Quality Index to Determine the Optimum Utility of Some Egyptian Stones as Ornamental Stones

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Abstract— A number of geotechnical analyses were carried out on selected samples from seven locations in Egypt. This was to assess the suitability of these rocks for ornamental uses. The analyses included uniaxial compressive strength, porosity, water absorption, hardness (SiO_2 content), resistance to abrasion and durability. Evaluation of these stones on the basis of a quality index (QI) scheme show that granite is an ideal ornamental stone used outdoor and indoor where marble is suitable mainly for enclosed spaces and serpentine permits both interior and exterior application.

Index Terms— Ornamental stone, Quality index, Marble, Granite, Serpentinite, Uniaxial compressive strength.

1 Introduction

An ornamental stone is a piece of stone used for decoration, this rock possesses beauty, durability, and stability, and it has been removed from its natural place of the origin for ultimate use for the construction of monuments. Geographical proximity, easy mining and transportation of the blocks from its original place make it more beneficial. The principal countries of producing ornamental stones in descending order are China, Italy, India, Egypt and Spain. These five countries contribute more than tow third of 53 million of metric tons of the total world production from 37 countries. Egypt produces more than 10 types of ornamental stones such as those made of grey granite, pink granite, marble, basalt, breccia, serpentinite, etc. [1].

Granite rocks are widely distributed all over the Egyptian Shield, constituting approximately 60% of its plutonic assemblage. Their colors are often white, pink, rose, grey, red, black and their derivatives. They range in composition from quartz diorite and tonalite, through granodiorite and quartz monzonite to normal granites and alkaline–peralkaline granites [2].

Marble is a precious ornamental stone used by man very early in history. True marble is found within the basement rock. The true marble is crystalline limestone that is characterized with diverse properties of dolomite. This kind of marble is available mainly in two places.

The first place is Wadi Al miyah which is located in the Eastern desert between Edfu and Marsa Alam, in this place, True marble has different color variation mainly white, black and gray. The second place in El sheikh Fadel that is in southeast of Ras Ghareb.

Serpentinite is one of the metamorphic rocks used by ancient Egyptians as building materials and ornamental stones. Serpentinites are referred to as "Green Marble" commercially, this name has no correspondence to their actual mineralogy, geochemistry and/or physical properties of serpentinites. Egypt is characterized by wide occurrence of serpentinites that are widely distributed in the Eastern Desert, particularly in the central and southern parts. Due to visual appearance obtained and good geochemical properties of serpentinites, they are still excellent large ornamental stones which are mainly used for structural purpose [3],[4].

This work aims to study these kind of stones and evaluate them as ornamental stones by compute a quality index using the weights of the parameters used and ratings by analyzing the determined physical and mechanical properties with an attempt to shed light on their mineralogical and chemical properties.

2. Location and Geological Setting

The present work has been investigated on seven types of ornamental stones in Egypt. Marble is represented in this study by three different types from three quarries as following:

- **Black marble**: El Barramia area Fig.2, Wadi El-Myah, Commercially known as Black Aspany. The rock body is made up of elongated rock mass with moderately higher elevation from the floor of the Wadi. The rock is massive, dark grey black in color and dissected by crowded white veins intersecting each other and scattered in the whole rock body [5].
- **White marble**: El Barramia area Fig.2, Wadi El-Myah, The white marble is commercially known Carrara.

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The hand specimen of marble is white in color and intersected by grey veins and massive to fine grain in texture. Under the microscope it is mainly of calcite and some nacre of quartz [5].

- **Sunny marble**: El sheikh Fadel marble quarry Fig.1, The hand specimen of marble white to brownish in color, fine grained in size and containing some lenses of quartz with some fractures. Under the microscope composed it is mainly of calcite and some traces from quartz and iron oxides as accessories. This rock containing some fossils [5].

Granite is represented in this study by three different types from three quarries as following:

- **Gray granite**: El Barramia area Fig.2, old granites, fine to medium grained and massive. It is characterized by quartz veins, and joints. It contains quartz, plagioclase, biotite, microcline and other accessory minerals. The quartz is colorless with euhedral shape [6].

