THERMAL DEGRADATION OF ENAMEL PAINT COATING ON CEMENT PLASTER

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ABSTRACT

The effect of temperature on the stability and visual color of enamel paint on cement plaster is evaluated through light intensity ratio of three primary colors (RGB). The painted cement plaster is isochronally heated in an electric resistance furnace at different temperatures for one hour. Up to 100°C the original color of the plaster samples remains more or less unchanged which are observed through optical image analysis. Again, thermal degradation of the samples becomes evident in color when they are heated beyond 200°C and at 350°C the color becomes already burned. The microstructural images of the samples at room temperature show fine and uniform grains. But at higher heating condition the microstructure of the sample is characterized by coarsening grain. The color of the heated samples are then studied through tristimulus color 'L*', 'a*' and 'b*' values which were analyzed and evaluated in MATLAB software. The results show that after 200°C the hunter 'L*' value starts to decrease greatly up to 250°C. The hunter 'a*' value shows an increasing trend up to 100°C and then begins to decrease until 200°C. After 200°C the same increasing character is showed till 300°C. The change of hunter 'b*' value remains insignificant up to 100°C and shows decreasing trend between 100°C-250°C range and an increase after 250°C up to 300°C. It is graphically shown that the proportion of all three colors decreases with the increasing temparature. The overall change of color occurs with increasing heating temperature due to moisture releasing, chemical changes and thermal degradation simulteneously.

Keywords: *Color, cement plaster, thermal degradation, tristimulus values, microstructure.*

1. INTRODUCTION

Enamel paint is a type of paint that air-dries to a hard, usually sheeny finish, used for coating surfaces that are outdoors or otherwise subject to hard wear or variations in temperature [1, 2]. For its availability, easy application, high durability and wide range of color variations enamel paint is frequently used on plasters, concrete, woods, metals etc. There are different types of enamel paint available to serve different purposes but generally 'Floor Enamel' paint is used in case of plaster, concrete, stairs, basements, porches, patios etc. Generally, dehydrated castor oil, titanium dioxide, colophony resin ester, anti-oxidants, zinc oxide, proprietary complex driers etc. are the main components of enamel paint [3, 4]. Usually enamel paints are applied with oil or water on the surface. A basic advantage of enamel paint is that it can dry quickly in exposed environment. The final output provides a lot smoother finish with little glossiness which depends on the oil content of paint. Though oil-based enamel paint takes a longer time to dry, it provides a long-lasting finish. Thus, enamel paint coating can last for many years. It is mildew-resistant and can be frequently washed if it gets stained. Moreover, the paint coating can resist the effect of high temperature on the material surface up to a certain temperature. At higher temperature certain physical changes on the coating can be noticed more specifically the change in colors of the material. The gradual changes of color can be identified using several parameters. The 'CIELAB' color space is one of them. It expresses color as three values. Those are 'L^*',' a^* 'and 'b^* '. L^* indicates the lightness from black (0) to white (100). Similarly, a^* indicates changes from green (−) to red (+), and b^* indicates from blue (−) to yellow (+). CIELAB was designed so that the same amount of numerical change in these values corresponds to roughly the same amount of visually perceived change [5, 6].

In the present paper, the thermal degradation of enamel paint coating over cement plaster is examined using simple optical images and microstructures of the samples. The thermal degradation is analysed by detecting the change of color of the composite samples subjected to isochronal heating at temperatures ranging from 25°C (room temperature) to 350°C for a period of one hour. The potential of the method is then verified through the visual color change as well as microstructures of the samples.

2. METHODOLOGY

Cement and sand are mixed into 1:3 ratios to produce the plaster samples. The dimension of plaster sample is 50 mm x 50 mm x 50 mm and six samples of same dimension are taken. All the samples are painted with white enamel paint on one particular surface. The samples are kept one day for drying. After drying the plaster samples are heated isochronally. An electric furnace is used for thermal treatment of the plaster samples. Heating is applied on different samples at room temperature (25°C) to 350°C range for one hour. Samples are tested for various physical and optical properties after coming into natural temperature.

The images of the heated samples are taken with DSLR camera for examine the visual changes. The optical micrographs of the samples are also taken with USB digital microscope for grain size analysis. The images of the samples are analysed through MATLAB software for determining the tristimulus color parameter L*, a* and b* values. The changes of these values with respect to temperature changes are shown graphically. The changes in proportion of the basic color red, green and blue with respect to temperature changes are also shown graphically. Figure 1 gives an idea about the setup of the experiment carried out for this study.

