DETERMINATION OF COLOR HOMOGENEITY BY IMAGE PROCESSING IN CEMENT BASED MORTARS

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With the development of computer technologies in recent years, the usage of image processing techniques in different areas have significantly increased. Image processing is the computer study for altering the measured or saved digital image data in a manner to fit for a purpose in an electronical media. In this study, by adding red iron oxide pigment (RIOP) into cement mortars in 2%, 4%, 6% and 8% ratios, physical and mechanical characteristics of the mortars were analysed, and color homogenization of them were determined by image processing method. On the manufactured samples, consistency, density, water absorption, porosity, compressive strength, flexural strength tests and image processing analysis by open source coded ImageJ programme were performed. Also, SEM-EDS analyses were performed in order to determine the inner structure characteristics of the samples. As a result of this study, changes in physical and mechanical characteristics of the mortars have been observed in different ratios. When it is desired to obtain a red colored mortar, it is determined by image processing analysis that 6% of red iron oxide pigment (RIOP) addition to the mortar mixture would give the optimum result.

Keywords: *Color Concrete, Image Processing, Microstructures, SEM-EDS*

1. Introduction

Concrete is the most popular construction material as it is durable, has a long-lasting life, doesn't corrode, behaves more stable against fire and is recyclable and sustainable. Colored concretes for decorative purposes can be produced by using white cement and different kinds of color pigments. Concretes produced by this way are also called as architectural concretes.

Besides the workability, strength and durability characteristics expected from a normal concrete, aesthetic concerns are also important in colored concrete production. In colored concretes, characteristics such as the effect of pigments on the setting of the cement, color constancy of pigments, resistance of pigments to medium conditions, effect of pigments on mechanical characteristics, heat resistance of pigments and water soluble salt amount of pigments have become more important[1].

In recent years, different image processing techniques are more commonly used in concrete technology. Nowadays, by the improvements in computer based technologies, many processes could be simplified and performed in a shorter time. Thus, applications such as image processing and digital image analysis methods are getting more popular [2]. As a natural consequence of the increase in usage areas of image processing techniques, these techniques have been investigated thoroughly and have found many application areas in the industrial areas. By using image processing methods, digitizing and processing the images could be performed without any error. Image processing is the computer study for altering the measured or saved digital image data in a manner to fit for a purpose in an electronical media.

A digital image is defined as [m; n] in a 2D limited area. Coordinates of pixels are [m; n], here, m, n are whole numbers. A (x; y) function is a function of a number of variables. Depth of color is shown with color (z) and time (t) [3]. When literature is searched, it is observed that application of image processing techniques on colored concretes are limited. It has been observed that performed studies were generally about examination of color stabilization of colored concretes that were exposed to different environmental effects [4, 5], using a methodology based on CIELAB color space to define the color and limits based on formulas to obtain the color difference and homogeneity in cement mixtures, and determination of required number of tests[6], determination of colors of concretes which were exposed to fire by spectrophotometer, [7] and evaluation of concretes that were damaged by fire by using the image processing technique [8].

In this study, color analysis were made by the image processing method based on the hypothesis that the more the red pigment ratio that the colored mortars contain, the more intense the mortar colors would be. For this purpose, experimental studies were performed on mortars obtained by adding red iron oxide pigment (RIOP) into white cement in 0% (Ref), 2%, 4%, 6% and 8% ratios. Consistency test was performed on fresh mortars while density, water absorption, porosity, compressive strength and flexural strength tests were performed on hardened mortars. Also, red

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color percentage was determined by image processing technique and inner structure characteristics were determined by scanning electron microscope (SEM-EDS) analysis.

2 Material and Method

2.1 Material

Aggregate: In preparation of mortar mixtures, CEN standard sand which was in accordance with TS EN 196-1 [9] standard was used. Standard sand was manufactured by Pınarhisar Limak Cement Factory. Sieve analysis of sand is given in Table 1.

Table 1

CEN Standart Sand Sieve Analysis

Square-Mesh Size(mm)	Cumulative Retained Material (%)
2.00	0
1.60	7 ± 5
1.00	33 ± 5
0.50	67 ± 5
0.16	87 ± 5
0.08	99 ± 1
2.00	0

Cement: White Portland Cement produced in accordance with TS EN 197-1 [10] standard was used. Chemical and physical analysis of cement is given in Table 2.

Table 2

Chemical, physical and mechanical characteristics of white cement.

