International Scientific Conference CIBv - Civil Engineering and Building Services
5th-6th November 2020

PETROGRAPHICAL CHARACTERISTICS AS AN INDICATOR OF PHYSICO-MECHANICAL PROPERTIES OF CONCRETE AGGREGATE

Lino Bianco and Gabriel Micallef

1. INTRODUCTION

Concrete is a widely used construction material. Aggregate is the main ingredient which accounts for nearly 75% of the volume, with the coarser fraction, depending on the mix proportions, accounting for 50 to 60% of the mix.

Recent research addressed the process of designing a prototype coffee table, from drawing to the production of an industrial item [1]. The final product made extensive use of concrete, walnut-finished timber components and black-finished steel elements (Figure 1). Concrete was utilised both in plane and edge orientations, the latter being useful to enhance the minimum thickness possible in order to reflect the concept of lightness. Whilst weight was a major drawback, concrete was nevertheless selected as the dominant product material. The surfaces were produced from freshly poured concrete in 25mm deep moulds designed for the panels. There were 5 moulds, each varying in form to correspond to the panels. They were constructed from melamine laminated particle board for (i) the production of a smooth finish and (ii) ease of demoulding. The sides of the moulds were manufactured in sanded pine wood as mitre edges could not be produced in melamine.

2. MATERIALS AND METHODS

2.1. Materials

Portland limestone cement CEM II/A-LL 42.5 R and local potable tap water were used in all the mixtures. Silica fume was introduced to improve the strength of the concrete. The coarse aggregate was of two sizes: 6.5 mm and 10.0mm. According to the aggregate supplier, the former was from Volujica Quarry in Port of Bar, Montenegro. The latter was from Wied Filep, Naxxar, Malta. The Volujica Formation outcrops at Bar and is composed of Late Cretaceous sediments of banked and stratified limestone with dolomite interbeds. Light brown banks, thick bedded rudist bioclastic biomicrites, lumakeles, and konkins are intercalated with dark brown medium beds of wackestones. The formation which outcrops at Naxxar is the Oligocene Lower Coralline Limestone, specifically the Magħlaq Member which is the oldest limestone quarried and distinguished for its high crushing value.

2.2. Type and size of aggregate

Particle density, water absorption and Aggregate Impact Value (AIV) was determined. To study the texture at micro level, aggregate was studied in thin section under a petrological microscope.

2.3. Mix design and casting of concrete

The mix design was for the C40 concrete. Silica fume was added at 5% by weight of cement. The water-cement ratio was kept at 0.55.

2.4. Testing regimes

A Zeiss Axioskop 40 transmitted light-microscope was used to analyse the thin sections of the coarse aggregate samples to establish the texture, porosity and permeability of the material. To evaluate the physical-mechanical properties of the concrete cubes, two testing regimes were used on the 28th day: ultrasonic pulse velocity (UPV) and compressive strength (CS).

3. RESULTS AND DISCUSSION

3.1. Petrographical characteristics of aggregate

The samples from Montenegro are completely recrystallized limestone consisting of sparry calcite mosaics (Figure 2a-f). The sizes of the calcite crystals in the former varies in the later they vary from 0.10×0.10 to 1.5×0.5 mm. With respect to Sample I-1, the limestone was most probably originally composed of fossils and/or bioclasts, which are of aragonite and high-Mg calcite composition. The aragonite and high-Mg calcite are unstable polymorphs and easily recrystallize into stable low-Mg calcite during diagenesis. The recrystallization completely obliterates the original limestone texture. Single and poorly expressed stylolites can be observed (Figure 2b). These were formed as a result of a pressure-dissolution process arising from overburden sedimentation or tectonic pressure. The stylolites are outlined by the presence of a dark brown to black insoluble residue that contains single, very fine-sized quartz grains (Figure 2b). In Sample I-2, dispersed black organic matter is observed in the mosaics. Several terrigenous quartz grains are recognized (Figure 2c and Figure 2d), as well as rare well-formed crystals of diagenetic quartz. Single dissolution seams (Figure 2e and Figure 2f) and stylolites can be observed (Figure 2f).

