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Relationship between Colour Intensity and Water Content in Crema Loja Limestone

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Abstract. The alterations to the visual properties of a Spanish limestone, Crema Loja, in relation to its water content are presented, measured and discussed in this work. A Computer Vision System previously developed, validated and patented by CTAP, was used. The study was carried out on different tiles with two surface treatments: polished and honed. A critical value of water content is proposed at the end of the study to avoid problems derived from alterations to the visual properties of this stone material due to moisture.

Introduction

In the stone industry, water is the preferred coolant used in almost every industrial operation (polishing, cutting, etc.). Stone, as a natural material, is characterized by its water absorption properties, which depend not only on each kind of material (marble, limestone, granite, etc.) but also on the particular properties of each individual piece, as it is a very heterogeneous material.

It can be easily verified that when a stone tile or slab is wet, its colour properties modify (the colour gets darker). This can generate problems in stone aesthetical classification, for example at the end of a polishing line when the material is still wet. It can also generate installation problems, when cement with water has been used, as the visual properties change due to the drying of the tile. The possible consequence is that the end user may not be completely satisfied because the product in its final location looks different from what was expected or because the final composition of tiles does not look homogeneous at all.

It is, therefore, necessary to study and quantify this phenomenon in order to prevent problems derived from it.

Materials and Methods

Crema Loja Limestone. To carry out the study a light brown limestone was selected. This kind of limestone is the most popular material for tiling in Spain and used in many other countries.

Crema Loja limestone is extracted in the South East of Spain, in the Andalusian province of Granada. It is a microcrystalline limestone with a light brown colour, showing stylolites, fossil and pores, and veins filled with calcite. An image of a polished tile is shown in Fig. 1.

Computer Vision System. A computer vision system consists of: i) a hardware, to obtain the images; and ii) a software, to analyse those images and turn visual properties into numerical data. The numerical data obtained can be used to identify each image using mathematical algorithms.

The main constituents of the hardware are:

- Chamber. To standardise the visual environment for capturing the images a closed chamber is needed. The place for the tiles where images are taken is fixed, as well as the setup for the lighting and capturing system.
- Lighting system. The lighting system provides uniform light to the chamber in order to obtain stable and repetitive images. In this case, diffused florescent lamps were selected and positioned in the chamber to obtain a uniform light distribution.

- Capturing system. The capturing system consists in an industrial digital camera, which allows obtaining a focused image of the tile placed inside the chamber using standardised light conditions. In this example, the camera used has a resolution of 1624 (h) × 1236 (v) 4.4 μm square pixels and is able to capture up to 25 frames per second with full resolution in a continuous mode operation.

Regarding the software, its main function is the image treatment when the numerical values are obtained from visual properties of the tiles. Some visual characteristics can be analysed: colour characteristics, contrast along the tile, the presence of veins and defects, etc.

There is a wide variety of possible configurations and applications of Computer Vision Systems that can be found in literature [1].

Fig. 1 - Image of Crema Loja limestone (tile dimensions: 40cm × 40cm)

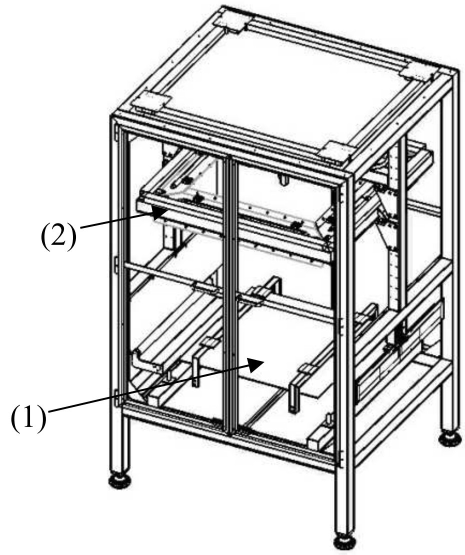

Fig. 2 - Computer Vision Prototype developed by CTAP.

Computer Vision Prototype. CTAP has developed, validated and patented a Computer Vision System for stone tiles [2]. The system includes hardware and software specially designed for image recognition of natural stone tiles. For further information about the system, patent information can be consulted. The Computer Vision System has been already used for classification of Blanco Macael marble with good results [3]. There are some other Computer Visions Systems available that have been successfully applied to natural stone aesthetical characterization and classification [4-8].

A prototype apparatus based in this system was used in the present study (see Fig. 2). Inside the chamber of the prototype one can find a surface to place the tiles in a fixed position (1) and, above this surface, a squared panel where the florescent lamps are positioned on the border and the industrial camera is fixed in the geometrical centre (2).