Chemical Characteristics	Value *(%)*	Physical Characteristics	Value
SiO_2	21.60	Specific Weight, g/cm^3	3.05
Al_2O_3	4.05	Specific Surface Area, cm^2/g	4570
Fe_2O_3	0.26	Whiteness	0.87
CaO	65.70	Start of Setting, min.	105
MgO	1.30	End of Setting, min.	135
SO_3	3.30	Volume Constancy, mm	1.00
Na_2O	0.30	**Mechanical Characteristics**	**Value *(N/mm^2)***
K_2O	0.35	Compressive Strength on 2nd Day	37.40
Free CaO	1.60	Compressive Strength on 7th Day	48.80
Chloride	0.01	Compressive Strength on 28th Day	59.70
Loss on Ignition	3.20		
Undissolved Residue	0.18		

Red Iron Oxide Pigment (RIOP): Iron oxide pigments are composed of oxides, and hydrates of oxides at different valency levels. They are differentiated as natural and synthetic as per manufacturing method. Compared with natural ones, synthetic ones are used more often. This is supported by large amount of colorants in synthetic type and low-cost pigments [11]. Iron oxides have got a large color range. In this study, red colored iron oxide pigment shown in Fig 1 was used.

Fig. 1 - Red Iron Oxide Pigment (RIOP)

Water in the Mixture: Düzce Municipality Konuralp Region municipal water was used in preparation of mixtures.

2.2 Method

Mixture Design: Test samples were prepared under laboratory conditions where the temperature is 20±2 ºC and relative humidity is 60%±5 in accordance with TS EN 196-1 [9] standard. Mixture Design is given in Table 3.

Table 3

Mixture Design

Sample Amount *(g)*	*0% (Ref)*	*RIOP-2%*	*RIOP-4%*	*RIOP-6%*	*RIOP-8%*
Cement	450	450	450	450	450
Water	225	225	225	225	225
CEN Standard Sand	1350	1341	1332	1323	1314
Red Iron Oxide Pigment	0	9	18	27	36

Prepared colored mortars were poured into moulds with 40×40×160 mm size and exposed to shocking and spreading process as it would make 60 drops in a minute on cement flow table. Also, cubic samples in 50×50×50 mm size were tapped on the concrete flow table. After shocking and spreading process, samples were covered with glass plates and were kept for 24 hours in a humidity chamber where relative humidity was 95%. Samples taken out at the end of that period were kept under water curing until the test day.

Determination of Consistency of Fresh Mortar: Consistency of the obtained mortars were determined in accordance with TS EN 1015-3 standard [12].

Density: Density values for produced 50×50×50 mm sized samples were determined in accordance with TS EN 12390-7 standard[13].

Water Absorption: Water absorption values of samples were determined in accordance with ASTM C1585 standard [14].

Porosity: Porosity values of prepared colored concrete samples were determined in accordance with ASTM C1585 standard [14].

Compressive and Flexural Strength: For compressive and flexural strength test, from each mixture 3 samples of 40×40×160 mm prismatic and 50×50×50 mm cubic mortar samples were produced in accordance with TS EN 196-1 standard. On cubic samples compressive strength test (for 7 and 28 days), and on prismatic samples flexural strength test (for 28 days) were performed in accordance with TS EN 196-1 standard[9].

Image Processing: In this study, samples of about 40×50 mm surface area were taken from colored mortar samples which were freshly prepared with 2%, 4%, 6% and 8% of red iron oxide pigments for image processing. To obtain the digital images of hardened samples a setting with a tripod, Canon EOS700D digital camera, product filming tent and led lights was constructed. With the help of the constructed setting, surface images with jpg extension in 4272×2848 pixel size which were in RGB color mode were obtained. All images of the mortar samples were taken at the same height from the sample surface and under the same lighting medium.

Analyses were performed by using the open source coded ImageJ programme on obtained images. Process steps of the analyses are given in Fig. 2.

