Color Match