- **Red granite**: Gebel Um Shaggier area Fig.1, younger red granites have similar characteristics to the famous Aswan monumental red granites, such as morphology, color, mineralogical composition, and crystal size. Course- to very coarse-grained and have subdural granular texture [7].

- **Pink granite**: Gabal El-Messala area Fig.1, the younger granitic rocks in Gabal El Messala are characterized by semicircular, coarse grain and pink color. This area appears the contact between Nubian sandstone and the basement rocks (granite). Large plutons and big blocks characterize these granitic rocks so uses economically as building materials [8].

Serpentine is represented in this study by one type as following:

- **Serpentine**: The Barramiya area Fig.2, antigorite is an essential serpentine mineral, with a minor amount of chrysotile, associated with talc-carbonates. Carbonates are the mixture of dolomite and magnetite with a trace amount of calcite. Trace amounts of chlorite, magnetite and chromite are also recorded [9].

Table 1. Location of studied rocks.

Stone name	Area	Latitude N.	Longitude E.
Black marble	Barramiya	25° 04' 56.50"	33° 47' 49.90"
White marble	Barramiya	25° 04' 23.10"	33° 47' 59.90"
Sunny marble	El Sheikh Fadel	28° 20' 49.40"	31° 48' 18.90"
Gray granite	Barramiya	25° 05' 16.50"	33° 47' 23.02"
Red granite	Um Shaggier	23° 15' 30"	31° 36' 46"
Pink granite	El-Messala	23° 58' 32.12"	33° 05' 49.20"
Serpentine	Barramiya	25° 01' 57"	33° 46' 37"

3. Sampling and Analytical Procedure

Twenty eight samples of each selected stones were collected at about 10–15 meter intervals, avoiding altered and fractured zones. The weathered interface materials were removed, particularly at the base of the profiles, to get fresh samples. Each sample represented a block measured at about 20–30 kg in weight.

3.1 Mineralogical and Chemical Characterization

The mineralogical and chemical characterizations of the samples studied were carried out using XRF and polarizing microscope. XRF was carried out using Phillips X-ray fluorescence Spectrometer Model PW16 Table 3. The loss on ignition was measured at 1000 C˚. Mineralogical composition of a rock is not enough to explain its geotechnical behavior because texture is also very important.

Fig. 1. Location map of the Study area.

By using polarizing microscope, microstructure variations

of studied samples were investigated in order to evaluate the effect of the texture and the mineralogical composition of the studied samples on their geotechnical behavior Table 2.

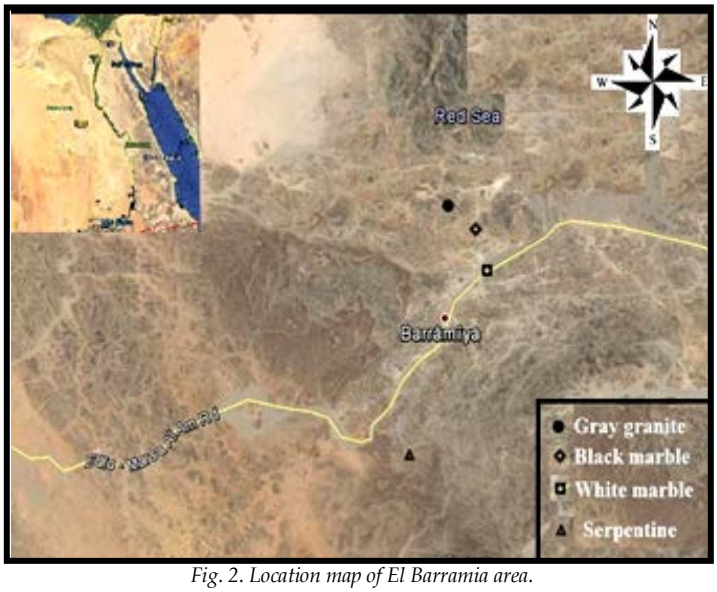

Fig. 2. Location map of El Barramia area.