Design of Experiments

The experiments were planned with the objective of determining the colour characteristics of stone tiles while varying their water content values.

Seven polished tiles and twelve honed tiles of Crema Loja were selected. The dimensions of the tiles were 40×40×2 cm^3. All the tiles were completely saturated in water after which initial surface images were captured. The weight of the saturated tiles was also measured. From this moment on, the tiles were placed in an oven under stabilized temperature conditions of 40ºC, with a tolerance of ±0.2ºC. Continuous weight measurements of the tiles and corresponding image captures were taken, until the tiles were completely dry. The dry tile weight (w_d) was considered as a reference, so that the percentage of water absorbed could be calculated from this value. The experimental design was similar to the one used to determine a drying curve but including images of the samples at each weight measurement.

The visual property extracted from the images and studied for every tile in every stage was colour intensity. Colour intensity is a term used to describe how light or dark a colour appears. To determine colour intensity, the images were turned into black and white. Intensity value was statistically processed for the whole tile with a histogram. The histogram shows the number of pixels in an image at each different intensity value found in the corresponding image. For an 8-bit grayscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those grayscale values. The final numerical value representative of each image was the Average Histogram, with a unit range from 0 corresponding to black (completely dark colour) to 256 corresponding to white (completely light colour).

Results

The data obtained for every tile can be summarised in three main parameters:

- Drying Time (min): the total time the tile has been in an oven at a stabilized temperature of 40ºC. Initial state considers a tile completely saturated in water. Time spent in stabilizing temperature in the oven has not been considered.
- Water Content (weight %): the total amount of water contained in the tile. It is calculated from the weight of the wet tile taken out of the oven at a certain drying time (w_w) and the dry tile weight (w_d) according to the following equation:

$$\text{Water Content (weight \%)} = \frac{w_w - w_d}{w_d} \times 100 \tag{1}$$

- Colour Intensity Average Histogram: the statistical value that represents the colour intensity in the whole tile (like stated earlier).

The results obtained from every tile are presented in Table 1 and Fig. 3 for the polished tiles; Table 2 and Fig. 4 for honed tiles.

Table 1. Results from polished tiles.

	Time at 40ºC [min]	0	5	10	15	170	258	1567
Tile 1	Water Content [wt%]	0.40	0.14	0.12	0.11	0.07	0.06	0.00
	Colour Intensity	171.66	176.54	177.50	179.11	182.44	182.03	182.65
Tile 2	Water Content [wt%]	0.44	0.16	0.15	0.14	0.09	0.07	0.00
	Colour Intensity	172.39	174.16	177.52	179.32	182.92	183.25	182.20
Tile 3	Water Content [wt%]	0.40	0.14	0.13	0.12	0.08	0.06	0.00
	Colour Intensity	175.47	176.15	179.24	181.75	183.41	183.28	182.99
Tile 4	Water Content [wt%]	0.42	0.14	0.11	0.11	0.07	0.06	0.00
	Colour Intensity	168.87	169.54	171.03	172.11	174.13	174.53	176.33
Tile 5	Water Content [wt%]	0.51	0.14	0.13	0.12	0.09	0.05	0.00
	Colour Intensity	163.08	164.44	165.81	166.85	170.26	171.30	173.14
Tile 6	Water Content [wt%]	0.43	0.12	0.09	0.09	0.06	0.05	0.00
	Colour Intensity	171.03	174.76	176.50	177.59	181.18	180.50	179.91
Tile 7	Water Content [wt%]	0.23	0.09	0.08	0.08	0.05	0.04	0.00
	Colour Intensity	172.26	174.76	175.20	176.98	178.12	177.59	177.94

