

The Application of Marble and Granite as Building Materials in Jordan

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ABSTRACT

Marble and granite rocks are very important in construction industry. Importing these materials to Jordan from other countries is expensive. This research aims at studying the physical and mechanical properties of Jordanian marble and granite which are widely used as building materials in construction industry in Jordan to ensure their compliance with the minimum construction requirements. Marble was tested for absorption, specific gravity, compressive strength, modulus of rupture, abrasion resistance and hardness. Results showed that Jordanian marble satisfies the minimum requirements as per ASTM C170, C99, C241 and Mohs scale. Specific gravity, absorption, flexural index, modulus of rupture and compressive strength properties were tested for Jordanian granite. The results revealed that the minimum requirements were achieved as per ASTM C97, C241, C880 and C99.

KEYWORDS: Jordanian marble, Granite, Metamorphic rocks, Compressive strength, Igneous rocks.

INTRODUCTION

In today's building environment, the emphasis is on safe, permanent and low maintenance products, of which stone leads the list in the minds of architects, designers and consumers worldwide. Without a consistent, realistic set of standards and testing procedures for stone products, the stone industry as a whole would be in disarray. The standards that have been developed and set in place for these products are important tools to help protect end users, individual companies and the industry from negative effects related to product failures. Materials' standards help prevent the use of stone products for unsuitable applications. For instance, without the minimum standards for abrasion resistance of stone subjected to foot traffic (ASTM C241), it would be more likely that very soft, easily damaged materials would be installed in commercial applications. This may cause the owner to incur

additional cost for repair and maintenance and negatively affect the reputation of the stone industry as a whole (MIA, 2016).

Marble and granite are widely used as construction materials in the Jordanian markets. Reports from some of end users were negative. Hence, testing such rocks for their engineering properties is imperative.

Marble is a non-foliated metamorphic rock consisting of coarse crystals primarily from limestone and dolomite. It is also defined as "a metamorphic crystalline rock composed predominantly of crystalline grains of calcite, dolomite or serpentine and capable of taking a polish (ASTM C119).

According to Georgia State University Department of Physics and Astronomy, pure marble composed of calcite is white. This versatile rock has been used for centuries by sculptors and artists. Modern uses include the construction of countertops and floors in home hallways and stairs due to its attractive colors such as green, brown, dark violet and black (Bani Baker et al., 2015).

Marble can be of two types, one composed of calcite and the other of dolomite. Dolomitic marble is much

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more resistant to acid attack than calcite marble. The color of marble ranges from brilliant white of calcite to black, including blue-gray, red, yellow and green, depending upon the mineral composition (MIA, 2012).

The occurrences of marble are found in many areas in Jordan: Al-Karak, Ajloun, Madaba and Amman. But the most abundant occurrence is in Ajloun. Its properties make it the most wanted Jordanian marble (El-Sewan Company for Stones, 2014).

Granite is an igneous intrusive rock and one of the hardest and most dense types of rock. It is defined as a visible granular, igneous rock generally ranging in color from pink to dark grey and consisting mostly of quartz and feldspar accompanied by one or more dark minerals (ASTM C615).

The significant physical and mechanical properties of granite make it meet the demands of several applications in construction industry, especially in ornamental finishing stages of buildings, pavings, city bridges and countertops.

JORDANIAN MARBLE

Jordan is one of the leading marble producing countries in the Middle East. The manufacturing process involves cutting and finishing marble obtained from quarries, where specific dimensional marble is prepared for various uses in specialized mills equipped with saws, polishing machines, among others.

Ajloun's marble is the most abundant in Jordan and is located on the ground surface. So, it is easy to excavate without blasting. That makes Ajloun's marble less expensive compared to other types of marble.

Marble does not occur in exploitable quantities in Jordan. However, thermo-metamorphosed limestone occurs as lenses and irregular bodies within the bituminous facies in the upper part of the Muwaqqar Chalk Marl Formation (Nassir and Khouri, 1982).

According to investigations of NRA, exploitable marble occurs in areas between Daba'a and Qatrana, south of Amman (Barjous, 1986).

