Study of Deterioration of Court Floor of Sultan Hassan Mosque in Cairo

ABSTRACT: The college- mosque of Sultan Hassan is considered one of the finest examples of Islamic architecture not only in Egypt but also in the East. Its open court is paved with different types of marble. These marble slabs suffer from severe deterioration. Causes of this deterioration were determined accurately through the ocular examination of the court and confirmed by the laboratory tests which were carried out on samples representing the three common types of marble used in the floor namely the white, the red and the black marble. Sun light and heat are the main deterioration factors and the consequent thermal expansion is the main property which led to the detected deterioration phenomena.

Conference Topic: Fine restoration of Islamic arts.
Keywords: Deterioration, thermal expansion, stress, deformation.

1. INTRODUCTION:

A study of the deterioration phenomena, causes and processes which affected any archaeological building is required before any treatment of it. Such a study should include investigation and the quantitatively describing of deterioration to get the proper understanding of the case and also to put the suitable plan of restoration and conservation.

In general, conservative provisions should be taken only after identification of the deterioration process, at least on a tentative basis, in order to reduce the risk that the action taken might result as useless or even damaging in the long run [7].

It is intended that this study of deterioration of the case of Sultan Hassan mosque will be used as a basis to create a database on deterioration of open courts floors of the Islamic archaeological buildings (mosques, palaces and houses) in Egypt. Such a database would form a valuable documentation of the present situation and an excellent tool to follow and quantify deterioration, restoration or other changes of our Islamic archaeological buildings in the future.

1.1. Description of the monument

It was built in 757 A.H. – 1356 A.D. by order of Sultan Hassan on a rock below the Citadel. Its interior is divided into four large halls (iwans) with lofty barrel vaulting surround an open extensive court (sahn) (the studied part) (Figure 1) which is paved by marble slabs of different colors. The biggest of the halls is situated to the east and is decorated with a frieze cut in stucco with fine Kufic letters from the Qoran on an artistic background of arabesques. The rear wall, with the prayer recess, is adorned with marble. The square domed apartment has an interesting inscribed frieze of carved wooden letters from the Qoran. The ceiling and the painted frieze have been partly restored [9].

Figure 1: General view of the studied open court.

2. RESULTS OF OCULAR EXAMINATION:

It is obvious from the examination that all kinds of marble which were used in the floor had seriously deteriorated.

An overall discoloration and colors reduction of the black, red and white marble slabs which represent the most common colors in the floor of the court; were observed. The discoloration was observed in the white marble slabs which have altered to slight yellow color while the color reduction took place in the black and red slabs (see Figure 2).

Cracks appear in the all kinds of marble which extend within the cleavage plans and the weakness levels between the crystals (see Figure 2).

Much of the mortar of the setting-bed and of the joint had lost its cohesion and as a direct consequence detachments took place either between the slabs themselves or between the slabs and the statumen (the stone blocks) or both of them as shown in (Figure 3).

Figure 2: Discoloration and color reduction in the white and in the red slabs respectively and cracks extensions in both of them.

Figure 3: Mortar of the setting-bed was altered to powder and dispersed on the surface of slabs causing their detachments.

Many slabs are not uniformly flat where a hump running the entire length of the north side of the court. It was observed that the deformations which affect the marble slabs vary between slight and severe degrees therefore and as a consequence of this variation; different types of deformations were produced.

The final result of marble slabs deformations is their complete detachment from the statumen (see Figures 4 and 5).

Figure 4: General view of the severe deformations which affect the marble floor of the court.

Figure 5: Detail from the last figure from other angle.

The author defined the types of deformations which affect the marble slabs as follows:

a) Warp
b) Buckle
c) Hump
d) Outcrop
e) Slide

More extensive definition of these types of deterioration and the mechanisms of their formations are given in Figures 6-10.