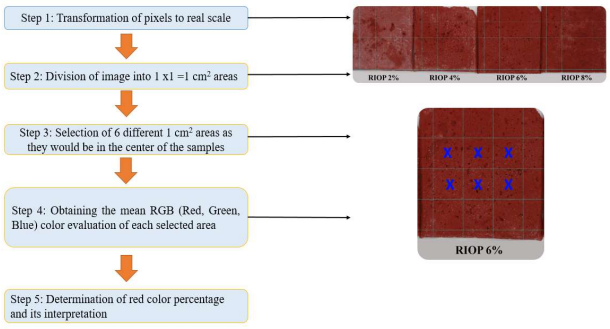

Fig. 2 - Process Steps

The percentages of the red value from the numerically obtained values were calculated using Eq. (1).

$$Red\ \% = \frac{R_{Mean}}{R_{Mean}+G_{Mean}+B_{Mean}}\ x\ 100 \qquad (1)$$

In this equation R_{Mean} is the average red value in an image, G_{Mean} is average green value in an image and B_{Mean} is average blue value in an image, Red % is the percentage of red value [2].

Scanning Electron Microscope (SEM-EDS): Scanning Electron Microscope (SEM-EDS) analyses were performed on specimens taken from samples after 28 days in Düzce University Scientific and Technologic Investigations, Application and Research Center. For SEM images of samples "FEI Quanta FEG250" instrument was used.

3. Findings

Results for flow diameter, density and water absorption obtained from the samples in the study are given in Table 4.

Table. 4

Flow Diameters, Density and Water Absorption Ratio

Materials	*0% (Ref)*	*RIOP-2%*	*RIOP-4%*	*RIOP-6%*	*RIOP-8%*
Flow Table *(mm)*	123.5	127.0	132.0	131.5	129.0
Density *(kg/dm³)*	2.19	2.14	2.16	2.15	2.16
Water Absorption *(%)*	10.0	9.3	9.0	8.7	8.7

When the consistency test results were examined, it was found that the flow diameters were obtained between 123.5 mm and 132 mm. According to the flow diameter of the reference sample, it was determined that red iron oxide pigments had positive effect on processability of mortars when their ratio was up to 6% and the processability started decreasing when this ratio was over 6%. It was observed that the density of the obtained samples were between 2.14 and 2.19 (kg/dm³). The density of the red iron oxide pigment added samples have decreased in comparison with reference sample. When water absorption ratios were examined, compared with 0 % (Ref) samples, it was observed that red iron oxide pigment addition has decreased the water absorption ratio.

In accordance with TS EN 196-1 standard, the flexural strength values for samples after 7 days and 28 days are given in Fig. 3 and 4, respectively [9].

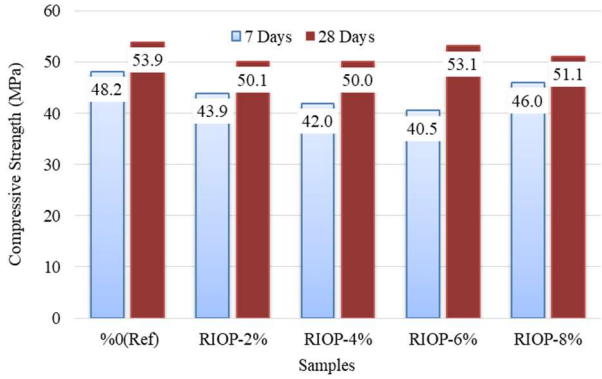

Fig. 3 - Mean Compressive Strength Results

When Fig. 3 is examined, it was observed that for samples after 7 days, the minimum compressive strength was obtained from RIOP-6%

samples, while the maximum compressive strength was obtained from 0%(Ref) samples. When red iron oxide added samples (2%, 4%, 6%, 8%) were compared against 0%(Ref) samples, it was determined that their compressive strength values after 7 days have decreased by 9% , 13%, 16% and 5%, respectively. When the compressive strength values of samples after 28 days were examined, it was observed that minimum compressive strength was obtained from RIOP-4% (50 MPa) samples, while the maximum compressive strength was obtained from 0% (Ref) (53.9 MPa) samples. When all batches were examined, it was observed that the compressive strength values increase in line with the increasing cure period. When other batches were compared against 0%(Ref) samples, it was determined that their compressive strength values after 28 days have decreased up to 7.2%. In this case, it is considered that the addition of red iron oxide pigment (RIOP) had a negligible effect on compressive strength values.

