# REPORT

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## Testing of Natural stone

(4 enclosures)

### Commission

Testing and assessment of to be used as outdoor façade panels. The marble is named *BIANCO CATTANI* and comes from Cava Tacca 133, Carrara (MS), Italy.

### Samples and testing

Prior to the sampling, Björn Schouenborg, CBI and Bent Grelk, Ramböll visited the quarries in Carrara 6-8th April for meetings with quarry owners and to obtain hand specimens for screening of potential marble types.

The subsequent sample preparation and transport to CBI was arranged by the quarry owner. CBI had provided detailed sampling and sample marking information but has no information about the actual sampling procedure. The requested number of specimens were received for discolouration test, laboratory bowing, petrography (AGA-Adjacent Grain Analysis) and flexural strength tests. More information about samples and tests is given in table 1.

**Table 1.** Overview of samples, tests and date of testing.

| Sample-identity | No. of specimens | Tested | Property | Method | Test finalised |
|---|---|---|---|---|---|
| Cattani | 10 | 5 | Laboratory bow test | EN 16306:2012 | 2016-08-09 |
| | 12 | 10 | Flexural strength | EN 12372:2006 | 2016-06-15 |
| | 5 | 5 | Flexural strength after bow test | EN 12372:2006 | 2016-08-09 |
| | 16 | 6 | Discolouration test | EN 16140:2011 | 2016-07-18 |
| | 1 | 1 | AGA<br>Including petrographic analysis | EN 16306:2012 (Enclosure C)<br>EN 12407:2007 | 2016-08-10 |



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## Test results

Average test results for the received specimens are given in the table below and detailed results in enclosures below.

**Table 2.** Test results.

| Characteristics | Cattani |
|---|---|
| Bowing potential (mm/m) | 0,27 |
| Flexural strength, reference (MPa), LEV * | 15,1 |
| Flexural strength, exposed (MPa), LEV * | 12,6 |
| Strength loss in % based on average values | 20 |
| Discoloration | T1 |
| AGA | 10-11 |

* Lower expected value (similar to characteristic value)

**The Swedish Cement and Concrete Research Institute (CBI)**
**Concrete and Stone**

Performed by

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## Enclosures

1 Determination of the resistance of marble to thermal and moisture cycling

2 Flexural strength of reference specimens and exposed specimens

3 Discolouration test

4 Petrographic description focussing on the AGA (Adjacent Grain Analysis) test: A quantitative measurement of the microstructure of the marble used as an indicative test of bowing potential and for follow up in quality control

Enclosure 1

# Laboratory bow test for marble according to EN 16306:2012

The test was conducted by Lovise Sjöqvist, CBI, in the period between 13th July and 2nd August 2016.

**Table 1.** Average bowing of Cattani marble.

| | Average Bowing (mm/m) | Standard Deviation | Recommended limiting value (mm/m) | No. of Cycles |
|---|---|---|---|---|
| Cattani | 0,27 | 0,034 | 0,4 | 50 |