Thin sections were taken from the selected stones (50X) Fig.3 and by using polarizing microscope, microstructure variations of studied samples were investigated in order to evaluate the effect of texture of the samples on their geotechnical behavior.

3.2 PHYSICAL PROPERTIES

Physical analysis (Density, Porosity and Water absorption) were carried out of the different type of the selected stones in accordance with the method out lined by [10],[11].

3.3 MECHANICAL PROPERTIES

Mechanical analysis included in this study are the uniaxial compressive strength, resistance to abrasion, durability and the point load strength. For the uniaxial compression test the correction of compressive strength values with respect to the L/D ratio (L = length and D = width) was conducted using the following formula According to [12],

$$Co = \frac{CP}{0.778 + 0.222\ D/L}$$

Where

Co Compressive strength values of the samples having a 1: L length to diameter ratio.

CP Compressive strength of the same samples for which $2 > (L/D) > 1/3$.

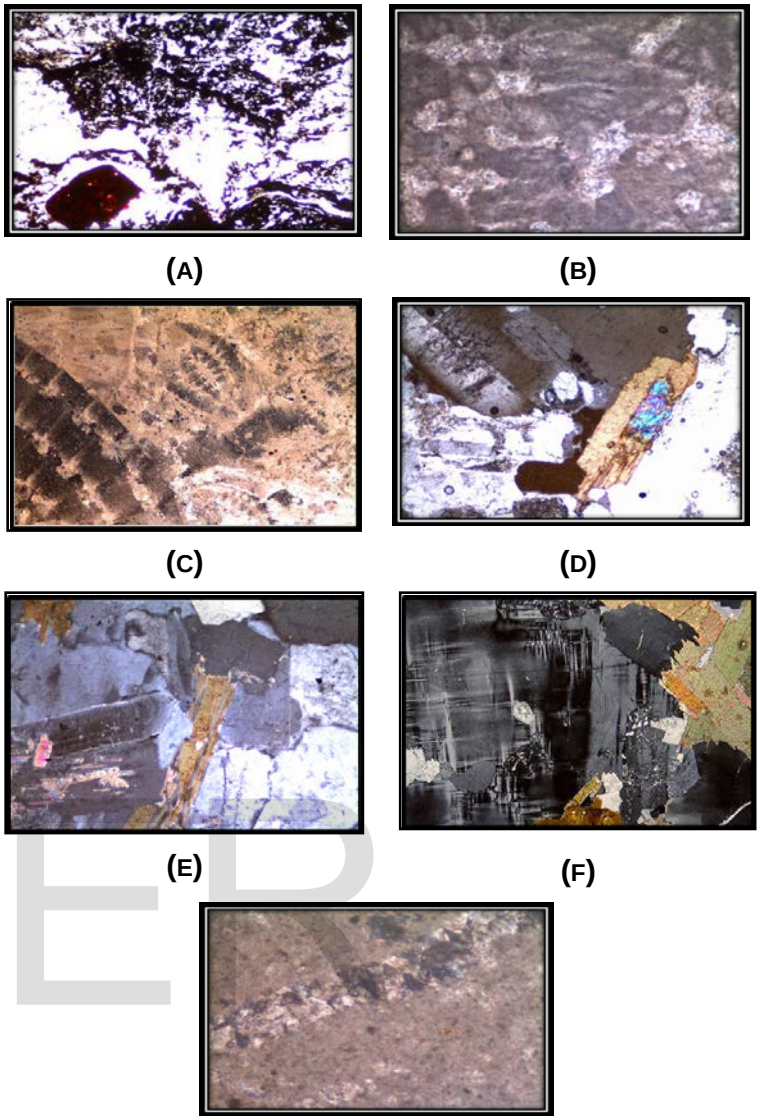

Fig. 3. Photomicrographs for the selected stones A: Black Marble B: White Marble C: Sunny Marble D: Gray Granite E: Red Granite F: Pink Granite G: Serpentinite

4. Evaluation of the selected stones as ornamental stones

Fitness for purpose is fundamental to the successful use of stone. There are sex basic keys to assist in the selection and specification of the right stone for the different purpose. The keys are relevant to all stone users and specifiers, and they provide a useful starting point for choosing the right stone. The four keys are (water absorption, strength, resistance to abrasion, durability, porosity and hardness).