Samples C-1 and C-2 are micrite limestones with fine bioclasts. According to Dunham's textural classification [2] they represent fine bioclastic wackestones because the matrix to allochems ratio is 80:20 and 85:15 for Sample C-1 and Sample C-2, respectively. In Sample C-1 micrite crystals that construct micrite matrix are irregularly recrystallized to form microspar and rarely to spar (Figure 3a). Fine bioclasts are the main allochems. Their sizes are ≤ 0.5 mm. Most bioclasts are completely recrystallized (Figure 3a, RB) and some are highly altered and difficult to recognize (Figure 3b, RB). Occasionally, preserved fragments of echinoids, bryozoa (Figure 3c, BR) and bivalve shells (Figure 3c, BSH) are present. Single benthic foraminifera occur (Figure 3a, F). Some fragments resemble algae (Figure 3a, A?). In places in the matrix, peloids < 0.15 mm in size (Figure 3b, MP), which are composed of dark micrite, are present. There are single quartz grains (Figure 3a, Q) which are silt sized.

In Sample C-2, the micrite in the matrix is often recrystallized into microspar and spar (Figure 3d). Fine bioclasts are the main allochems (Figure 3e, RB). Most often they are recrystallized and/or altered and are difficult to determine. One more preserved fragment of bivalve shell (Figure 3e, BSH) can be seen. Some bryozoa bioclasts are found. Benthic foraminifera are sporadically represented (Figure 3d, F). Interparticle porosity, mainly observed in the matrix, is about 5% (Figure 3d).

3.2. UPV and CS

Figure 4 illustrates the effect of varying coarse aggregate size on the UPV and CS after a 28-day curing process. The UPV for concrete manufactured with 6.5mm and 10.0mm aggregate is plotted for the panels in Figure 4a and for the cubes in Figure 4b; the CS for the cubes is plotted in Figure 4c. Strong correlations exist between UPV and CS for rocks and concrete; UPV increases with the increase in CS [3]. Regression analysis shows a reliable correlation of UPV with compressive strength for high porous limestone in dry and wet conditions, both lowered in the later conditions [4].

Figure 1 – Coffee table: conceptual impression (a) and finished product (b).