Jordanian marble is hard, dense, partially

recrystallized and strongly affected by tectonic movements. It is varicolored by iron oxides, bituminous matter and traces of chromium, nickel, vanadium and uranium bearing minerals (Nassir and Khouri, 1982).

In construction material industries in Jordan, especially ornamental stone industry, mainly marble and granite are of high importance and widespread. Rocks of different colors are quarried at depths of 20-60 m from various sites and processed in more than 2000 registered factories in Jordan to produce marble and granite (Bani Baker et al., 2015).

Marble is formed predominantly of calcite (CaCO_3), feldspar and quartz. Recent studies demonstrated the possibility of incorporating marble and granite sludge slime as additives into clay-based ceramic products (Ferreira et al., 2002; Crespo and Rincon, 2001).

PROPERTIES OF MARBLE

Jordanian marble composed of dolomite consists of 28% MgO, 1% SiO₂, 69% CaO and 2% Fe₂O₃.

Marble was tested for six major physical and mechanical properties: absorption, specific gravity, compressive strength, modulus of rupture, abrasion resistance and hardness. Test results satisfy the minimum allowance of using marble in construction industry as per ASTM requirements except for absorption which exceeded the minimum benchmark as listed in Table 1.

Table 1. Physical and mechanical test results of Jordanian marble

Property	ASTM requirements	Jordanian marble
Absorption	ASTM C97<0.75%	1.8-3.9%
Specific gravity	ASTM C97>2.5	2.49-2.58
Compressive strength	ASTMC170>52 N/mm ²	79.5N/mm ²
Modulus of rupture	ASTM C99>7N/mm ²	10.1 N/mm ²
Abrasion resistance	ASTM C241>10 units	127 units (NRA, 2013)
Hardness	Mohs scale>3	3-3.5

GRANITE IN JORDAN

Jordan's estimated reserves of granite include nearly 15 million metric tons. Granite is located in Aqaba in huge granite mountains, which are located on the surface in very large quantities. Granite is also located in Jabal Umm Ishrin, Wadi Rahma, El-Quwayra, Ras-En-Naqab, Petra, Wadi El-Lehyana, Qurayqira, Ashshobak and Al-Karak. These rocks form the basement of Jordan and are considered to be the north eastern extension of the Afro-Arabian shield (referred to as Nubo-Arabian shield). The basement rocks in the southwest of Jordan are predominantly igneous in origin and constitute the northern most portion of the Arabian shield (Rabba et al., 1996).

In Jordan, feldspar deposits are found in alkali granite rocks, leucogranite, feldspar pegmatite and alkali-rich granite, occurring as medium- to coarse-grained, light colored igneous rocks such as aplites and alaskite, respectively, have a granite composition and are characterized by low content of iron-bearing minerals. These deposits are located in the following areas: Al-Jaishieh area, 6km south of Aqaba, Wadi Sadir Mulghan area, 25km north of Aqaba and 8 km to the west (Shakrour et al., 2010).

There are different types of granite rocks depending on the chemical composition and constituents of quartz, mica and feldspar. Natural granite in Jordan is available in many colors: black, ruby red, mauve, pink, violet and gray.

PROPERTIES OF GRANITE

Granite is primarily composed of feldspar, quartz and other minerals in varying percentages as listed in Table 2.

Absorption, specific gravity, compressive strength, modulus of rupture, abrasion resistance and flexural strength tests were conducted on Jordanian granite samples. Results as listed in Table 3 reveal that granite passes the ASTM requirements for application as building material in construction industry.