Figure 1: Experimental setup, a) plaster samples, b) enamel painting, c) electrical furnace and d) heated samples

3. RESULTS AND DISCUSSIONS

For analysing the thermal degradation of the plaster samples, all six specimens were isochronally heated at different temperatures for one hour and the corresponding optical images were recorded, which are shown in Figure 2. The images show that, the samples are thermally affected when they are heated with increasing temperature. But up to 100°C no significant change is found. After 100°C the color change is noticeable and it is because of the evaporation of water molecules from the paint. After 200°C the color has changed drastically because of the chemical change of paint ingredients [7]. Finally, at 350°C the sample got burned and the paint layer came out from the plaster.

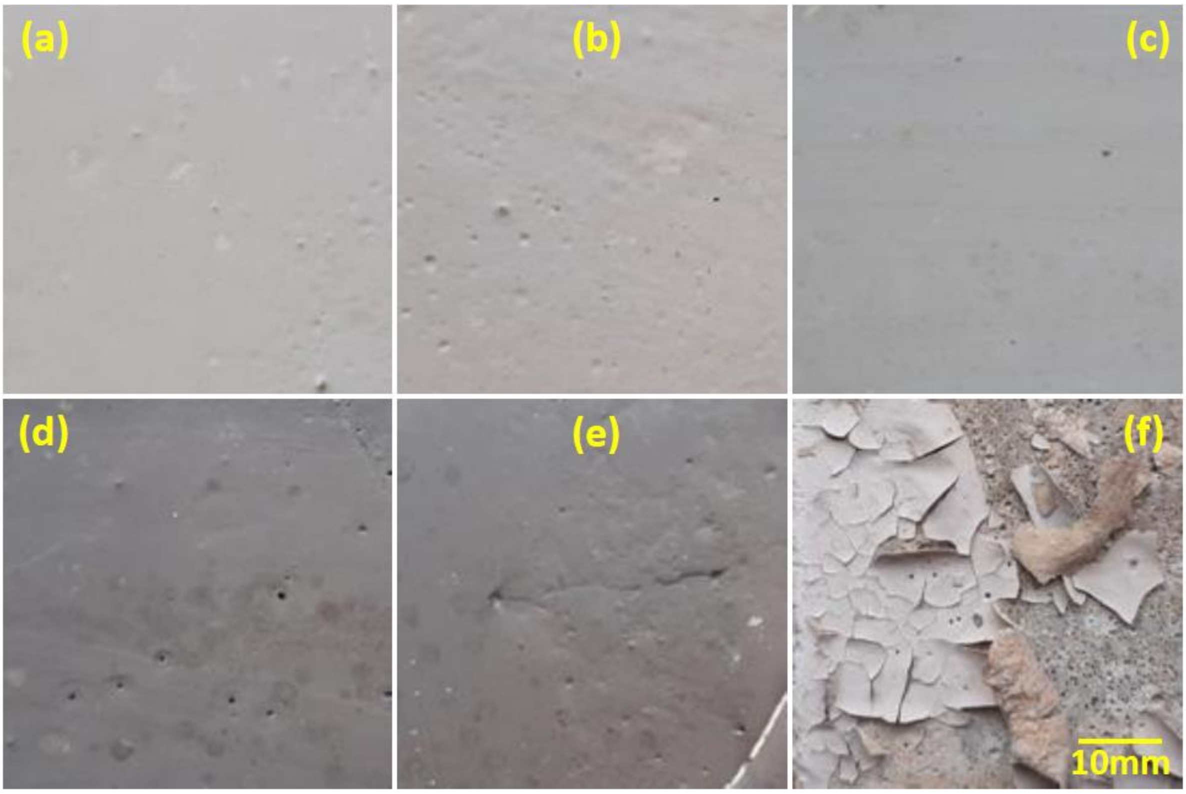

Figure 2: Change of color of different plaster samples after heating at different temperatures for 1 hour, a) 25°C b) 100°C, c) 200°C, d) 250°C, e) 300° and f) 350°C

The microstructures of the samples are taken for grain analysis which is shown in Figure 3. The change in grain sizes also remains insignificant up to 100°C. Because of the evaporation of water molecules, the grain size becomes thicker after 100°C and changes drastically after 200°C due to the chemical change of carbonaceous materials of paint [8]. At 350°C the microstructure defines total burning structure of the coating layer.