Table. 2. The petrographic description of the studied stones according to thin sections.

Stone type	Description
Black Marble(A)	Composition is calcite, iron oxides. Texture decussate (Horn Felsic). Grade of metamorphism is high. Type of metamorphism is regional. And granularity fine to medium.
White Marble(B)	Composition is calcite, recrystallization shell fragments. Texture decussate (horn felsic) type of metamorphism thermal. Grade of metamorphism low. Granularity fine grains.
Sunny Marble(C)	Composition of calcite as major constituent associated with traces of iron oxides and opaque minerals. The matrix of the rock composed of very fine-grained calcite (micrite) admixed with small and crushed fossil fragments and admixed with traces of iron oxides and opaque minerals. Microfossils and shell fragments present as large to medium size and embedded in the matrix of very fine grained calcite.
Gray Granite(D)	Composition granite consist of quartz, plagioclase, orthoclase, biotite and iron oxides. Coarse to medium grained. Texture is equigranular. The mode of occurrence is plutonic. Acidity is from 65% to 70%.
Red Granite(E)	Composition mainly of potash feldspars (about 50-55%), quartz (about 15-20%), plagioclase (about 15-20%) and mafic minerals (as biotite& hornblende 7- 10%) with rare amounts of muscovite and opaque minerals.
Pink Granite(F)	Composition mainly of quartz (45-55%), microcline (35%), plagioclase (15%) and biotite (5%). Quartz is predominantly fractured indicating deformation under brittle conditions and show grnoblastic texture. Coarse to medium grained. Texture is equigranular. The mode of occurrence is plutonic.
Serpentinite(G)	Composition is quartz, shell fossil fragments, iron oxides. Texture bio-chemical. Origin bio-chemical. Granularity fine to medium. Grade of metamorphism high.

Table. 3. Geochemical analysis for the studied stones.

Comp.	A	B	C	D	E	F	G
SiO_2	6.02	Traces	Traces	71.5	73.9	75.7	50.7
Al_2O_3	0.63	0	0.08	10.9	13.8	10.3	8.01
Fe_2O_3	0.44	0	0.12	2.49	2.60	3.1	9.6
TiO_2	0	0	0	0.72	0.20	0.4	2.1
MgO	4.41	29.29	39.02	3.24	0.80	0.3	10.2
CaO	86.1	69.8	57.5	4.5	1.5	0.3	18.5
K_2O	0	0	0.06	2.29	3.50	4.5	0
Na_2O	0	0	0.06	4.01	4.02	4.6	0
P_2O_5	0.40	0	0	0	0.45	0.09	0
CL	0.77	0.84	0.99	0	0.01	0	0
SrO	0.23	0	0	0	0	0	0
MnO	0	0	0	0.23	0.01	0.03	0.5
∑	99.07	100	98.9	99.9	100	99.6	100

Table. 4. Physical and mechanical properties of the studied stones.

Properties	A	B	C	D	E	F	G
Density gm/cm³	2.68	2.62	2.86	2.57	2.62	2.67	2.82
Porosity%	1.04	0.26	1.08	0.37	0.46	0.58	0.30
Water absorption%	0.21	0.03	0.49	0.028	0.04	0.049	0.036
Abrasion gm/cm²	0.380	0.45	0.40	0.052	0.054	0.072	0.189
Compressive Strength Kg/cm²	378.5	433.2	408.5	895.4	836.8	454.0	454.0
Slake Durability%	97.94	96.51	97.0	99.75	99.55	99.31	99.69
Point load testKg/cm²	62.02	46.8	44.46	98.05	94.46	89.12	44.96

The quality index is used to rate the potential use of the selected stones as ornamental stones. The basic ideas are taken from other rock mass classification techniques [13],[14].

Clifford Teme [15] used the quality index method to evaluate some Nigerian carbonate rocks for the building construction industry.

