COLOUR, ITS MEASUREMENT AND APPLICATION IN ARCHAEOLOGY

Lalchandra B. Tiwari, *Ph.D.(Sc.)*

What is colour?

Colour is a sense, which makes the object more appealing and attractive to the observer. The colour perceived by an observer results from the interaction of a light source, a sample and an observer. An observer perceives colour by detecting light reflected from an object that is imaged onto the retina at the back of the eye. The perceived colour depends on the spectral power distribution (SPD) of the light source, the reflectance of the object and the spectral response of the eye.

Role of light in Colour Perception

Out of the various factors, the most important factor on which the colour depends is the light. If there is no light source, there won't be any colour. In general, colour perception is dependent of the amount of light that enters the eye. The eye is so constructed that the amount of light that enters it is controlled, to a great extent. If the amount of light is too small, we can see no colours, this everybody has recognised during a night time walk. If the amount of light is too large, we are blinded and cannot recognise colours. Besides the light, some of the other factors on which the colour depends are:

- Observer
- Nature of surroundings
- Background of the sample
- Angle of viewing
- Thickness of the sample.

If the same colour is observed under two different illuminants by an observer, it will seem different. Similarly, if the same colour is observed under the same illuminant condition by two different observer, there will be a difference in describing the colour by the observers. This is called as metemerism.

Importance of Colour

Colour not only shows its beauty in nature but also in our daily life colour plays an important role. Our day starts with brown coloured tea or coffee. The decorations of our house make the mind cheerful with suitable choices of wall paints, curtains and furnitures. The dresses we wear should have proper matching to bring decency in our get-up. Proper choices of colours in offices and work places increase efficiency in work. If one have to hide the defect of any material then it can be done by using a proper colour combination. Colour makes the goods more attractive. Groceries packed in attractive colours will always be favoured by the customers.

Why Colour Measurement Required?

Any industrial product is subjected to fixed quality standards. Among other criteria, colour is a decisive one, which is often standardised. The colour quality is checked at the raw material, during production and in the final inspection.

Various industries e.g. textiles, dyes, plastics, paints, pharmaceuticals, foods, agriculture, cosmetics etc., in India have become more conscious of measurement of colour parameters of their products and approaching us for calibration of colour measuring instruments used by them. This demand is increasing year by year particularly due to increase in export potential of Indian goods on account of economic liberalisation. The industry has become more conscious of quality due to increase in competition in the global market where quality is the main yardstick to judge the commodity.

The artist and the scientist differ in understanding of colours because the artist is mainly concerned with producing colour combinations, using existing paints to make an art very pleasant and live, while the scientist is related to both the synthesis of dyes and pigments and obtaining various shades using colour combinations. The scientist analyses the existing colour, its causes and consequences and measures and expresses it in definite terms.

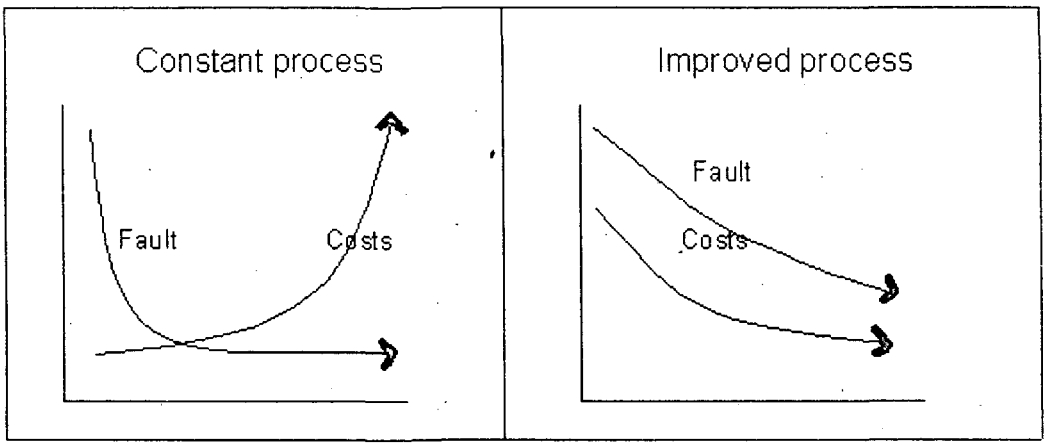

Fig.1 : Correlation between faults and costs

Figure1 shows the correlation between faults and costs. In constant processes (left) a reduction of faults raises the costs. If the producer decides to make improvements of production (right) not only the number of faults will decrease, but also the costs involved.

Colour checks are required in all sectors of industry and for a whole variety of products.

In the modern technology, the problem of colour measurement is very important and essential. The science of colour has been developed in terms of CIE system and tremendous advances have been made in the techniques of colour measurement mainly due to the advent of spectrophotometers and computers. The 1976 - CIELAB colour space is the most widely used method for measuring and ordering the object colour. At present many advanced and sophisticated computer colour matching techniques have been developed.