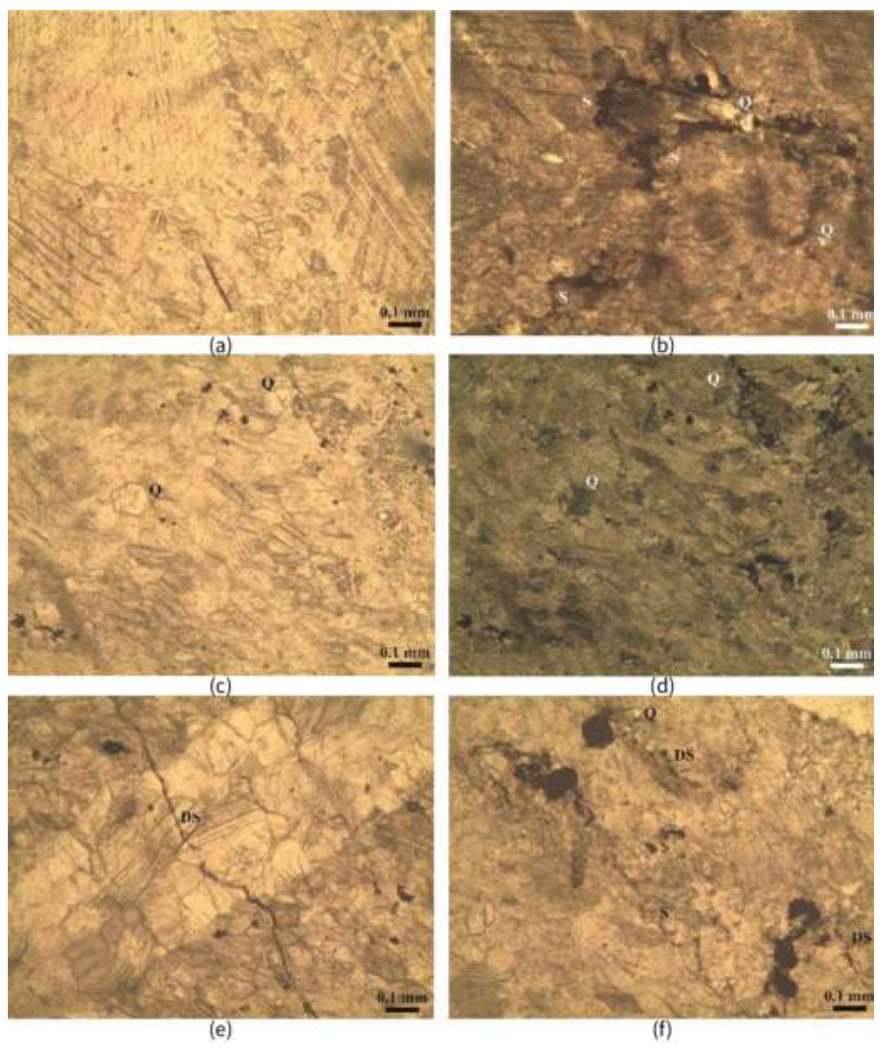

Figure 2 - *Sample I-1:* plane-polarized light: (a) sparry calcite mosaics, calcite crystals are of various sizes and (b) plane-polarized light: sparry calcite mosaics with poorly expressed stylolites (S) and single quartz grains (Q); *Sample I-2:* (c) plane-polarized light: sparry calcite mosaics, calcite crystals are of various sizes and single quartz grains (Q), (d) cross-polarized light: same view as (c), (e) plane-polarized light: sparry calcite mosaics crossed by dissolution seam (DS) and (f) plane-polarized light: sparry calcitbe mosaics with poorly expressed stylolites (S), dissolution seams (DS) and single quartz grains (Q).

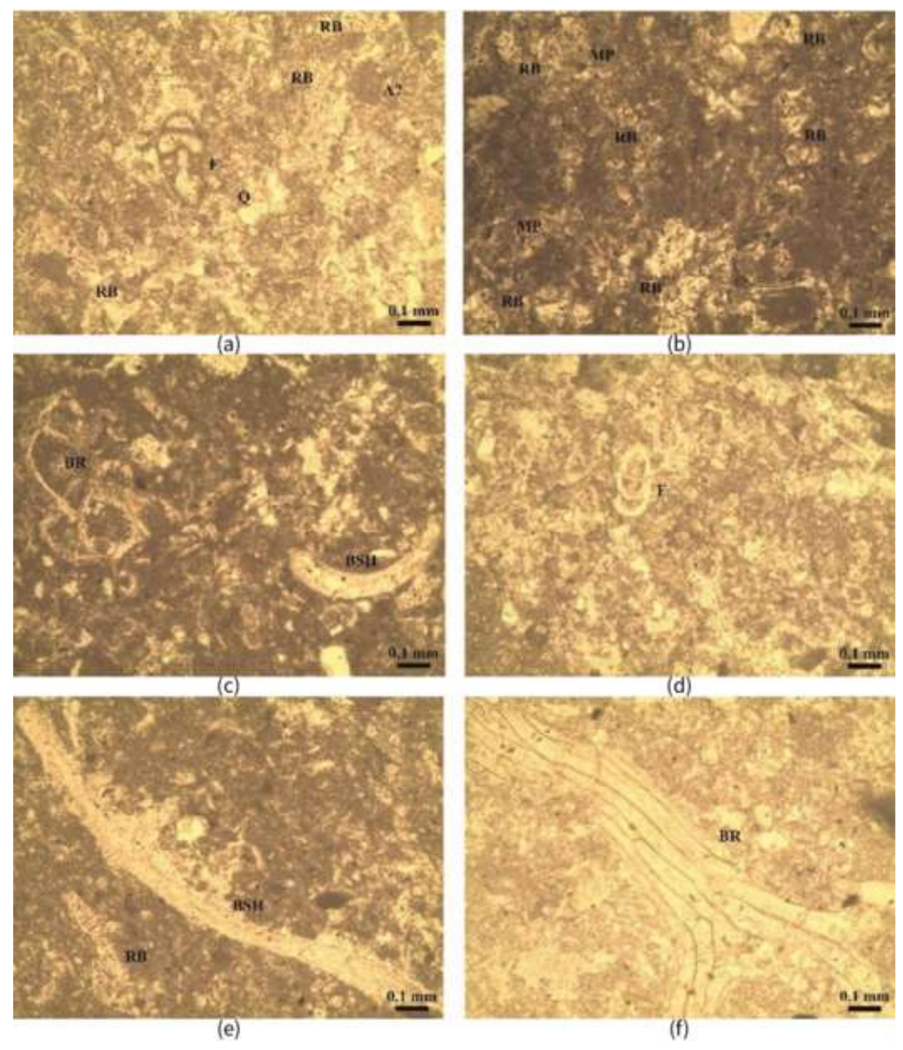

Figure 3 - *Sample C-1:* plane-polarized light: (a) micrite matrix is irregularly recrystallized to microspar and spar, recrystallized bioclasts (RB), alga fragment (A?), foraminifera (F) and quartz grain (Q), (b) completely recrystallized and highly altered bioclasts (RB) and micritepeloids (MP) and (c) fragments of bryozoa (BR) and bivalve shell (BSH); *Sample C-2:* plane-polarized light: (c) micrite matrix is irregularly recrystallized to microspar and spar, foraminifera (F), (e) recrystallized bioclasts (RB) with part of more preserved fragment of bivalve shell (BSH) and (f) a part of more preserved fragment of bryozoa (BR).