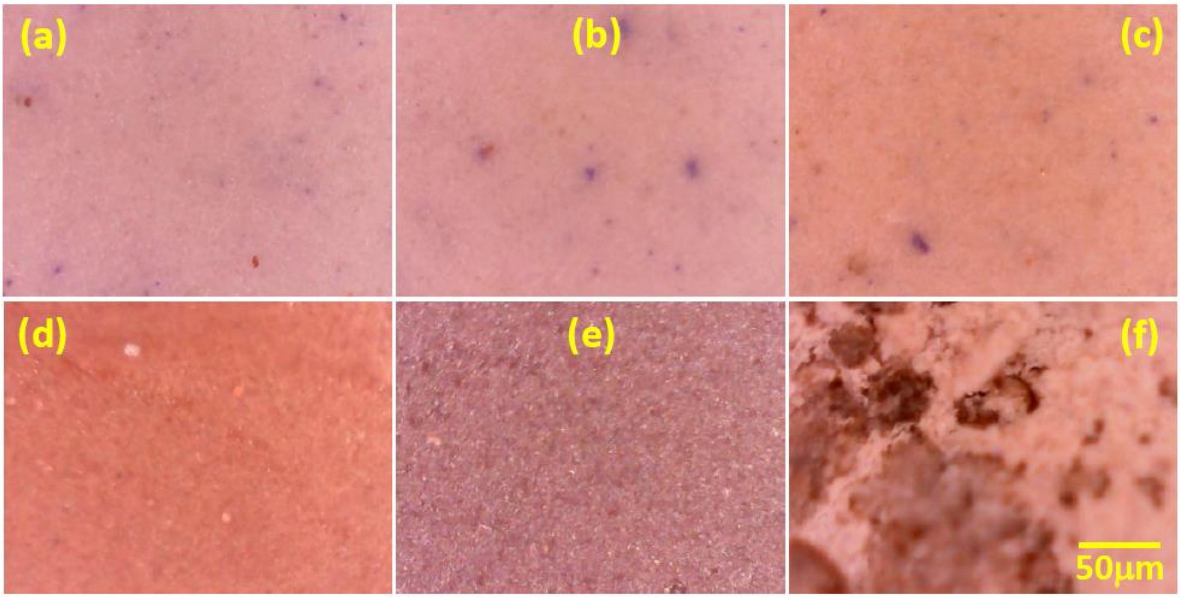

Figure 3: Optical micrograph of color of different plaster samples heated at a) 25°C , b) 100°C, c) 200°C, d) 250°C, e) 300°C and f) 350°C for one hour.

The color change of the samples are examined by tristimulus colour parameter ‘L*’, ‘a*’ and ‘b*’ values. The graphical representations of change of these values are shown in Figure 4. The ‘L*’ value vs heating temperature graph shows that up to 200°C there is a small decrease in ‘L*’ value. After 200°C the value starts to decrease greatly up to 250°C and then shows a slight increase from 250°C to 300°C. The ‘a*’ value vs heating temperature graph indicates the increase of ‘a*’ value up to 100°C and then a significant decrease up to 200°C and then again shows an increase with a large slope till 250°C and finally with a smaller slope till 300°C. The change of ‘b*’ value remains insignificant until 100°C and then shows a decreasing behaviour up to 250°C and finally increases from 250°C to 300°C range before the samples got burned. It seems to be increase in darkness by the heating effect. Because of the heating effect the color of the samples begins to get darker and so the portion of relatively darker colors like black, red and blue increases. Especially in 200°C to 250°C range the change in color becomes evident and thus the changes in ‘L*’, ‘a*’ and ‘b*’ values have occurred with a larger slope. Here, decrease in ‘L*’ value indicates increase of black portion. Similarly, the increase of ‘a*’ value and decrease of ‘b*’ value indicates the increase of red and blue portion respectively.

