Research on characterization methods of efflorescence on cement-based decorative mortar

X F Liu¹, J H Peng², J X Zhang²,³ and J D Qu³

¹School of Civil Engineering and Architecture, Chongqing University of Science and Technology, Chongqing 401331, China
²College of Materials Science and Engineering, Chongqing University, Chongqing 400045, China
³Chongqing Jianda Building Materials Co., Ltd, Chongqing 400030, China

Corresponding author and e-mail: X F Liu, lpioneer@sina.com

Abstract. The cement-based decorative mortar is a kind of good finishing material because of its abundant shape and wide range of colour change, with efflorescence. The lack of characterization methods of efflorescence degree seriously hinders the further research and application of cement-based decorative mortar. In this paper, the characterization methods of the efflorescence degree of decorative mortar was studied by image processing technology. The results show that the effects of colours in different grey scales on mortar appearance can be distinguished by the image processing techniques, and colours in efflorescence region would be obviously affected when their grey scales were 15 higher than that of matrix colour. Furthermore, the functional is proposed which was proposed could not only quantitative feature the efflorescence degree well but had a good conformance with the actual value.

1. Introduction
Cement-based decorative mortars are provided with rich shape, wide range of color change, durable protecting building. But the efflorescence and colour aberration are aesthetically undesirable, which hinder the further research and application of cement-based decorative mortars. It is key of Characterization methods of efflorescence degree. So far, mainstream characterization methods are qualitative analysis and short of quantitative feature[1-7]. This paper pays close attention to relevance of efflorescence degree and gray scales by the image processing techniques, in order to achieve quantitative featuring the efflorescence degree.

The minimum unit of digital image is called pixel with the attributes of color, gray and so on, which corresponds to the plane coordinate of image. Usually, the gray level is divided into 256 levels from dark to bright in image processing: 0 represents all black, and 255 represents all white. Image gray analysis is characteristic of wide coverage, good continuity, large amount of information, high efficiency and non-destructive imaging, and it is intuitive, image and easy to obtain, so it has been applied in scientific research. The image of efflorescence sample is a comprehensive representation of the density and efflorescence degree in mortar. The shading degree varies for difference thickness of white efflorescence substance on the surface of mortar, so it shows a certain color difference. The deeper the thickness of efflorescence substance on the specimen surface, the higher the gray value.
Therefore, the efflorescence degree can be evaluated by the color grayscale of different areas on the sample surface.

2. Image processing and analysis of efflorescence samples

The mix ratio of mortar is that 32.5 grade white cement: sand: iron oxide red: water=1: 2.30: 0.015: 0.35. After stirring and statically setting 5min, the mortar was smeared on 150mm × 70mm × 5mm cement fiberboard, immersed in water for 8 hours after standard curing for 1 day, and then continue to be maintained standard curing for 3 days to surface dry, such as sample no.1 in figure 1; adding appropriate admixture to mix ratio, Under the same operation, sample 2 was obtained as shown in figure 2. The samples were taken photographs by digital camera, as shown in figure 1 and figure 2. The sample s were taken photographs by digital camera, as shown in figure 1 and figure 2. The first one is a serious efflorescence mortar sample with a cluster distribution of efflorescence components, the surface color distribution is uneven and mottled. The second is consistent colour without efflorescence.

![Figure 1. Image of specimen one.](image1)

![Figure 2. Image of specimen two.](image2)

The preliminary processed sample image was inputted by MatLab7.0 Software, and was converted to grayscale image by Image conversion function of rgb2gray, such as figure 3. And it was extracted image grayscale matrix and converted to grayscale distribution histogram by the program of MatLab, such as figure 4.

![Figure 3. Grayscale image of specimen one.](image3)

![Figure 4. Gray histogram of specimen one.](image4)

It can be seen from figure 3 that the gray value of the sample is random, that is, the gray value of each point is different and irregular. It was due to randomly distributing of sand and cement, bubble and color difference during the molding process, and efflorescence. It can be seen from figure 4 that the grayscale distribution of sample 1 image is relatively wide, 100-255, but mainly concentrated in the range of 160-240.

3. Characterization functions of efflorescence degree

3.1. Characterization of efflorescence degree

Grayscale value of any pixel on the sample image was extracted by the program of MatLab, Abbreviated to gi.

The colour of the same age sample can be selected as the base color of the sample by multi-group image analysis, and the Corresponding gray value is bi. The area does not affect the appearance of
mortar with a deviation of less 5 than bi. When the gray value is more 15 than bi, it will obviously affect the appearance of mortar. Therefore, the image gray threshold of efflorescence is determined as bi+15.

The base color of mortar sample varies with mix ratio and curing conditions, so the image gray threshold should be different. As shown in figure 1, the gray value bi is 170, and the gray threshold of the image is 185 when there is an obvious efflorescence.