Importance of colour measurement : In Food industry, coffee is one of the most popular beverages. Every brand requires a certain roasting time to obtain the desired roasting degree and hence the taste. The defined roasting time is controlled by means of a given roasting colour. If the beans become too dark, the coffee will taste bitter and the beans shrink. In this case, more beans will be required to reach the prescribed net weight. In this case, colourimetry saves cost and maintains quality. Similar examples are – milk powder, tomato ketchup, ice cream, fruit juices, flour etc.

In Automobile industry, colour producers, car manufacturers and repair shops defines hues and agree upon colour tolerances. In this case, colours are measured to match touch-up; colours for repaired cars to the entire satisfaction of the car owner. This is the problem especially for ageing cars. What is more the clients have become much more exacting in the past few years, accepting only the best quality. Hence the spray shop, the car owner and the insurance company must be furnished with a means to decide whether the agreed tolerances e.g. for a repaired car are observed.

The above examples for Automobile and Food production are true for all sectors of industry. To come out from these problems, colour measurement is necessary.

How colour is converted into CIE 1976 (L*a*b*)?

The energy is radiated from the source and strikes the object out of which some gets absorbed and some gets reflected or transmitted from the surface of the object. Most of the object gets reflected or transmitted from the surface of the object.

Now, from the reflected light, the reflectance can be measured by using the formula,

$$\text{Reflectance} = \frac{\text{Reflected Light}}{\text{Incident Light}}$$

From the reflectance of the object, the Tristimulus values XYZ can be calculated by using the formula,

$$X = \sum_{\lambda=400}^{700} x_\lambda R_\lambda S_\lambda \; ; \quad Y = \sum_{\lambda=400}^{700} y R_\lambda S_\lambda \; ; \quad Z = \sum_{\lambda=400}^{700} z_\lambda R_\lambda S_\lambda$$

Where,

x,y &z ➡ colour matching functions (i.e. the spectral response of the eye);

R ➡ reflectance of the object;
S ➡ SPD of the light source,
λ ➡ Wavelength, and

X,Y and Z represents Red, Yellow and Blue respectively.

By using the Tristimulus values, the colour is specified in (Y,x,y) mode in CIE 1931 system, where x, y, z are the chromaticity coordinates as given below,

$$x = \frac{X}{X+Y+Z} \; ; \quad y = \frac{Y}{X+Y+Z} \; ; \quad z = \frac{Z}{X+Y+Z}$$

And Y is brightness factor.

From the Tristimulus values i.e. X, Y, Z, CIE 1976 (L*a*b*) can be calculated,

$$L^* = 116(Y/Y_n)^{1/3} - 16$$

$$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}]$$

$$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]$$

where, X_n, Y_n and Z_n are the Tristimulus values for a particular standard illuminant and observer.

In the equations L* indicates the lightness and darkness of the sample, a* indicates whether the sample is redder or greener and b* indicates the bluer and yellower nature of the sample as shown in Figure2.

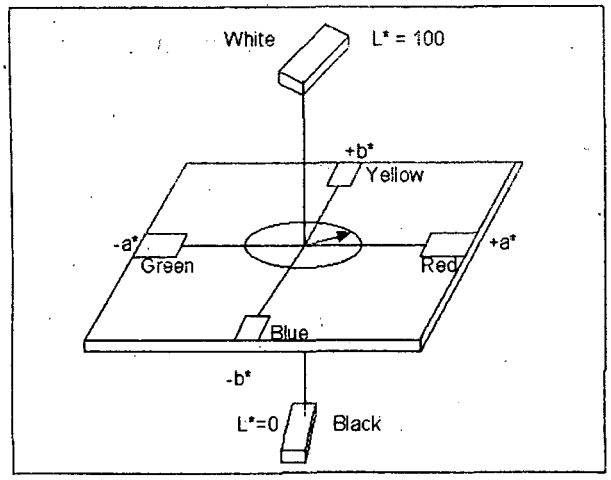

Fig.2 : CIE 1976(L*a*b*) colour space

Colour in Archaeology

Applications of Colour Science and Technology in the fields of Textiles, Dyes, Plastics, Paints, Pharmaceuticals, Cosmetic Industries have been carried out in the Applied Physics Laboratory, U.D.C.T. For the first time, the application of a colour measurement has been extended in the field of Archaeology.

Recording of the colour of sculptures, paintings and miniatures and the changes which take place seasonally, with climatic changes and with time are an important aspect of this work. In the field, this is mostly done from colour charts, but these must be related colorimetrically to something more permanent and this will usually lead to plotting on the chromaticity diagram. The keeping of specimens of such materials in a museum is unsatisfactory from the colour point of view, as this will change where pigmentation is involved, so records of original colour are required.

The preservation of paintings presupposes not only a clear understanding of the artists' methods and materials, but also the behaviour of these materials under varying conditions of humidity and temperature. The step in the chemical conservation of paintings is, therefore, the study of the methods and materials employed in their execution.

The preservation of oil paintings and miniatures is equally complicated, but being portable they can be kept in museums under controlled conditions of humidity and temperature. It is therefore, necessary to bear in mind the fundamental difference between preservation of paintings in museums, where relative humidity and temperature can be controlled and the preservation of paintings in monuments, where no such control is practicable.