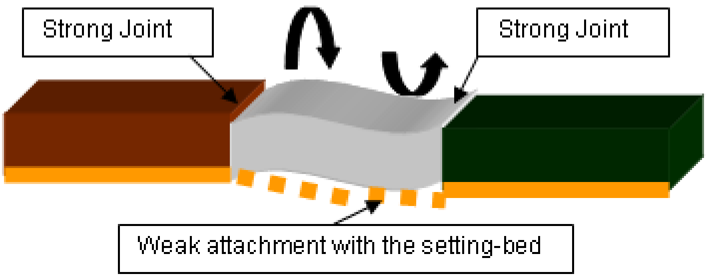

Figure 6: Shows warp of marble slab.

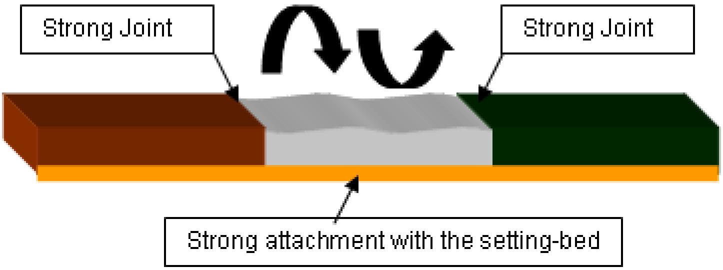

Figure 7: Shows Buckle of marble slab.

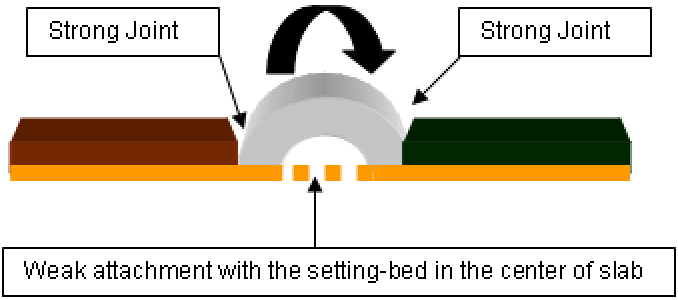

Figure 8: Shows hump of marble slab.

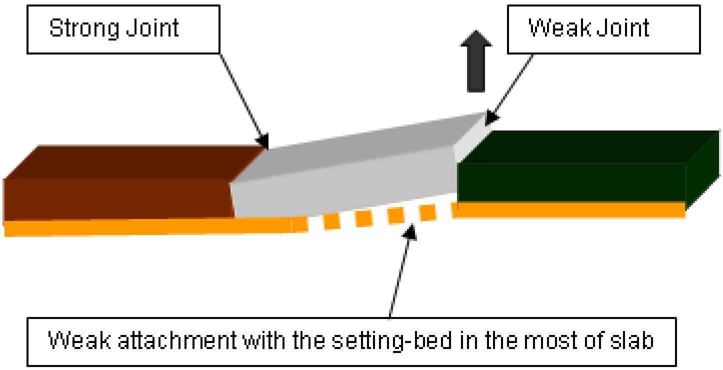

Figure 9: Shows outcrop of marble slab.

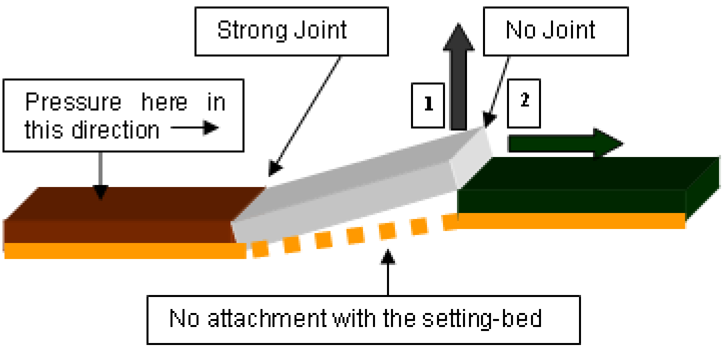

Figure 10: Shows the advanced stage of outcrop; the slide.

