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Thermal deterioration of marbles: Gloss, color changes

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H I G H L I G H T S

- This article define marble behavior to slow and fast temperature changes.
- Changes in surface gloss and color parameters (*L*, *a*, *b*) due to thermal shock and thermal ageing cycles.
- Effects of *L*, *a*, *b* changes on surface gloss changes highlighted.

A R T I C L E I N F O

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A B S T R A C T

Marbles are widely used as construction materials because of their high resistivity to common conditions, and to their aesthetic appeal. Aesthetic qualities such as color, gloss and polishability are important for rock used as constructions materials. But marbles as building stones show complex weathering phenomena. Thermal effects are important weathering factors affecting the aesthetical and physico-mechanical properties of marbles.

This study assesses changes to surface aesthetic properties of some marble samples due to heat. For this purpose thermal ageing and thermal shock cycles were inflicted on six types of marble samples of differing colors. Marble samples of shiny surfaces were prepared. In thermal shock cycles, samples were heated up to 105 °C for 18 h then placed for 6 h in distilled water. In thermal ageing cycles, the samples were placed in an oven for 18 h then allowed to cool for 6 h at room temperature. At the end of cycles 4, 8, 12, 16 and 20, gloss measurements were recorded; at the end of the last cycles color changes were evaluated. The relationships between gloss and color parameters were also investigated. Thermal shock has more important effects on marble surface properties than the thermal ageing cycle. L^* and b^* parameters constituted an important effect on glossiness and these parameters were strong indicators for predicting gloss loss.

1. Introduction

Natural stones and marbles have special characteristics such as color, texture and grain size. Accordingly, they have been commonly used as a decorative material for cladding the outside of walls and buildings either with structural (columns, floors, etc.) or decorative purposes (reliefs, statues, etc.) [1,2]. The aesthetic properties depend on several factors, such as texture, shape and size of grains, color, and surface gloss [3,4]. With a fine surface finish, the aesthetic properties of marbles are maximized. According to their function, natural stone products can be grouped to the following categories:

- Slab products.
- Rough products.
- Special products.

Sawed marbles have surface irregularities. Accordingly, marble slabs or other products are usually polished. At the end of the polishing, the surface becomes shiny reflective (glossy) and mirroring [4]. The gloss and color are key parameters for evaluating the efficiency and value of the polishing process [5–11].

Gloss is defined by ASTM as the capability of a surface to reflect incident light. It is related to polishing and has an effect on the aesthetic attributes of rock [12,13]. Gloss is related to roughness, because reflectance capacity of surface are related surface smoothness [2,14].

Color is the other main physical property that influences the marketability of marble. Chemical content and physical properties of marble leads to varying colors. The final color of marbles varies depending on the impurities. For example iron-oxides gives rise to yellow, yellowish or reddish colors, and manganese oxides and carbonic impurities give rise to dark bluish, violet or black colors. In the marble industry, color identification is described by well-known colors (brown, red, white, honey, lilac, cherry, sky blue,

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etc.) and textures are described as leopard, tiger, etc. In Turkey there are specific marbles named Akşehir beige, Elazıg cherry, Marmara gray, etc. [15].

When compared to such building materials as wood or mud, stone is generally assumed to be the most durable material. But despite this common belief, stone can deteriorate and many factors will affect it [16]. Marble marketability is affected by many factors such as thermal changes, chemical contaminants, salt crystallization, solar radiation, pollution (notably acid rain) and bio deterioration [4,17]. In marble decay, thermal effects play an important role. Thermal effects, especially when coupled with other environmental factors such as water content, and chemical exposure, change petrographic, mechanic and surface properties of marble. These changes lead to deterioration from increased porosity and loosening of rock cohesion [18,19]. Increasing temperature and related thermal expansion cause tensions that lead to cracks and increased pore volume. Such deformations lead to oxidation, decomposition and polymorphic transformation, and these effects decrease marble surface quality [20,21]. Stone durability is usually more affected in urban environments. Usually changes in color, stains, efflorescence, and material loss are common aspects of stone materials decay. In order to avoid such decay, accelerated durability tests were carried out and decay processes observed [3,22].

This study investigates thermal shock and thermal ageing effects on the color and gloss values of the polished surfaces of some Turkish marble. The samples were subjected to a thermal shock and thermal ageing chamber, and the influence of these stresses on color and gloss and the relationship between gloss and color changes were determined.