The characterization function of efflorescence degree is generalized, as shown in 1. In which the alphabet f means efflorescence degree, pi means the percentage of a certain gray level corresponding pixel to total pixel, ri means efflorescence influence coefficient.

\[ f = \sum_{i=1}^{255} r_i \times p_i \]  

Prior to this, random 20 volunteers rate the same group of 20 samples with different efflorescence degrees, which is defined as 100 at full whitening and 0 without efflorescence. The following matrix equations are established based on the evaluation, as shown in 2.

\[ p_{20,70} \times R_{70,1} = f_{20,1}, \]

\[ p_{k,i} p_{k,i+1} \ldots p_{k,255} \times r_k = r_k \quad (k \in [1, 20], k \in N) \]  

The matrix equation is used to calculate \( r, r_{i+1}, r_{i+2}, \ldots, r_{255} \), as in table 1.

| g    | r  | r  | g  | r  | g  | r  |
|------|----|----|----|----|----|----|
| 186  | 0.136 | 200 | 0.413 | 214 | 0.55 | 228 | 0.65 | 242 | 0.845 |
| 187  | 0.145 | 201 | 0.368 | 215 | 0.531 | 229 | 0.746 | 243 | 0.925 |
| 188  | 0.184 | 202 | 0.366 | 216 | 0.506 | 230 | 0.741 | 244 | 0.914 |
| 189  | 0.208 | 203 | 0.442 | 217 | 0.515 | 231 | 0.794 | 245 | 0.934 |
| 190  | 0.28  | 204 | 0.445 | 218 | 0.538 | 232 | 0.794 | 246 | 0.87  |
| 191  | 0.32  | 205 | 0.506 | 219 | 0.585 | 233 | 0.829 | 247 | 0.883 |
| 192  | 0.294 | 206 | 0.49 | 220 | 0.576 | 234 | 0.798 | 248 | 0.971 |
| 193  | 0.285 | 207 | 0.509 | 221 | 0.653 | 235 | 0.76  | 249 | 0.992 |
| 194  | 0.333 | 208 | 0.486 | 222 | 0.582 | 236 | 0.794 | 250 | 1.005 |
| 195  | 0.293 | 209 | 0.538 | 223 | 0.63  | 237 | 0.778 | 251 | 1.046 |
| 196  | 0.269 | 210 | 0.512 | 224 | 0.68  | 238 | 0.798 | 252 | 1.034 |
| 197  | 0.349 | 211 | 0.498 | 225 | 0.663 | 239 | 0.858 | 253 | 1.062 |
| 198  | 0.309 | 212 | 0.486 | 226 | 0.714 | 240 | 0.854 | 254 | 1.073 |
| 199  | 0.288 | 213 | 0.498 | 227 | 0.708 | 241 | 0.88  | 255 | 1.094 |

### 3.2. Correlation analysis

In order to explain the relationship between the influence coefficient and the gray value, the correlation between the influence coefficient and the grey value was analyzed by the program of MatLab based on the least square method. The results show that there is a good linear correlation between the two factors, as shown in figure 5.
Figure 5. Correlation between coefficient and grey values.

When the grey value corresponding to the base colour of bi is 170, the image grey threshold of efflorescence is 185, there is the following relation, as shown in 3.

\[ r_i = 0.0125g_i - 2.1369, R^2 = 0.9778 \] (3)

When the grey value of the base colour is between 160 and 190, such as the number of bi is 180, there is a similar relationship, as shown in 4.

\[ r_i = 0.0126g_i - 2.1346, R^2 = 0.9753 \] (4)

Therefore, the conclusion is that the influence coefficient of different grey values on the efflorescence degree of decorative mortar can be expressed as 5 when the basic colour grey value of the sample is 160-190.

\[ r_i = \frac{g_i-b_i}{100(240-b_i)} \times (255 - b_i)(g_i > b_i) \] (5)

In this way, the efflorescence influence coefficient of different grey values can be calculated for any sample of the basic colour grey value in this interval by 5, and then the efflorescence degree was calculated by 1.
Figure 6. Evaluation and calculated values of efflorescence degree.

Figure 6 shows a comparison of the value of the evaluation to the calculated value of the efflorescence degree from low to high of 20 samples. The results show that the calculated value is similar to the value of the evaluation value. Especially when the efflorescence degree is low, it has better consistency.

3.3. Sources of deviation
The above function as 1 can be used to characterize the efflorescence degree of mortar samples, but there are some errors in some degree. The main sources of deviation are as follows, firstly, the defects affect the image gray value such as color aberration and small pits on the surface inevitably formed in the process of mortar molding, but there is no effective method to eliminate the influence of the above defects on the image gray value. Secondly, the brightness of surface colors of mortar varies with moisture content of mortar, which will affect the grayscale value of efflorescence region color and the base color. Thirdly, the image gray value varies with deviation of light in the process of photography and uneven exposure of the image. Therefore, it is necessary to make the mortar spread evenly, ventilate and dry to the similar humidity, the same light in the process of photography as far as possible.

4. Conclusions
The grey value in the sample image is random, and the grey value of each point is irregular. The area does not affect the appearance of mortar with a deviation of less 5 than the image grey value of the base colour. When the grey value is more 15 than the image grey value of the base colour, it will obviously affect the appearance of mortar.

The characterization function of efflorescence degree is generalized, \( f = \sum_{i=b+15}^{255} r_i \times p_i \), which is proposed could not only quantitative feature the efflorescence degree well and has a good conformance with the actual value.

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