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A Case Study of the Compressive Strength of the Typical Rock Formations in Lebanon

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Abstract: The Characteristics of the Lebanese Rock Formations is not well known. In general the types of rocks have been identified but what is lacking is the most important parameter that is the strength of these rock formations. In this study the strength of ten different rock types are investigated.

Key words: Lebanese Rock Formation, strenght, rock types, compressive, anticlines, syncline

INTRODUCTION

The three fundamental divisions of Lebanon; A western Mount Lebanon rising to 3083 m, a central Bekaa Valley and an eastern Jebel Lubnan al Sharqi or Anti-Lebanon Range with Mount Hermon at 2814 m. It is worth remembering that the Bekaa is almost everywhere above 850 m in altitude and that this is as high as some of the highest mountains of many countries.

There is a hierarchy of folds in Lebanon. The major geological structures of the area, Mount Lebanon, the Bekaa and the Anti-Lebanon (Fig. 1 and 2) are basically two very large NNE-SSW trending anticlines separated by a large syncline. They have however been broken up and disrupted later by a series of major and minor faults. These form what we can call the first order structures or mega structures. Smaller folds occur locally but, in general, the brittle limestone rocks of the region have deformed more by faulting than folding. Perhaps the most spectacular folds are the overturned beds at Nabi Ayoub along the southwestern part of the Baruk-Niha ridge. Immediately east of the Yammouneh Fault a number of small NE-SW trending anticlines occur. Other good folds occur in the Tripoli area (i.e., at Jebel Terbol). A major fold that is widely seen is the NNE-SSW trending Western Lebanon Flexure that runs from the western edge of the Chouf up to the latitude of Tripoli inland of the coast. This feature is technically a monocline and in places gives steep and even vertical dipping rocks.

ROCK TYPES IN LEBANON

Almost all the rocks in Lebanon are sedimentary rocks and most of these are pale limestones (Fig. 1). These and/or the snow cover may be the origin of the name as L-B-N is 'white' in the Semitic languages. Despite the vast thickness of limestone one can say that the variation in limestone types is rather limited; much of it is so fine grained that it needs a microscope to show any interesting features. The most varied sequence of sediments is that which extends from Late Jurassic to the Middle Cretaceous (Fig. 2) and shows a considerable variety of limestones, sandstones, clays and volcanic ashes (Fig. 3). The ashes tend to weather to a bright red or purple color and to give fertile soils. The only igneous rocks are basaltic flows and intrusions of a variety of ages. The only metamorphic rocks are confined to narrow bands around the edges of the intrusions.

ROCK TYPES

Ten different types of rock were investigated in this study. The types of rocks are listed according to their Lebanese known local names.

Testa: A pure white limestone can be found in high Jbeil (Byblos) and Batroun region (Tartej).

Ersali: A brown to yellow limestone, can be found in Ersal (North Baalbeck)

Kesrwane: A massive gray to brown limestone can be found in Kesrwan region (Bekaata).

Deir El-Ahmar: Mixed ivory and pink massive limestone, found in Deir el- Ahmar (on the road between Bcharre and Baalbeck).

Cheera: A massive light, sometimes dark, brown limestone can be found in North Lebanon in high Koura region (above Amioun).