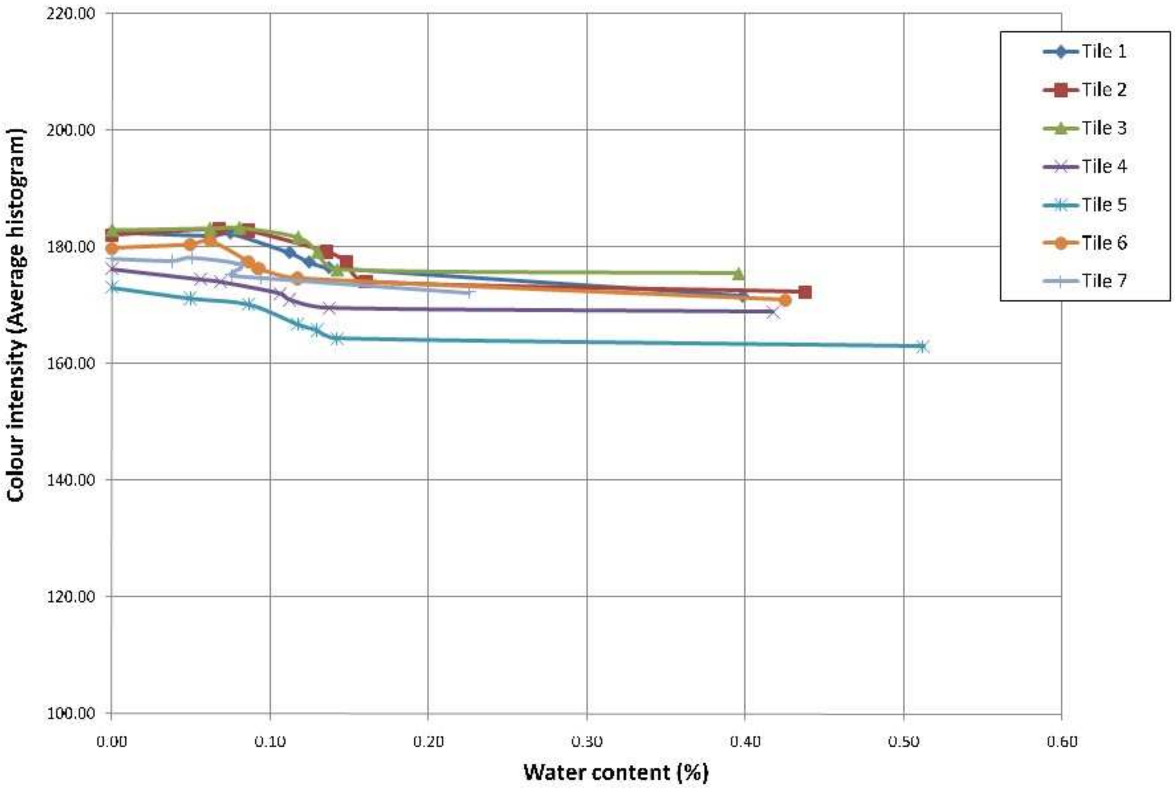

Fig. 3 - Graphic representation of the dependence between the colour intensity and the water content on polished tiles of Crema Loja limestone.

Table 2.Results from honed tiles.

	Time at 40ºC [min]	0	5	10	15	170	258	1567
Tile 1	Water Content [wt%]	0.55	0.20	0.16	0.12	0.06	0.05	0.00
	Colour Intensity	175.06	187.90	190.09	190.81	195.21	193.72	193.78
Tile 2	Water Content [wt%]	0.39	0.24	0.17	0.13	0.07	0.05	0.00
	Colour Intensity	175.40	180.80	188.03	190.10	193.02	192.23	192.02
Tile 3	Water Content [wt%]	0.29	0.09	0.04	0.03	0.01	0.02	0.00
	Colour Intensity	171.25	172.56	180.25	181.55	182.43	181.07	182.89
Tile 4	Water Content [wt%]	0.28	0.10	0.06	0.05	0.04	0.02	0.00
	Colour Intensity	171.22	172.55	178.76	180.55	181.66	180.94	181.08
Tile 5	Water Content [wt%]	0.33	0.11	0.08	0.07	0.03	0.02	0.00
	Colour Intensity	146.15	154.81	158.20	160.67	161.86	161.65	162.80
Tile 6	Water Content [wt%]	0.39	0.09	0.07	0.05	0.04	0.02	0.00
	Colour Intensity	125.20	133.12	136.28	138.12	139.21	139.71	144.44
Tile 7	Water Content [wt%]	0.56	0.32	0.26	0.21	0.11	0.07	0.00
	Colour Intensity	174.50	187.55	0.00	191.71	194.49	193.44	193.35
Tile 8	Water Content [wt%]	0.39	0.29	0.21	0.15	0.09	0.06	0.00
	Colour Intensity	178.67	186.62	191.72	196.49	197.28	197.41	197.02
Tile 9	Water Content [wt%]	0.63	0.40	0.14	0.10	0.06	0.04	0.00
	Colour Intensity	162.96	168.57	177.28	180.74	183.66	183.39	183.27
Tile 10	Water Content [wt%]	0.47	0.20	0.14	0.12	0.06	0.04	0.00
	Colour Intensity	162.33	169.46	175.20	177.29	180.08	180.11	180.80
Tile 11	Water Content [wt%]	0.29	0.13	0.09	0.08	0.06	0.04	0.00
	Colour Intensity	171.91	182.28	186.14	187.38	188.22	187.64	187.92
Tile 12	Water Content [wt%]	0.39	0.08	0.05	0.05	0.03	0.01	0.00
	Colour Intensity	170.68	184.76	185.71	186.64	187.02	186.48	186.62