Tarun Kumar [16] aimed to develop a standard analysis system based on micro geoparametrical and geotechnical studies which would help in the determination of the in-situ value of decorative stones and found that this technique is more accurate than the ad hoc methods currently used for quarrying and will reduce wastage of good quality stones, improve handling and have significant transport savings. Also helpful in managing the environment as regards land use.

Mahrous, A.M [17] used the quality index classifications to determine the suitability of limestone for different purposes such as building, road construction and cement manufacture.

The method of evaluation involves three steps. The first is to

assign weights to the parameters, the second step is to analyses the determined physical and mechanical parameters by assigning ratings and the final step is to compute a quality index using the weights and ratings.

4.1. Assigning weights

On the basis of the relative importance of the physical and mechanical parameters as criteria for the quality of the selected stones as ornamental stones, the parameters are classified qualitatively into six categories and are assigned weights for indoor and outdoor applications Table 5.

Table. 5. Weight assigned to various parameters.

Category	Parameter	Weight (outdoor)	Weight (indoor)
1	Uniaxial compressive strength (CS)	6	2
2	Hardness (H) (SiO_2 content)	5	1
3	Abrasion (A)	4	3
4	Water absorption (W)	3	5
5	Porosity (P)	2	6
6	Durability (D)	1	4

4.2. Assigning rating

The six parameters are divided into different intervals and a rating is assigned to each interval as indicated in Table 6. The most significant interval has a rating of 5 and the least significant a rating of 1.

4.3. Quality Index, QI

To evaluate a specimen, the quality index is computed by taking the sum of the product of weights and ratings of all the parameters, i.e.:

$$QI = CS_wCS_r + H_wH_r + A_wA_r + W_wW_r + P_wP_r + D_wD_r$$

Where subscripts w and r indicate the weights and rating for each parameter. On the basis of this equation, a general quality scheme is given in Table 7 and the studied stones evaluated are shown in Table 8, 9.

Parameter	Rating				
	1	2	3	4	5
Uniaxial compressive strength (kg/cm^2)	< 250 Very low	250-500 low	500-750 medium	750-1000 High	>1000 Very high
Hardness (SiO_2 content %)	<5 Very low	5-25 low	25-50 medium	50-75 High	>75 Very high
Abrasion %	>0.5 Very low	0.5-0.3 low	0.3-0.1 medium	0.1-0.05 High	<0.05 Very high
Water absorption %	>0.75 Very high	0.75-0.5 High	0.5-0.25 medium	0.25-0.1 low	<0.1 Very low
Porosity %	>2 Very high	2-1.5 High	1.5-1 medium	1-0.5 low	<0.5 Very low
Durability %	<30 Very low	30-60 low	60-85 medium	85-98 High	>98 Very high

Table. 6. Ratings assigned to various ranges of the parameter

Table. 7. Quality assessment of the selected stones as ornamental stones

Class	*Quality index value*	*Description as Ornamental stone*
I	*>100*	*Excellent*
II	*80-100*	*Very good*
III	*60-80*	*Good*
IV	*40-60*	*Fair*
V	*20-40*	*Poor*
VI	*<20*	*Very Poor*

5. Result and Discussion

From the results obtained in table 10 and Fig. 4, marble is a carbonate rock that is easy to grind and polish but has lower hardness compared with granite. The products made of this material are not resistant to the adverse weather conditions, which makes them suitable mainly for enclosed spaces. However, marble is much more richly colored and patterned than granite.

Marble's beauty will last for generations and is versatile enough for use throughout the home in such places as fireplace surrounds, ornamental furnishings, walls, flooring, and bathrooms.

Table. 8. Calculation of quality index for different rocks on outdoor applications

Rock type	CS		H		A		W		P		D		QI
	w	r	w	r	w	r	w	r	w	r	w	r	
Black marble	6	2	5	2	4	2	3	4	2	3	1	4	52
White marble	6	2	5	1	4	2	3	5	2	5	1	4	54
Sunny marble	6	2	5	1	4	2	3	3	2	3	1	4	44
Gray granite	6	4	5	4	4	4	3	5	2	5	1	5	90
Red Granite	6	4	5	4	4	4	3	5	2	4	1	5	88
Pink Granite	6	3	5	5	4	4	3	5	2	5	1	5	89
serpentine	6	2	5	4	4	3	3	5	2	5	1	5	74