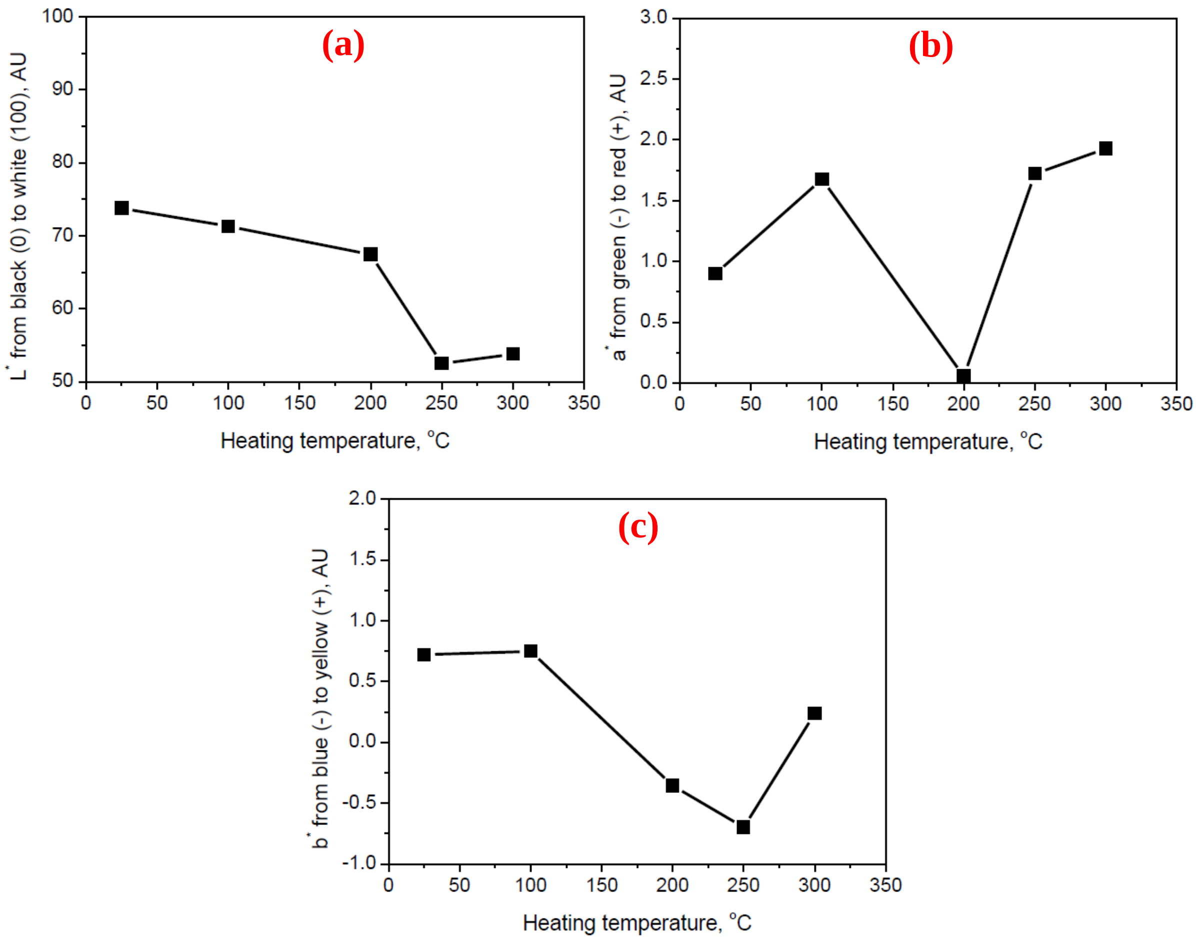

Figure 4: Change of color of plaster samples after heating at different temperatures for one hours, a) L* , b) a* and c) b*

The proportion of three basic colors (Red, Green and Blue) with respect to temperature changes are shown graphically in Figure 5. The red color proportion shows a decreasing trend with a smaller slope up to 200°C and then decreases drastically till 250°C. Finally, it shows a slight increasing trend from 250°C to 300°C before getting burned. Similarly, the Blue and Green color proportion also show almost the same pattern. It happens because when the samples are heated the proportion of black color (black color indicates the absence of other colors) increases as the samples tend to be burned. Thus, the proportions of all three colors begin to decrease [9].