Table 2. Chemical components of granite

Component	Percentage (%)
Silica	70-77
Alumina	11-14
Potassium oxide	3-5
Soda	3-5
Lime	1
Iron (Fe ₂ O ₃)	1-2
Iron (FeO)	1-3
Magnesia	0.5-1
Titian	0.38
Water	0.03

Table 3. Physical and mechanical test results of Jordanian granite

Property	ASTM requirements	Jordanian granite
Absorption	ASTM C97<0.4%	0.26%
Specific gravity	ASTM C97>2.56	2.64
Compressive strength	ASTM C170>131MPa	198.75MPa
Modulus of rupture	ASTM C99>10.34 N/mm ²	26.31N/mm ²
Abrasion resistance	ASTM C241>25%	25.6% (NRA, 2013)
Hardness	Mohs scale	6-6.5
Flexural strength	ASTM C880>8.27MPa	13.1MPa

APPLICATION OF MARBLE AND GRANITE AS BUILDING MATERIALS

Due to availability and low cost of Jordanian marble and granite that pass the requirements stated by ASTM and the Jordanian specifications for building materials, they are widely used in construction industry as building materials.

Marble is used for its beauty in architecture and

sculpture. Moreover, it is an abundant and low-cost commodity used in crushed stone prepared for construction projects. It is also widely used in hallways, guest rooms, decorations, washrooms and stairs. Jordanian marble has high absorption compared to ASTM C97 which can range from 1.8% to 3.9%. Some rocks are being sold to the end users in Jordanian markets as marble, although these rocks do not pass the minimum requirements to be used as construction materials. These rocks are mainly hard limestone (sedimentary rocks) which did not reach the

metamorphic rock state. Hence, some marble rocks have foliation, which makes them inappropriate for construction applications.

Jordanian granite passes all requirements stated by ASTM to be used as construction material. Granite is generally more expensive than marble. However, due to its resistance to acidity and very low absorption, it is widely used in kitchen countertops, solid slab decorations, building stones, flooring tiles, paving stones, curbing and other decorations. Figure 1 shows multiple photos of marble and granite uses in buildings.

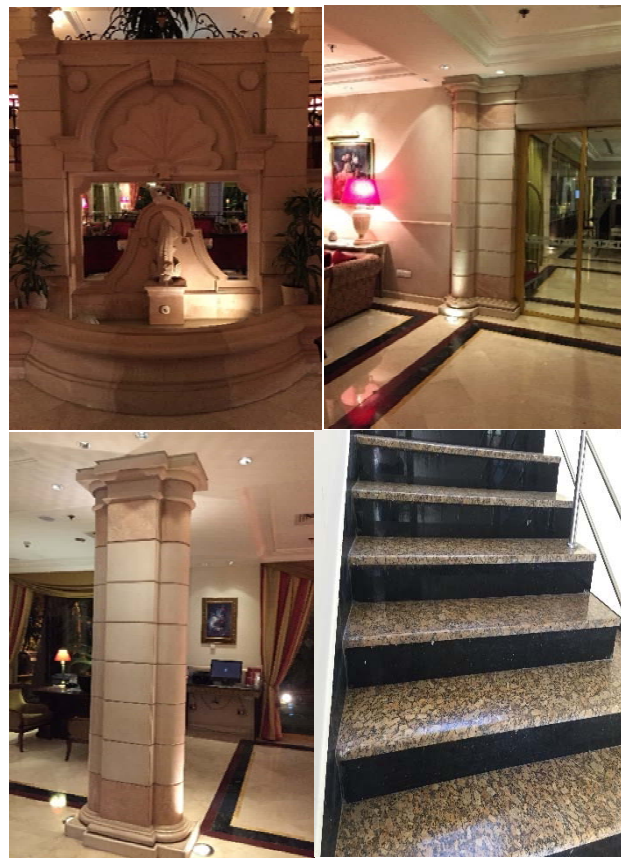


Figure (1): Application of marbel and granite as building materials in Jordan

CONCLUSIONS

- Jordanian granite satisfies the specifications of ASTM: C97, C99, C170, C241, C503 and C880.

Hence, it can be used in industry by the end users as a construction material with confidence.

- Jordanian marble does not pass the minimum benchmark requirement for absorption according to

ASTM C97. Generally, it has higher absorption than 0.75%.

- Some rocks in Jordanian markets are being sold to

end users as marble (metamorphic rocks) while they are hard limestone (sedimentary rocks).

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