3. DIAGNOSIS:

From the above mentioned results of ocular examination the author attributes the all determined deterioration phenomena mainly to sun light and heat to which the court floor is exposed directly daily in the summer season.

The discoloration and colors reduction are due to the light of sun and the all other determined deterioration phenomena are due to its heat.

According to Winkler [8] the amount of transmitted light through crystalline marbles depends on the optical orientation of calcite, micas and other minerals with relation to the slab. Scattering of light occurs along the crystal boundaries, by tiny included gas bubbles and by pigments. Grain size, pigments, inclusions and mean grain orientation are a major factor in the light transmission of marbles. A wet or polished marble surface disperses less light than a dry surface; polishing also increases the light transmission.

The author attributes the discoloration and the reduction of marble colors to some photochemical reactions especially in the accessory minerals which play the main role in producing the marble color during its geological formation and before its using and incorporation in the archaeological building.

The climate in Cairo is the typical desert climate contrasts daytime dry heat with cool nights freshened by Nile breezes. Cairo has only two seasons: approximately eight months of summer and four months of winter. In the hottest of the summer months, June, July, and August, the average daily maximum temperature is 95° F (35° C) and the average daily minimum is 70° F (21° C). The summer temperature has reached as high as 117° F (47° C) [2].

The change of temperature in Cairo between day and night is very high and this makes the exposed floor of the open court heats in the day and cools in the night by radiation towards the black sky. This change of temperature in one day can be considered one cycle of expansion and contraction. Such daily cycles according to Torraca [7] are important sources of stress.

Two somewhat different phenomena due to fluctuation of temperature are recognized: stresses may be set up either by the unequal expansion and contraction of the component minerals or by the expansion and contraction of the surface layers relative to the underlying stone [6].

The author attributes strongly the all deformations types of marble slabs in the studied court floor to the thermal expansion and not to the moisture expansion because the ocular examination proved that no deformations were found in the marble slabs around the fountain centralized in the court which is used up till now for washing (wdoa) before every prayer as shown in (Figure 11).

Figure 11: The slabs which are around the fountain and always exposing to the water do not suffer from any deformations produced by expansion.

An example of the effect of thermal changes on marble is quoted by Kessler [4]. Certain marble tombstones were found to have developed a curvature. Kessler showed that, after heating, marble does not contract to its original length, but suffers a permanent set, a further deformation being produced at each repetition of the experiment [6].

The expansion and contraction because of the change of temperature cause serious movements in the floor structure and if a slab is restricted between other slabs and joints neatly with them they cause stresses resulting in deformations and cracks.

According to Joseph [3] the cracks and pores in rock form a continuous, interconnected network. One side of a crack slips over opposite side under differential stress.

4. EXPERIMENTAL:

4.1. Definition of the measured property

Thermal expansion property can be defined as follows; if the variation of linear dimension of a solid is **Δl/l= *ƒ* (t)**, the expansion coefficient is:

$$\alpha = \frac{\Delta l/l}{dt} = \frac{d f(t)}{dt}$$

It is expressed in relative variation of length by degrees for a given temperature. Naturally when ***ƒ* (t)** is a linear function in a certain temperature interval, the coefficient **α** *is a constant in that interval* [5].

4.2. Preparation of the tested samples

Fifteen samples from the three different colors of marble; the white, the red and the black; five samples from each color; were cut in the cylindrical shape with 5 cm diameter and 10 cm long.

4.3. Test method

4.3.1. Apparatus

The apparatus used for the determination of the thermal expansion is that one recommended by DIN 52450 [1].

4.3.2. Procedure

The procedure which was followed is according to RILEM, 1980 [5] where the samples were placed after drying in the apparatus. The apparatus samples assembly was placed in a thermal chamber where temperature was 10 °C.

The temperature was made to vary from 10 to 50 °C at a rate not exceeding 10 °C/h. Simultaneous recordings were made of temperature changes and deformation of the samples.

4.4. Formulation of results

The expansion coefficient was expresed by the ratio of the relative deformation of the sample to the temperature variation. It was expressed in m/m.°C.