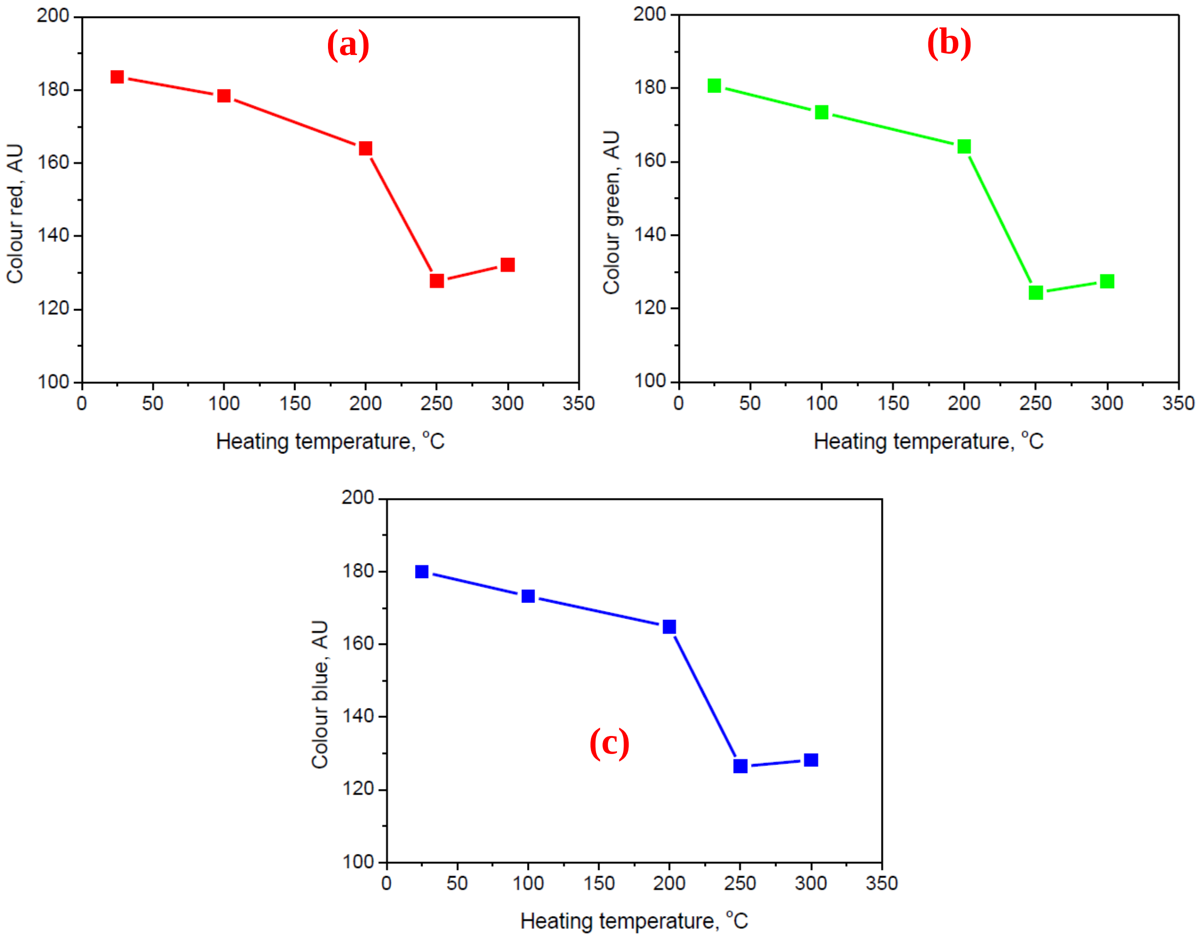

Figure 5: Change of color of plaster samples after heating at different temperatures for one hours, a) Red , b) Green and c) Blue

4. CONCLUSIONS

To achieve an approximate idea of safe temperature of enamel paint coated cement plaster in terms of heating as well as thermal degradation is the main contribution of the study. A simple visual inspection method is applied to analyse the thermal degradation of the plaster samples. Particularly, the degradation is analysed based on the change in color of the optical images of the samples taken after every thermal treatment performed at a certain interval of temperature. No significant change in color of the images is observed up to the heating performed at 100°C. It is because only after 100°C the water molecules from the painted surface begin to evaporate. After 200°C the changes become more noticeable as the carbonaceous materials of paint start to be changed chemically. When the samples are heated at 350°C the enamel coating on plaster is burned completely as reflected in corresponding colour of the sample images. The microstructure analysis also shows the coarsening of grains with increasing temperatures. Finally, the variation of tristimulus colour parameters indicates the effect of significant increase of darkness after heating beyond 200°C. The proportion of combination of three basic colors (RGB) also decreases with increasing temperatures and thus it is very much correlational with the visual examinations.

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