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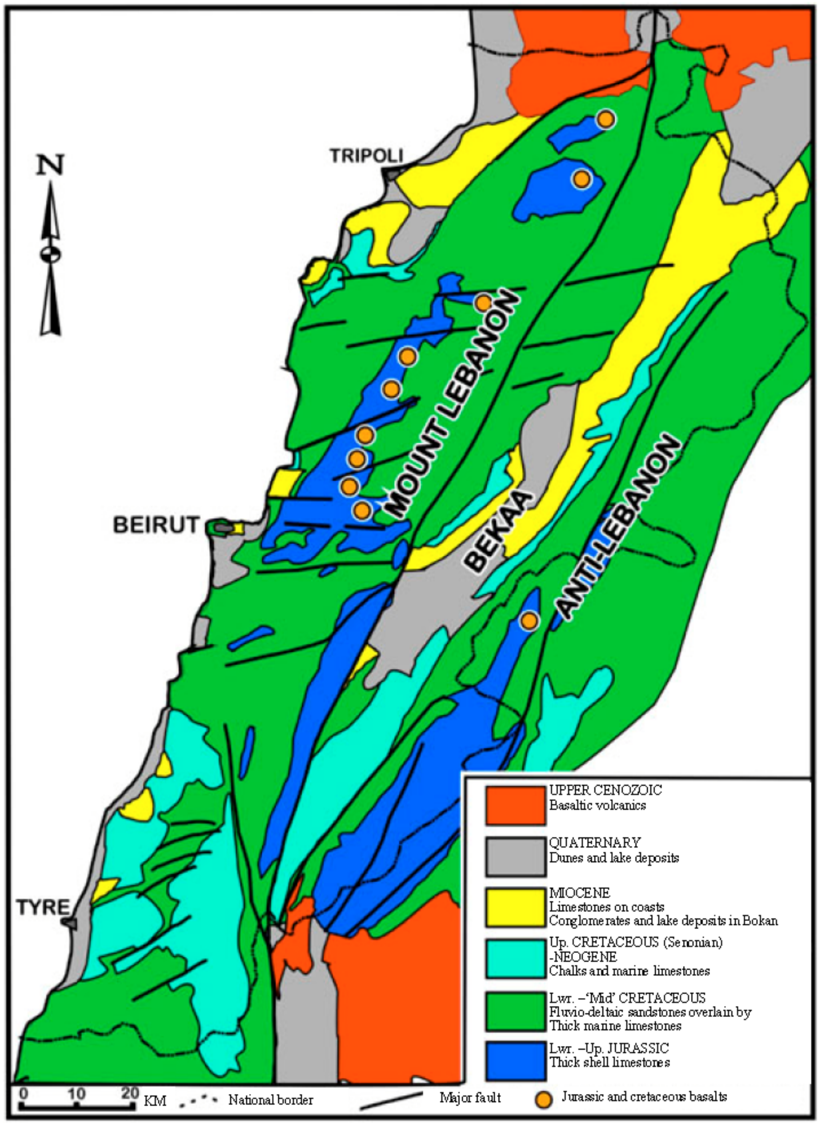

Fig. 1: Simplified Geological Map of Lebanon (http:// almashriq.hiof.no/ddc/projects/geology/geology-of-lebanon)

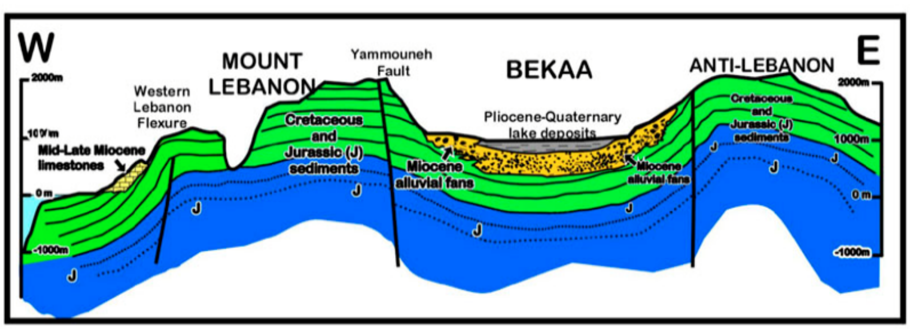

Fig. 2: Schematic East-West Cross Section Across Northern Lebanon (http://almashriq.hiof.no/ddc/ projects/geology/ geology-of-lebanon)