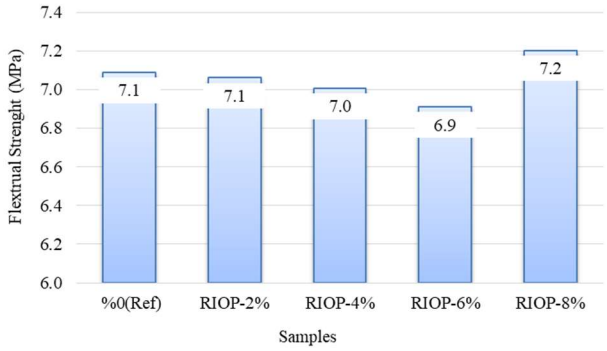

Fig. 4 - Mean Flexural Strength Results

Flexural Strength values have decreased for mixtures that were added 2%, 4% and 6% red iron oxide pigment compared with the sample that was added 0%(Ref) red iron oxide pigment. However, this value showed increase for mixtures that were added 8% red iron oxide pigment. It was observed that the maximum flexural strength value was 7.2 MPa (RIOP-8%) and the minimum flexural strength value was 6.9 MPa (RIOP-6%). Here, it is considered that the addition of red iron oxide pigment has a negligible effect on flexural strength values.

3.1.Image Processing

Red% values obtained from image processing are given in Fig. 5 with the related standard deviations.

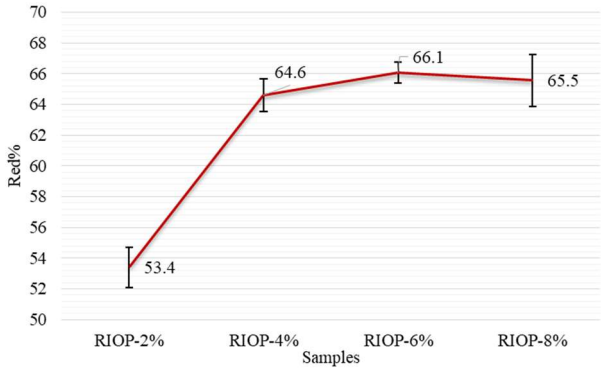

Fig. 5 - Image Processing Analysis Graph

For each batch, mean red percentage values obtained as a result of image processing analysis made on 6 different 1 cm^2 areas were determined as 53.4%, 64.61%, 66.07% and 65.55%, respectively (Figure 5). Standard deviations for these values were 1.32, 1.06, 0.67 and 1.69, respectively. When standard deviations were taken into account, it was observed that the values were low. According to the available data, it can be said that the color distribution in each cm^2 were very close to each other and in other words there was a homogeneous distribution. It was found that the amount of added red iron oxide pigment could be used up to 6% for the samples to get the red color. It is considered that red color reaches the optimum point in values up to 6% and addition of oxide dye over 6% has no effect on changing the colors of the samples.

SEM-EDS results obtained for determination of inner structure characteristics are given in Fig. 6.

In the SEM-EDS analysis performed for determination of inner structure characteristics of the samples (Fig. 6), it was observed that the inner structure had a few porous and vitreous structure. Also it was determined that there were hydrated phases as C-S-H and ettringite. Although the densities of red iron oxide pigment (RIOP) added samples were low, it was observed in SEM analysis that it filled up the pores due to its fine particulate structure.

4. Results and Recommendations

In this study, not only the effect of the addition of red iron oxide pigment in different ratios (0%, 2%, 4%, 6%, 8%) on physical and mechanical characteristics of cement mortar is examined, but also Red% values have been determined by image processing. Results obtained from the study are given below.