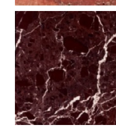
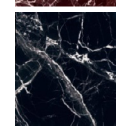
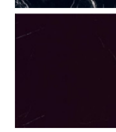
2. Experimental setup

Two thermal cycles of thermal ageing and thermal shock were inflicted on differently colored marbles, and two main measuring instruments were used: a gloss-meter and color meter.

2.1. Materials

Six marbles were investigated. The sample code, commercial names, and stone types of the samples are given in Table 2.1.

Table 2.1
Sample code, commercial names, stone types of samples.

Sample code	Commercial name	Stone type	Color type	
MB	Best Cream	Limestone	Beige	
E	Crystal Emperador	Dolomite	Light brown	
KT	Red Travertine	Travertine	Light red	
EV	Rosso Levanto	Limestone	Dark red	
HY	Verde Antico	Limestone	Dark green	
Sİ	Black Pearl	Limestone	Black	

The samples were examined in two groups. Sample of the first group have light color, samples of the second group dark color. The polished surface and 200 mm × 200 mm × 20 mm sized samples were collected from marble processing plants in Turkey. The physical properties were determined suggested by TSE procedures [23–25]. The physico-mechanical properties of marbles are shown in Table 2.2, results of XRF analysis in Table 2.3 and results of XRD in Table 2.4.

2.2. Thermal cycles

Two sets of samples from each rock type were prepared and thermal treatments were inflicted on samples prior to starting the cycles; every four cycles gloss measurements were performed on the surface of the samples. Six samples were prepared from each marble. A total of 20 thermal ageing and thermal shock cycles were performed. Prior to starting the cycles and at the end of the cycles, color analyses were performed at nine different points marked on the sample surfaces.

Two different thermal treatments were used.

2.2.1. Thermal ageing chamber

The first thermal treatments were performed with procedures suggested by Lam dos Santos et al. 2011, with minor modification [26]. To provide uniformity, thermal condition at the thermal shock and thermal ageing cycles 200 °C indicated in Santos 2011 was applied at 105 °C. The specimens were subjected to cycles of heating (105 °C) and cooling in air (room temperature 20 °C). The samples spent 18 h in an oven, then 6 h at room temperature (20 °C). This type of test is called thermal ageing. At the end of the every four cycles gloss measurements were recorded.

2.2.2. Thermal shock chamber

The second thermal treatments were performed with procedures suggested by TS 14066 [27]. The specimens were heated in the same way as explained in (a) and then were rapidly immersed in distilled water at 20 °C. The water was kept constant at 20 ± 1 °C. Test samples spent 18 h in an oven then stayed in distilled water for 6 h. In this study, a Nuve KD400 oven was used. This type of test is called thermal shock. At the end of every four cycles, the gloss measurements were recorded.

In this study the gloss measurement was done using a Q TQC GL0010 60° solo gloss meter at 60° angles for each stone sample.

A gloss-meter sends light at a certain angle to the surface and determines the surface gloss numerically based on the reflection angle of the light. It can be done on rough surfaces. Gloss-meters are less sensitive to vibrations and seem to be partially appropriate for quality-control measurements conducted in commercial facilities [1]. Gloss values are expressed in GU (gloss units).

The color was assessed using a Hunter CIELAB colorimeter. In the CIELAB system, the color is quantified according to three chromatic coordinates: L parameter represents lightness or luminosity ($L = 0$ dark; $L = 100$ white); "a" parameter is the red–green axis ($a > 0$ red; $a < 0$ green); and "b" parameter is the yellow–blue axis ($b > 0$ yellow; $b < 0$ blue[1]) [28]. The CIELAB coordinate system is shown that in Fig. 2.1.

3. Result and discussion

3.1. Gloss changes owing to the thermal chamber

Figs. 3.1 and 3.2 indicate the gloss values of the marble samples during thermal ageing and the thermal shock chamber.

As can be seen in Figs. 3.1 and 3.2, cycle progressions led to a decrease of the surface gloss value. In addition, the glossiness of the marbles was not uniformly affected by the thermal shock and thermal ageing. The graphics show that depending on the increase in the number of cycles, surface gloss values decreased very slowly and at on a changeable scale. As the thermal shock cycle was increased, glossiness decreased in all of the marbles. The most important decrease was realized in Light red travertine. Especially in the first four cycles, Red travertine showed a different loss of gloss values. It was fast in the early stages and slower later on. This may owe to the fact that Red travertine has many open porous.

[1] For interpretation of color in Fig. 2.1, the reader is referred to the web version of this article.