**Figure 1.** Bowing development during the 50 thermal and moisture cycles.

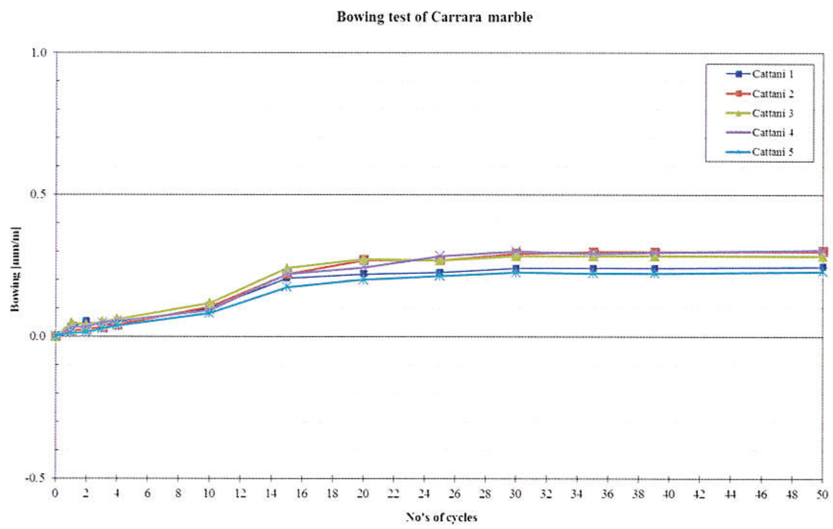
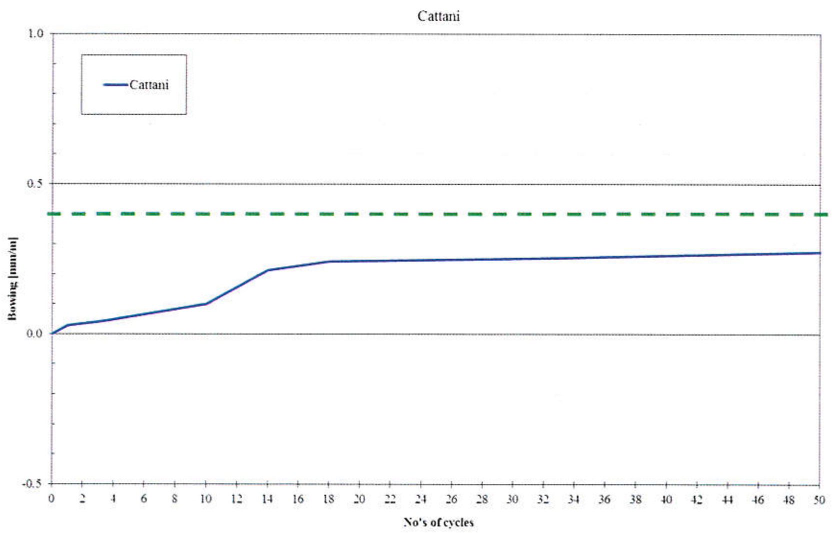



**Figure 2.** Bowing development during the 50 thermal and moisture cycles. Average values are shown. The recommended limit value is shown in green.



Enclosure 2

# Flexural strength according to EN 12372 of reference specimens and exposed specimens

## Reference samples

**Natural Stone : Flexural strength 3-point load**

| | |
|---|---|
| **Method:** | SS-EN 12372 |
| **Diameter of the loading device:** | 20 mm |
| **Distance of the rollers:** | 350 mm |
| **Load velocity:** | 0,25 MPa/s |
| **Temperature:** | 40 |

| | |
|---|---|
| **Commision no:** | 6P00238 |
| **Sample:** | Cattani |
| **Trading name:** | Cattani |
| **Stone:** | Marble |
| **Date:** | 2016-06-15 |
| **Operator:** | Lovise Sjöqvist |

| Specimen | Length, l (mm) | Width b (mm) | Height, h (mm) | Distance (mm) | Load (kN) | Flexural strength (MPa) |
|---|---|---|---|---|---|---|
| 1 | 400 | 100,5 | 31,8 | 350 | 4,08 | 21,1 |
| 2 | 400 | 100,6 | 31,3 | 350 | 3,21 | 17,1 |
| 3 | 400 | 100,7 | 31,8 | 350 | 3,94 | 20,3 |
| 4 | 400 | 100,5 | 31,3 | 350 | 3,28 | 17,5 |
| 5 | 400 | 100,2 | 31,8 | 350 | 4,14 | 21,4 |
| 6 | 400 | 100,3 | 31,6 | 350 | 3,90 | 20,5 |
| 7 | 400 | 100,6 | 31,2 | 350 | 3,05 | 16,3 |
| 8 | 400 | 100,4 | 31,8 | 350 | 3,33 | 17,2 |
| 9 | 400 | 100,1 | 31,6 | 350 | 4,32 | 22,7 |
| 10 | 400 | 100,9 | 31,5 | 350 | 4,10 | 21,5 |
| | | | | | | |
| **Mean value** | 400,0 | 100,5 | 31,6 | | 4 | **19,6** |
| **Standard deviation** | 0,0 | 0,2 | 0,2 | | 0,5 | **2,3** |
| Variation coefficient | | | | | 12,4 | 12 |
| Characteristic value K | *5%-fractile (75% confidens level)* | | | | | 15,1 |