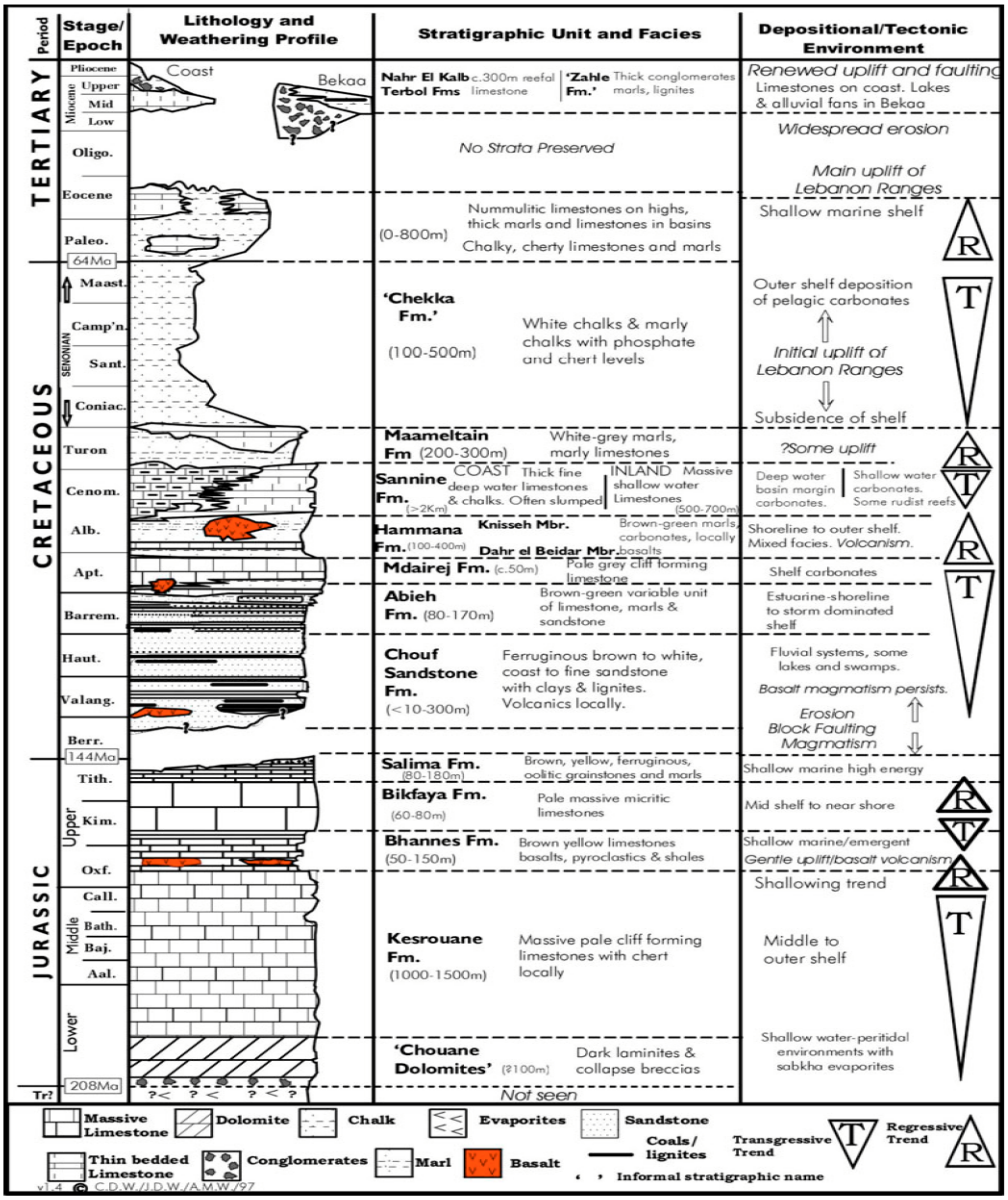

Fig. 3: Summary stratigraphic table (http://almashriq.hiof. no/ddc/projects/geology/geology-of-lebanon)

Sidawi: An ivory white chalky limestone can be found in Saida (Sidon) region.

Basalt: The only igneous rock in Lebanon, can be found in Akkar region (North Lebanon, on the Syrian border).

Abou dofr: A mixture of yellow and brown, sometimes blue, limestone can be found in Kartaba region (medium to high Jbeil region).

Kour: A white to yellow limestone can be found in Kour (middle Batroun region).

Sawan: A pure blue to gray massive limestone can be found in Nahr Ibrahim region.

Figure 4 show the rock types in their Natural setting and during testing sample collection and testing.