Table. 8. Calculation of quality index for different rocks on intdoor applications

Rock type	CS		H		A		W		P		D		QI
	w	r	w	r	w	r	w	r	w	r	w	r	
black marble	2	2	1	2	3	2	5	4	6	3	4	4	66
White marble	2	2	1	1	3	2	5	5	6	5	4	4	82
Sunny marble	2	2	1	1	3	2	5	3	6	3	4	4	60
Gray granite	2	4	1	4	3	4	5	5	6	5	4	5	99
Red Granite	2	4	1	4	3	4	5	5	6	4	4	5	93
Pink Granite	2	3	1	5	3	4	5	5	6	5	4	5	98
serpentine	2	2	1	4	3	3	5	5	6	5	4	5	92

Table. 10. Quality indices for the different studied stones

Stone type	QI outdoor	Class	QI indoor	Class
Black marble	52	IV (Fair)	66	III (good)
White marble	54	IV (Fair)	82	II (v. good)
Sunny marble	44	IV (Fair)	60	III (good)
Gray granite	90	II (v. good)	99	II (v. good)
Red Granite	88	II (v. good)	93	II (v. good)
Pink Granite	89	II (v. good)	98	II (v. good)
serpentine	74	III (good)	92	II (v. good)

Marble especially stands out in the bath. It can be applied on almost every surface, including vanities, shower walls, tub decks and flooring.

Marble is more susceptible to staining by many foods, spilled liquids and other household materials, it's not recommend their use for kitchen countertops. Softer and more porous than granite, marble is more suitable for less-trafficked, formal areas.

Granite is a symbol of hardness, strength and durability. The products made of granite materials are practically eternal. Granite is a much more durable and functional stone than marble. Granite's crystalline structure is far more resistant to abrasions, staining and discoloration than most marbles. Denser and stronger than all natural stones, granite is an excellent choice for high traffic areas where class and style is desired.

Granite feels at home in a country farm house as well as a modern high rise. The variety of colors and textures are traits that set granite apart from the rest. This remarkable stone is ideal for kitchen countertops, accent islands, bar tops, dining tables, flooring, etc.

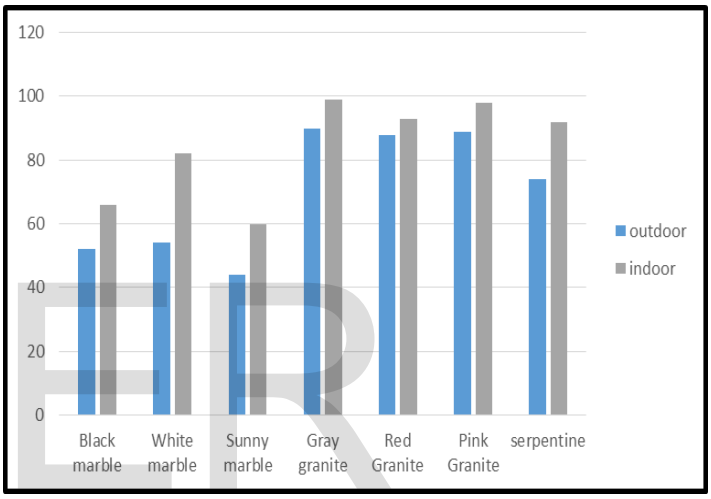

Fig. 4. Outdoor and Indoor Quality Index for selected stones

Serpentine is a siliceous metamorphic stone of igneous origin, composed originally and essentially of hydrated magnesium silicate. Veined with calcite or dolomite, it is usually green to greenish-black.

Serpentines is resistant to weathering but suffer from acidic cleaning agents in interior use, whereas the serpentine with a high content of talc used on external faces would undergo an increase in volume and a consequent rapid degradation.

Great durability of serpentine permits both interior and exterior application. Serpentine is a very stable interior decorative stone, but is readily attacked outdoors by a polluted urban atmosphere with a high SO_4 content.