## Samples exposed to the "cladding bow test"

**Natural Stone : Flexural strength 3-point load**

| | |
|---|---|
| **Method:** | SS-EN 12372 |
| **Diameter of the loading device:** | 20 mm |
| **Distance of the rollers:** | 350 mm |
| **Load velocity:** | 0,25 MPa/s |
| **Temperature:** | 40 |

| | |
|---|---|
| **Commision no:** | 6P00238 |
| **Sample:** | Cattani |
| **Trading name:** | Cattani |
| **Stone:** | Marble |
| **Date:** | 2016-08-17 |
| **Operator:** | Lovise Sjöqvist |

| Specimen | Length, l (mm) | Width b (mm) | Height, h (mm) | Distance (mm) | Load (kN) | Flexural strength (MPa) |
|---|---|---|---|---|---|---|
| 1 | 400 | 100.3 | 31.4 | 350 | 3.01 | 16.0 |
| 2 | 400 | 100.2 | 30.0 | 350 | 3.05 | 17.8 |
| 3 | 400 | 100.9 | 29.8 | 350 | 2.99 | 17.5 |
| 4 | 400 | 100.4 | 31.5 | 350 | 2.59 | 13.7 |
| 5 | 400 | 100.3 | 31.5 | 350 | 3.11 | 16.4 |
| 6 | 400 | 100.4 | 31.1 | 350 | 2.84 | 15.3 |
| 7 | 400 | 100.6 | 31.7 | 350 | 2.80 | 14.6 |
| 8 | 400 | 100.3 | 31.3 | 350 | 2.61 | 14.0 |
| | | | | | | |
| **Mean value** | 400.0 | 100.4 | 31.0 | | 3 | **15.7** |
| **Standard deviation** | 0.0 | 0.2 | 0.7 | | 0.2 | **1.5** |
| Variation coefficient | | | | | 6.9 | 10 |
| Characteristic value K | *5%-fractile (75% confidens level)* | | | | | 12.6 |

This means approximately 20 % reduction in flexural strength due to the bow test.

Enclosure 3

# Discolouration test for marble according to EN 16140:2011, Annex B

The discolouration test has been found especially useful to assess the potential risk of brownish staining of marble. Given that there is any easily oxidized sulphides in the marble, they will be affected by repeated heating and cooling. The latter in a weak alkaline solution.

Figures a and b illustrate the test specimens before and after exposure to 20 cycles. **N.B!** The colours do not completely match the original, despite white balancing of the photos. The comparison to reference specimens (R1 and R2) are therefore crucial for the assessment!

**Figure 1a.** Test specimens before the exposure, including two reference specimens.

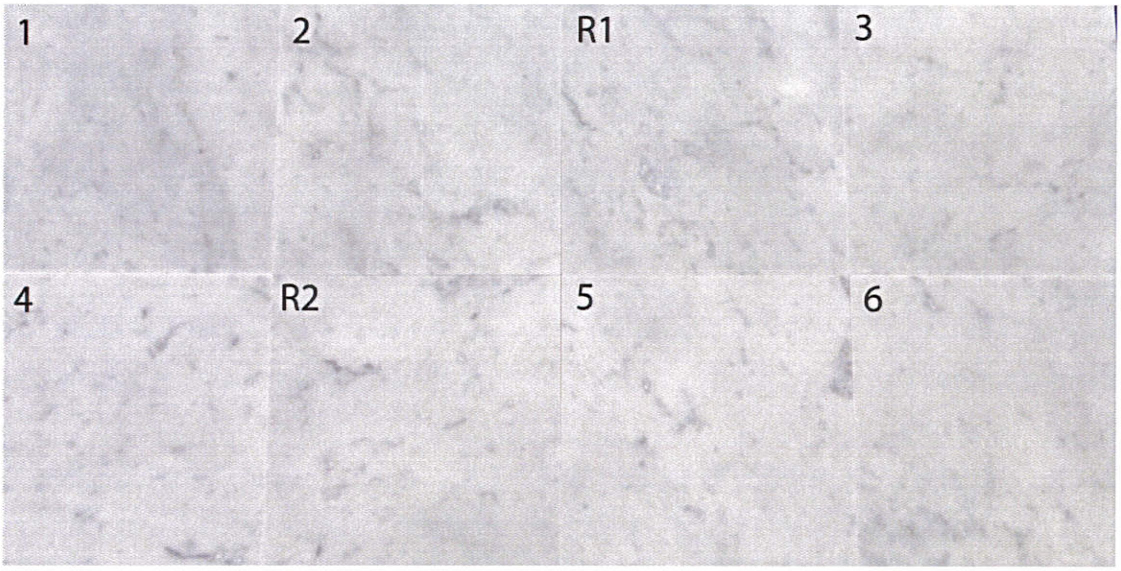
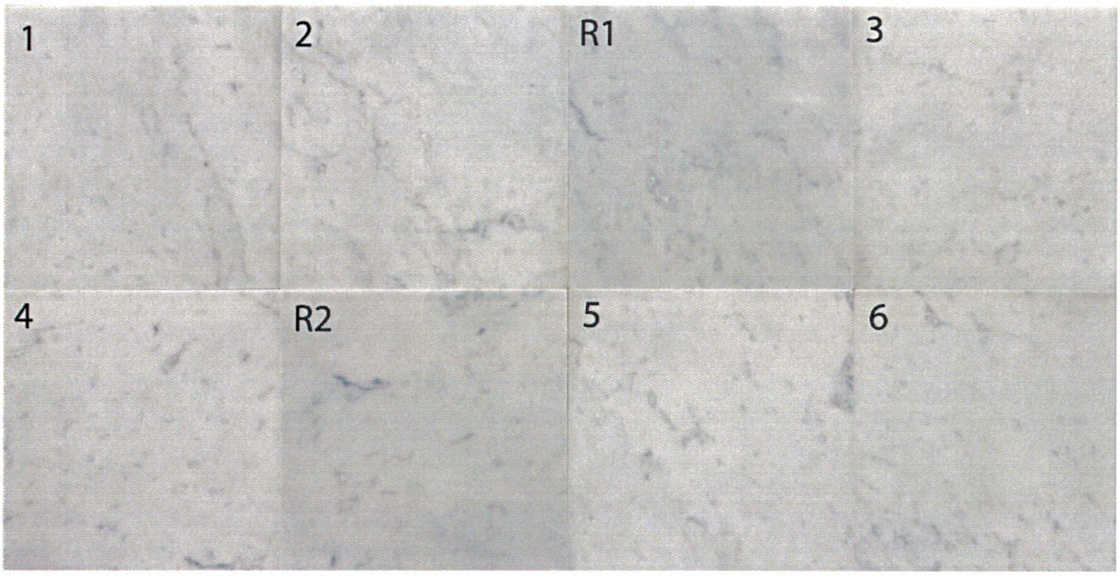