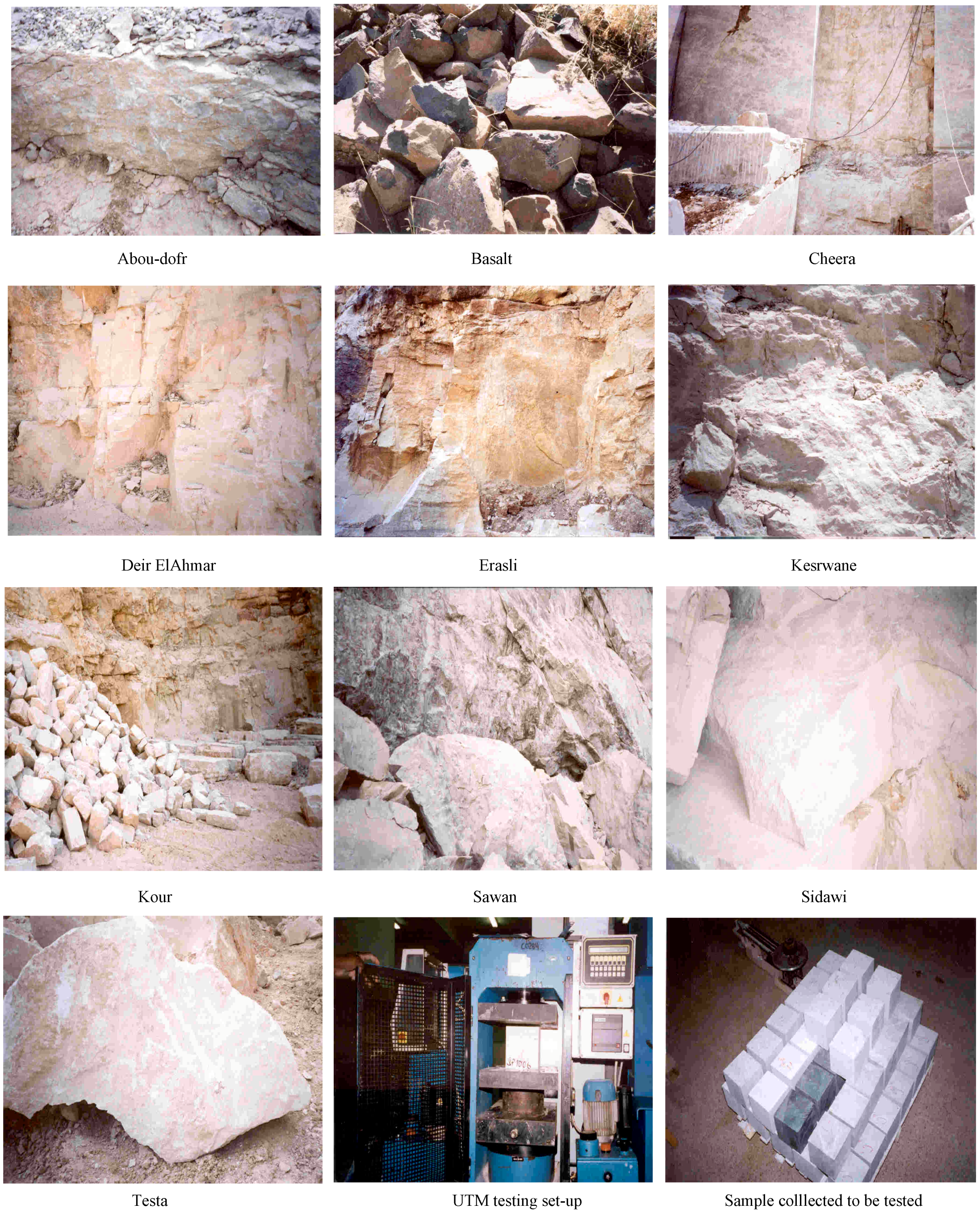

Fig. 4: The different types of rock formations and test procedure

MATERIALS AND METHODS

Six samples of each one of the ten rock formation types are collected in forms of 15×15×15 cm cubes. The following test results are recorded in conformation with ASTM (1997) (American Standard Testing Method) and they follow:

Absorption and porosity: An absorption and porosity tests are performed on the rock samples according to

ASTM C97-96. Each sample is weighted before and after it is immersed for 48 h in water.

$$\text{Absorption\%} = \frac{(\text{SW} - \text{DW})}{(\text{DW})} * 100 \qquad (1)$$

SW = Saturated Weight of the sample, in grams, (after immersion).
DW = Dry weight of the sample, in grams, (before immersion).

$$\text{Porosity\%} = \frac{(\text{Vv})}{(\text{Vt})} * 100 \qquad (2)$$

Vv = Volume of voids in the sample, in cm^3.
Vt = Total volume of the sample, in cm^3.

The volume of voids is obtained by simply assuming that (SW-DW), which is the weight of water absorbed by the sample, is the volume of water since the density of water is 1g cm^{-3}. Also, this volume of water is assumed to be the volume of the pores inside the sample. Vt = $15*15*15$ cm^3.

Compressive strength: Compressive Strength test are performed on the samples after the absorption and porosity tests would have been accomplished. The tests are performed according to ASTM C 170-90. Each sample is placed the Universal Testing Machine (UTM) and the sample is tested to failure, thus measuring its Compressive Strength (CS) in kg cm^{-2}. The samples are to be tested randomly regardless of the direction of any pre-existing cracks.

RESULTS

The Table 1 displays the test average of samples results for the ten different rock formation types.