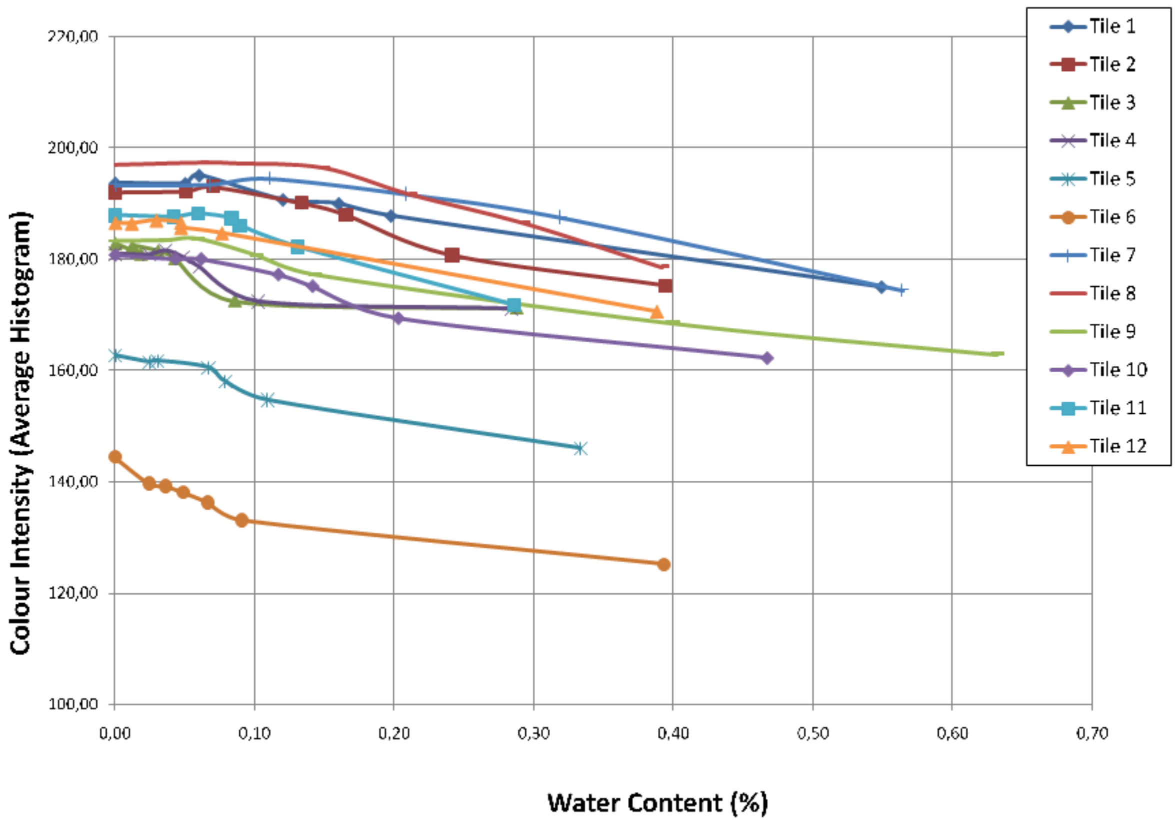

Fig. 4 - Graphic representation of the dependence between the colour intensity and the water content on honed tiles of Crema Loja limestone.

Conclusions

The conclusions that can be withdrawn from this work are the following:

1) There is dependence between colour intensity and water content in Crema Loja tiles.

2) Wet tiles are always darker than dry tiles.

3) Alterations in colour intensity of Crema Loja tiles due to water content are more noticeable in honed tiles than in polished tiles, as the difference in Colour Intensity from dry to wet tiles is larger.

4) The pattern of Colour Intensity variation with water content for Crema Loja limestone can be considered similar for both polished and honed tiles. However, some tiles show a much larger variation in colour intensity due to their water content.

5) The graphical representations of Colour Intensity versus Water Content suggest a horizontal line below a critical value of water content. This possible model should be validated by more experimental data, to make reliable numerical correlations with the lower values of water content. The critical water content seems to be very low for both polished and honed tiles (lower than 0.1%).

6) For future developments of automatic classification of natural stone tiles based on their colour intensity, drying treatment is suggested to eliminate the water content below a critical value. The critical water-content value, for each material, has to be experimentally determined.

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