5. RESULTS AND DISCUSSION:

The results obtained from the measured property can be shown in table 1 and figure 12.

Table 1: The thermal expansion coefficient values of the tested samples of marble.

Sample No.	Thermal Epansion Coefficient (x 10^{-6}/°C)
WM1	6.9
WM2	6.5
WM3	7
WM4	6.7
WM5	6.9
RM1	7.1
RM2	6.7
RM3	6.8
RM4	6.4
RM5	6.9
BM1	7
BM2	6.2
BM3	6.5
BM4	6.9
BM5	7.1

Legend: WM: White Marble, RM: Red Marble, BM: Black Marble.

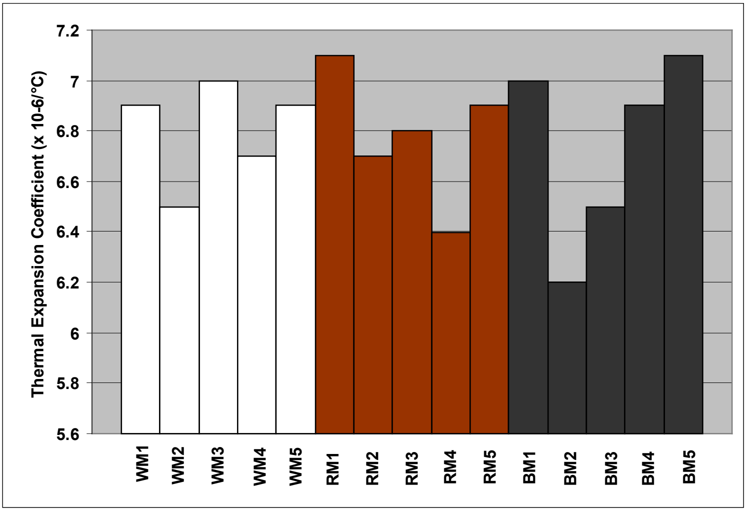

Figure 12: A comparison between the thermal expansion coefficient values of the measured marble samples of the different three colors.

The experimental confirmed the presented scientific view of the author concerning the attribution of the deformations types and cracks to the thermal expansion due to the temperature degree where the obtained results showed that the thermal expansion coefficient values of the three different kinds of marble according to their colors which range between 6.2 and 7.1 x 10^{-6}/°C are high and as a consequence the increase in their lengths which can be considered serious movements is enough to cause stresses. Such these stresses lead to the detected different types of deformations and cracks.

The comparison between the thermal expansion coefficient values of the five samples of each color on one hand and between the values of the three studied different colors of marble on the other hand showed that the differences between them are relatively small and this is due to their same mineralogical composition; where marble is composed of large crystals of calcite (calcium carbonate). The slight differences between them can be due to the accessory minerals, the impurities and to the weathering products which can be formed in marble before cutting from the quarries.

One red marble sample and one black; RM1 and BM5 respectively have 7.1 x 10^{-6}/°C and this is the highest thermal expansion coefficient value between the all values of the measured samples of three colors and this means an increase of 0.1 x 10^{-6}/°C for them more than the others. This difference is considered very slight and also was found in only one sample from five measured samples in each color; therefore the author can not say that the red and the black marble are more sensitive to the temperature and as a consequence more thermal expansive.

6. CONCLUSION:

The author recommends do not leave the court of the mosque continuously open especially in the summer season in order to avoid the very serious effect of the sun light and heat on the marble floor. Such this recommendation can be achieved by using mobile shelter which can be opened and closed at the suitable times according to the temperature degree.

The study of the effect of sun light on stone generally and on marble especially needs more efforts and experiments from the specialists because very few literatures mentioned it and at the same time many factors play important roles in this process should be determined. Such these factors may be determine to what extent the stone color is altered by sun light.

The study of the differences between the thermal expansion coefficients of the different kinds of marble due their colors needs more investigations to determine surely which kind has the higher thermal expansion coefficient and which has the lower and which compound or element is responsible for this.

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