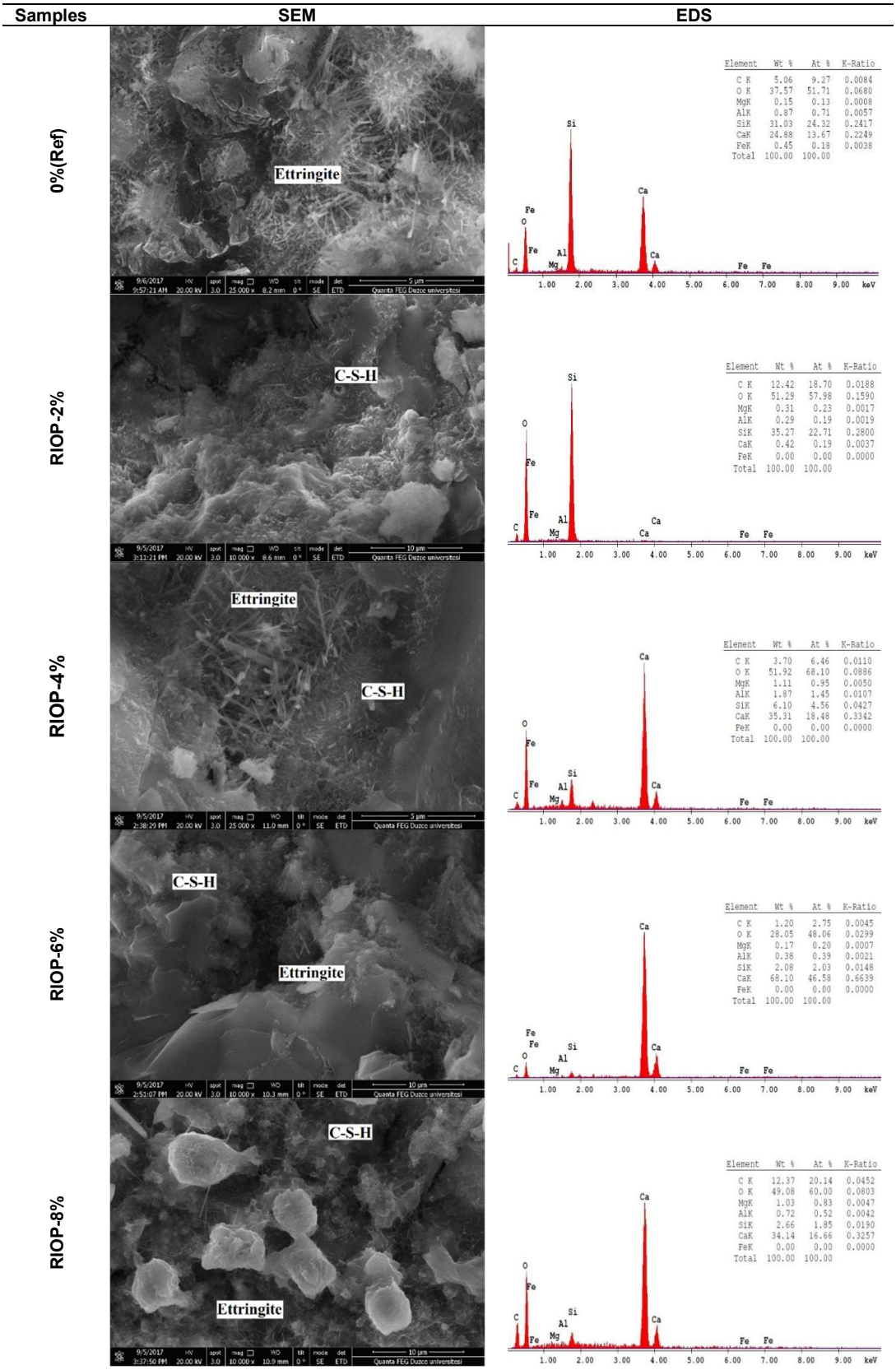

Fig. 6 - SEM-EDS Analysis

- The highest flow has been observed in RIOP-4% samples among red iron oxide pigment (RIOP) added samples. According to reference samples, it is determined that addition of red iron oxide pigment up to 6% have increased the processability of the mortar, while the processability have decreased when the ratio was over 6%.
- It is observed that density of the samples was between 2.14 and 2.19 (kg/dm^3) and addition of red iron oxide pigment have decreased the density of the samples. It is determined that addition of red iron oxide pigment has filled the mortar voids due to its fine particulate structure and has decreased the water absorption ratios.
- Compressive strength values have increased with increasing cure period in all batches, and optimum value has been obtained from RIOP-6% samples. Flexural strength has decreased in all batches compared to 0%(Ref) samples and after 28 days of cure period, the flexural strength of samples having 8% red iron oxide pigment had the maximum value as 7.2 MPa. It is determined that addition of red iron oxide pigment have decreased compressive and flexural strength values in a negligible ratio.
- It is observed that in image processing analysis the maximum value in Red% values have been obtained from RIOP-6% (64.61%) samples and the mixture had shown a homogeneous distribution in every section with a standard deviation value of 0.67.
- As a result of the SEM analysis of the samples, it is observed that addition of red iron oxide pigment has formed of a porous and vitreous structure in the inner structure of the concrete. From the images, it is determined that there were phases such as C-S-H and ettringite.

As a result of the study, it is determined that when it is desired to obtain a red colored mortar, the optimum result would be obtained by adding 6% of red iron oxide pigment (RIOP) to the mixture and more than 6% of red iron oxide addition to the mixture would have no effect in coloring the mortar to red.

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