**Figure 1b.** Test specimens after the exposure, including two reference specimens that are not exposed.



Enclosure 4

# Petrographic analysis with a focus on microstructure: Adjacent Grain Analysis (AGA) EN 12407:2007 and EN 16306:2012 Enclosure C

## Test procedure

The microstructure is quantified using linear traverses for the grain size and the Adjacent Grain Analysis (AGA) for the complexity of the microstructure. Increased complexity is favourable as regards durability. This was done on thin section under a polarising microscope. The principle of the AGA-method is that the amount of adjacent grains is counted around the median-sized minerals/grains in the sample (Fig 1).

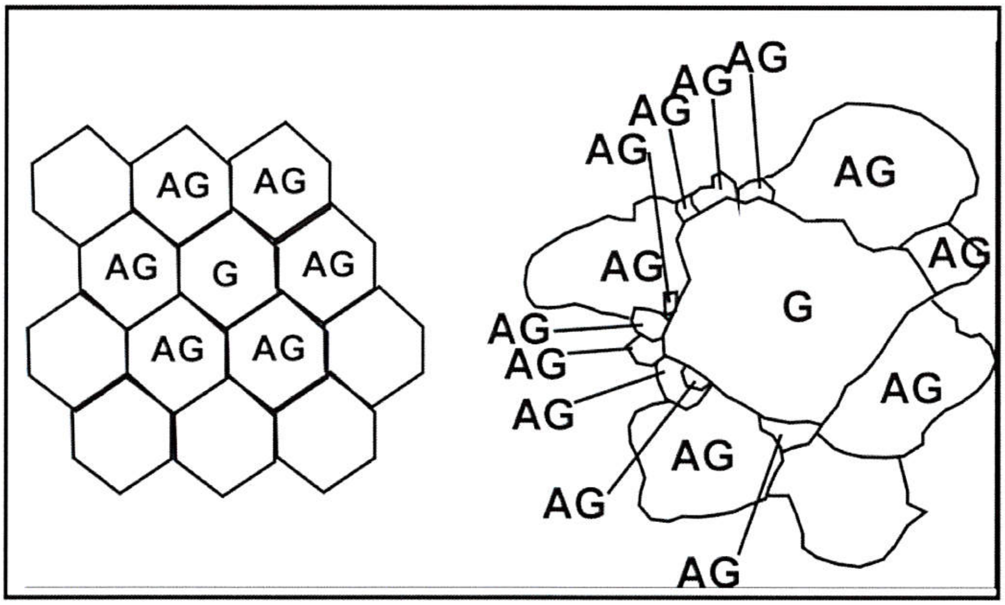



**Figure 1**. Schematic image of an granoblastic polygonal texture (left), and a seriate interlobate texture (right). The image also shows how the adjacent grains AG are counted.