The most favorable environmental conditions for proper preservation of paintings are an average temperature of 20°C with only minor fluctuations, a relative humidity of 60%, effective ventilation for preventing stagnation of moist air and freedom of air from dust and other impurities.

Damage due to fungus is a very common feature of Indian wall paintings as well as sculptures. The fungal growth is encouraged by high humidity and unless the monuments are absolutely watertight, seepage of rainwater into the interior not only results in damage to plaster, but it also encourages fungal growth on painted surfaces. Formaldehyde and thymol have been found to be effective in eradicating the fungus.

In **Tambekarwada, Vadodara**, for elimination of the varnish layer from the painted surface, ethyl alcohol and acetone were found to be satisfactory. Butyl alcohol and sulfuric ether were also put to some use. A touch of ammonia in ethyl alcohol was found effective in the regeneration of the blue colour, which had become very dull. Turpentine was brought into use to prevent the running of colours. On painted surfaces, where the solvent action of the above named chemicals was not satisfactory for the removal of varnish, methyl alcohol was found to be effective. The treatment has resulted in the regeneration of all odd colours in their original brightness.

In **Bagh Caves**, Cave No. 2, the paintings were practically invisible through a thick layer of smoke and tarry and fatty accretions. Chemical treatment of the paintings involved applications of 10% solution of ammonia in rectified spirit. This softened the smoke to some extent and made possible its partial removal with the help of absorbent cotton soaked in spirit. A mixture of 1:10 triethanolamine and butyl lactate was then applied to the painted surface. With the help of this cleansing mixture, the effect of which was greatly accelerated by the addition of 10-20% water, the smoke was dissolved away into a thick black emulsion, which had to be eliminated from the painted surface with copious amounts of rectified spirit. The treatment of these paintings has been an extremely laborious and time-consuming process; it has, however, brought to light many panels. After this successful treatment, some of the treated paintings have suffered considerable deterioration, due to the ingress of rainwater. Suitable measures of structural conservation have to be taken for the stoppage of percolation of water into the painted caves.

In **Badami Caves**, the paintings, surviving in patches only, were found covered with dust, dirt and incrustations of various kinds. They had been preserved in the past with shellac and vinyl acetate, and thick coats of hard thus formed on the paintings. The famous panel, depicting the betrothal of Siva and Parvati, also survived in patches only and most of the pigments, pink, red, green, yellow, blue, black, brown and white were lost. The old preservative was easily removed with a mixture (2:1) of toluene and methylated spirit. The removal of dust, dirt etc., was successfully carried out with a mixture (2:1:2) of butyl lactate, toluene and butyl alcohol. For red and green colours, which were hidden under layers of incrustations, benzene and acetone were found effective. The surviving remains of these highly fragmentary paintings have, however, been preserved and the pigments protected from further deterioration.

In **Ajanta Caves**, the paintings, which are on mud plaster, finished with a thin layer of limewash, on the walls and ceilings in this group of caves, were found covered with accretions, on the walls and ceilings in this group of caves, were found covered with accretions like soot, oil, cobwebs, insect nets and insect cocoons. These accretions had accumulated through long neglect. With the passage of time, the oily accretion become hard and it cemented other accretions to the painted surface.

The above chemicals are effective or not, it can be found by using the colour measurement techniques. In the present investigation few places like Tambekarwada, Vadodara; Bagh Caves; Badami Caves; Ajanta; Ellora; Khajuraho and other archaeological places are included to transform the colour of paintings to colour parameters of CIELAB Colour Space and CIE System of colour measurement, and also fading phenomena and remedies for preservations etc.

Application of colour measurement in Archaeology will begin by recording the colour of different glasses at the Rajabai Tower of University of Mumbai after getting the necessary permissions from the University authorities.

Acknowledgement: I am thankful to Dr.K.L. Mankodi, Director-Research Studies, Franco-Indian Pharmaceuticals Ltd., Worli, Mumbai, for his encouragement and cooperation.

References:

1. Judd D.B., Wyszecki G., *Colour in Business, Science and Industry*, John Wiley and Sons, Inc 1975.
2. Wright W.D., *The measurement of colour*, Hilger & Watts Ltd.
3. Billmeyer Jr. F.W. and Saltzman Max, *Principles of Colour Technology*, John Wiley and Sons.
4. Roderick McDonald, *Colour Physics for Industry*, Second Edition, The Society of Dyers and Colourists 1997.
5. Chamberlin G.J., Chamberlin D.G., *Colour its Measurement, Computation and Application*, Heyden & Son Ltd. (1980).
6. Gangakhedkar N.S., *Understanding Computer Colour Matching*, Rutu Prakashan 1991.
7. Tiwari L.B., *Instrumental Colour-Match prediction*, M.Sc.-II project, U.D.C.T., 1998-99.
8. Lal B.B., *Preservation of Mural Paintings*, **83-88**, Ancient India 1962.
9. Anni Berger-Schunn, *Practical Colour Measurement*, John Wiley & Sons, Inc. 1994.
10. Heinrich Zollinger, *Color A Multidisciplinary Approach*, Wiley-VCH, 1999.