Table1: Average test results for ten samples of each rock mass type

Type	DW	SW	Absorption	Porosity	CS (MPa)	Density
Testa	8522.50	8589.93	0.79	2.01	76.65	2525
Ersali	8462.83	8564.83	1.21	3.02	78.68	2507.67
Kesrwane	9025.5	9065.33	0.44	1.18	73.45	2674.17
Deir Al-Ahmar	9145.33	9151.33	0.066	0.18	120.33	2709.67
Cheera	9330	9342.33	0.132	0.36	84.87	2764.5
Sidawi	8188	8448	3.177	7.70	83.83	2426
Basalt	9970.83	9973.67	0.0288	0.0837	115.15	2954.5
Abou-dofr	9067.5	9078.5	0.1217	0.325	57.8	2686.5
Kour	8872.5	8895.33	0.258	0.676	71.18	2628.67
Sawan	8711.67	8827	1.324	3.417	100.72	2581.17

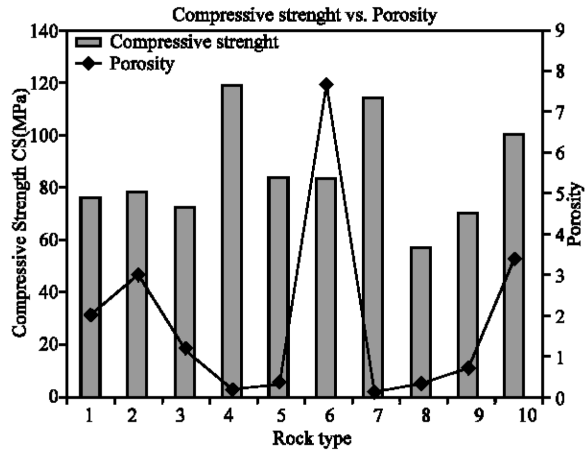

Fig. 5: Compressive strength vs. porosity

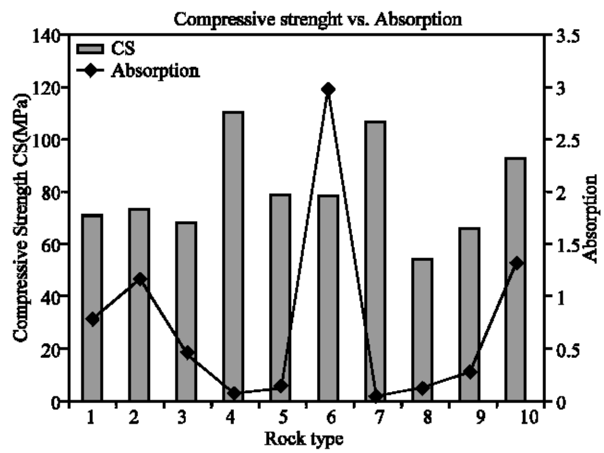

Fig. 6: Compressive strength vs. absorption.

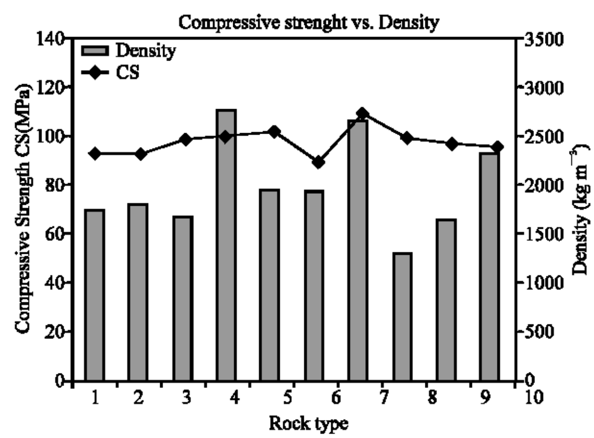

Fig. 7: Compressive strength vs. density

In an attempt to interpret the obtained data, the following Fig. 5-7 show the relationship between Compressive Strength (CS) and porosity , absorption and density.

CONCLUSION

When confronted with a set of data (like the ones shown above), there are a number of questions that have to be addressed:

- What data should be included in the analysis?
- What equation should be fitted?
- What method of fitting should be adopted?
- How to classify the rocks for engineering purposes?

The results would show elements that are likely to fail at the extremes. Given the variability typical of rock test results it is likely that any one criterion is as suitable overall as any of the alternatives. The strength of the rock mass is only a fraction of the strength of the intact strength. The reason for this is that failure in the rock mass is a combination of both intact rock strength and separation or sliding along discontinuities. The latter process usually dominates. Sliding on discontinuities occurs against the cohesional and/or frictional resistance along the discontinuity.

The classification of rocks for engineering purposes is just a rating system by which one can sense how to deal with these rock formations in the design of foundations and sub-surfaces structures like tunnels. Accordingly one of the most common classifications is listed below (Stag and Zienkiewcz, 1972; Das, 1998):

- A very high strength > 220 MPa
- B high strength 110-220 MPa
- C medium strength 55-110 MPa
- D low strength 27.5-55 MPa
- E very low strength <27.5 MPa

Thus it is obvious from the results obtained, the rocks formation of the Eastern Mediterranean Coast vary from high strength to medium strength. Finally, there does not seem to be a clear cut relationship between strength and Porosity or Density.

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