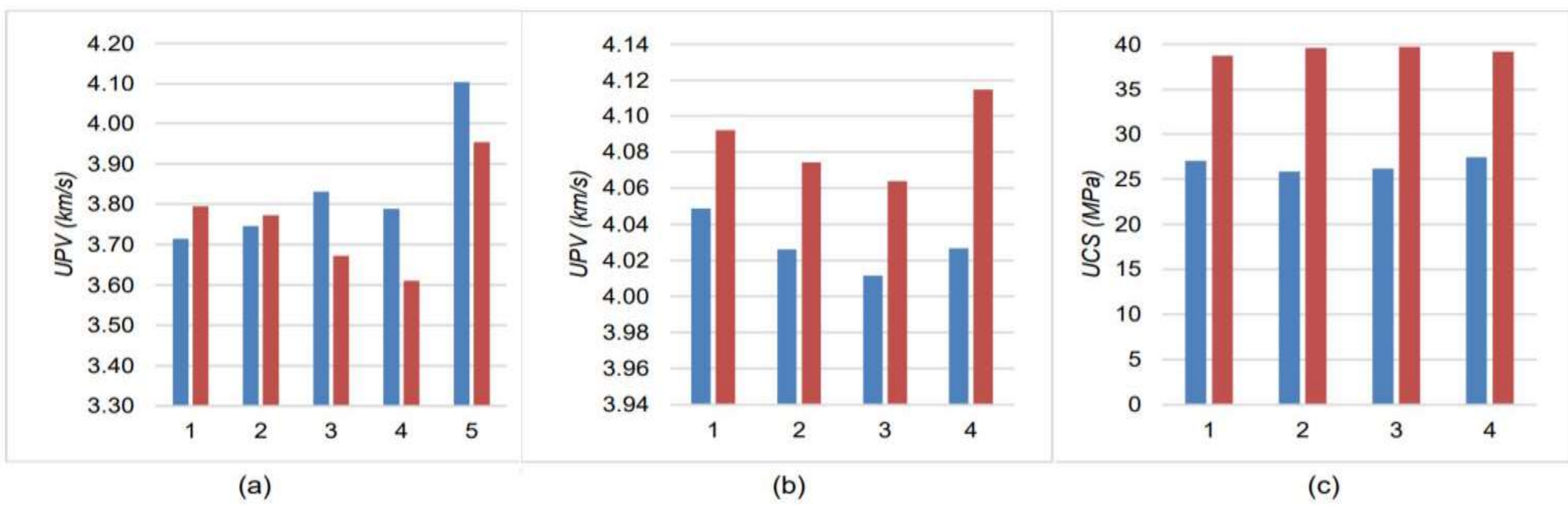

Figure 4 - UPV after 28 days (air-cured) for panels (a) and for control cubes (b); CS after 28 days (air-cured) for control cubes (c). Blue and red refer to 6.5mm and 10.0mm aggregate respectively.

References:

[1] Micallef G 2018 *An Architecture of Communication: Exploring the gap between design and production* (University of Malta: M Arch dissertation).
[2] Dunham R J 1962 Classification of carbonate rocks according to depositional texture *Classification of carbonate rocks* ed W E Ham (Tulsa, Oklahoma: American Association of Petroleum Geologists) Memoir 1, pp 108-121.
[3] Sertçelik I, Kurtuluş C, Sertçelik F, Pekşen E and Aşçı M 2018 Investigation into relations between physical and electrical properties of rocks and concretes *Journal of Geophysics and Engineering* **15** 142.
[4] Vasanelli E, Colangiuli D, Calia A, Sileo M and Aiello M A 2015 Ultrasonic pulse velocity for the evaluation of physical and mechanical properties of a highly porous building limestone *Ultrasonics* **60** 33-40.

Acknowledgements: The authors would also like to thank Professor Elena Koleva-Rekalova from the Geological Institute of the Bulgarian Academy of Sciences, Sofia, for the microphotographs and her advice on petrographical interpretations, and Nicholas Azzopardi, concrete technologist and senior laboratory officer at the Civil and Structural Engineering Laboratory, University of Malta, for his support in undertaking the physical testing of the materials focused on in this study.
The authors would like to acknowledge their gratitude to Martin Djakovic and Mileva Milić from the Geological Survey of Montenegro for professional support in describing the geology and petrography of the Volujica formation respectively.