6. Conclusions

seven types of stones were been classified using the quality index to evaluate them as ornamental stones and the results shows that granite is a very good in outdoor and indoor applications where marble is suitable mainly for enclosed spaces and serpentine permits both interior and exterior application.

Gaining information to make an informed choice can often be difficult, especially with the large volume of untraceable and untested material flooding into the country. As an end-user of

stone, it is up to you to demand at least the basic information you require to make an informed choice. Evaluation of basic technical data such as water absorption, strength (compressive and/or flexural), abrasion resistance and durability will give you the ability to choose what best suits your needs.

REFERENCES

[1] S. Nopoli, Marina di Carrara [M]. Internazionale, Italy.Obert, Leonard Duvall Wilbur I.(1967)Rock mechanics and the design of structures in rock[M].John Wiley and Sons, New York, London,Sydney,pp.650., 1988.

[2] M. F. El Ramly, "A New Geologic Map of The Eastern and South-Western Desert of Egypt.Scale 1:1000, 000," Annals Geological Survey of Egypt vol. V12, pp. pp.1-18, 1972.

[3] B. G. Aston, Harrell, J.A., Shaw, I., "Stones in Ancient Egyption Materials and Technology" (eds. P.T.Nicholson and I. Shaw)[m]. 2000.

[4] H. J.A., "Stones in Ancient Egypt [M]," Department of Enviromental Science, Univ. of Toledo, USA.World Wide Web Address:http://www.eeescience.utoledo.edu/egypt/, 2007.

[5] M. Abdel Rahman, Abdel Nasser., "Variation of Geotechnical properties of rocks in relation to microgeological factors," Ph.D. Thesis, Assiut University, Egypt, January, 1998.

[6] T. J. Fowler, "Pan-African granite emplacement mechanisms in the Eastern Desert, Egypt," Journal of African Earth Sciences Journal of African Earth Sciences, vol. 32, pp. 61-86, 2001.

[7] H. M. Assran, "Petrology and radioactivity of the famous Aswan monumental red granites new occurrence, Gebel Um Shaghir area, South Western Desert, Egypt," Arab J Geosci Arabian Journal of Geosciences, vol. 8, pp. 7719-7729, 2015.

[8] S. A. Issa, M. A. Uosif, and L. M. Abd el-Salam, "Natural radionuclide concentrations in granite rocks in Aswan and Central-Southern Eastern Desert, Egypt and their radiological implications," Radiation protection dosimetry, vol. 150, pp. 488-95, 2012.

[9] I. Ismael and M. Hassan, "Characterization of some Egyptian serpentinites used as ornamental stones," Chinese Journal of Geochemistry, vol. 27, pp. 140-149, 2008.

[10] R. E. Goodman, Introduction to rock mechanics. New York: Wiley, 1980.

[11] ISRM, Suggested methods for determining the uniaxial compressive strength and deformability of rock materials. International Society for Rock Mechanics, 1979.

[12] L. Obert and W. I. Duvall, Rock mechanics and the design of structures in rock. New York: Wiley, 1967.

[13] S. Murthy, "Evaluation of physic-mechanical properties of granitic rocks," Indian Min Eng. Jl 2:77–87, 1992.

[14] J. A. Blanco, Fallick, A., Peinado, M., Pereira, D., Thomas, H., Upton, B., Yenes, M. Characterization of serpentinites to define their appropriate use as building stones [J]. Geological Reasearch Abstracts.7. 2005.

[15] S. Clifford Teme, "An evaluation of the engineering properties of some Nigerian limestones as construction materials for highway pavements," ENGEO Engineering Geology, vol. 31, pp. 315-326, 1991.

[16] C. Tarun Kumar, Rima Singh, S. K., "Classification of black decorative stones from Warangal District, Andhra Pradesh, India," Bull Eng Geol Environ Bulletin of Engineering Geology and the Environment, vol. 64, pp. 167-173, 2005.

[17] A. M. Mahrous, M. M. Tantawi, and H. El-Sageer, "Evaluation of the engineering properties of some Egyptian limestones as construction materials for highway pavements," JCBM Construction and Building Materials, vol. 24, pp. 2598-2603, 2010.