Calcite crystal belongs to the hexagonal crystal system. In an "ideal" even-grained granoblastic texture, all calcite crystals share grain boundaries with six grains, which are referred to as *adjacent grains* AG (Figure 1). N.B! This is not ideal for the durability aspects! An increasingly irregular grain boundary or a more heterogeneous grain-size distribution will result in an increased number of adjacent grains. In a calcite marble with a heterogeneous grain size distribution, the largest crystals have the highest number of adjacent grains whereas the smallest crystals can have less than six adjacent grains. A larger number of AG occurs also in calcite marble with complex grain boundaries.

## Test results

The analysed sample is a fine grained (0,02 – 0, 2mm) calcitic marble (Figure 2) with irregular, lobate texture and a heterogeneous grain size (Figure 3), where an large number are calcite crystals, smaller then 0,1 mm due to recrystallization of the marble. For macroscopic images, see Enclosure 3. The median grain size is ~0,14 mm. The total number of adjacent grains are counted to be 10 (median value) and 10.7 as a mean value (Figure 4).

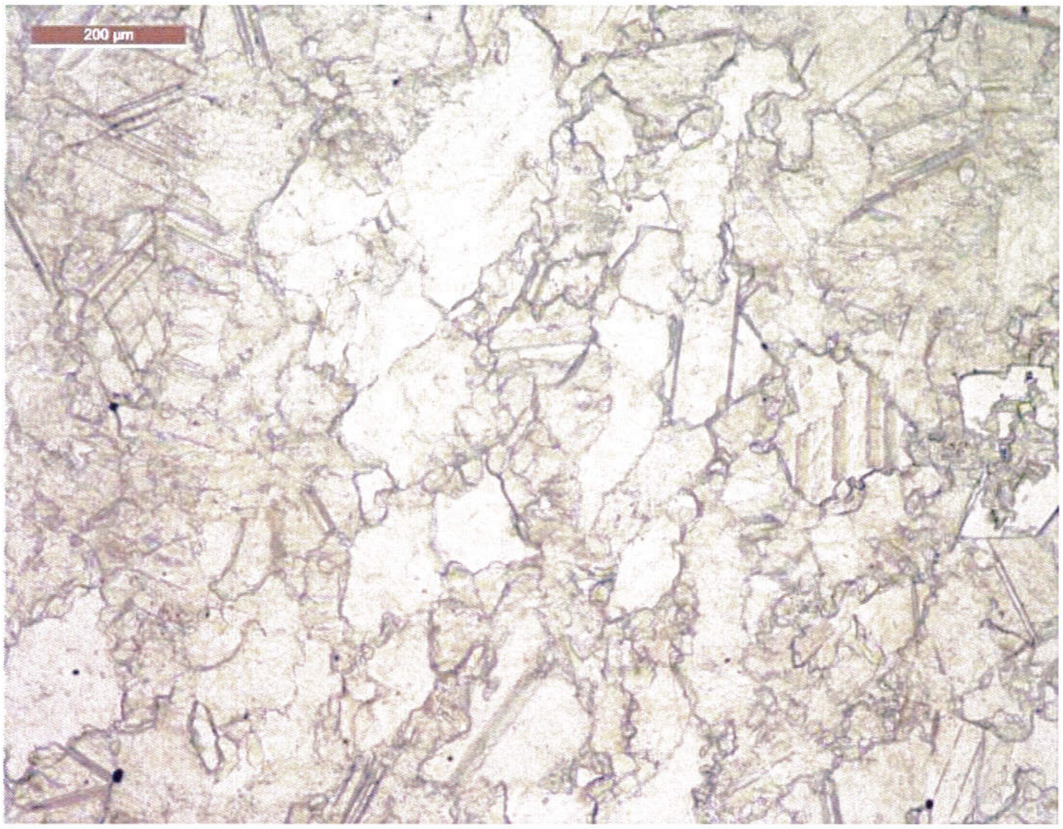



**Figure 1**. The photograph shows the microstructure of the grains as well as grain size. A large variation in grain size is revealed. Note scale bar at the top left of the photo.

Enclosure 4

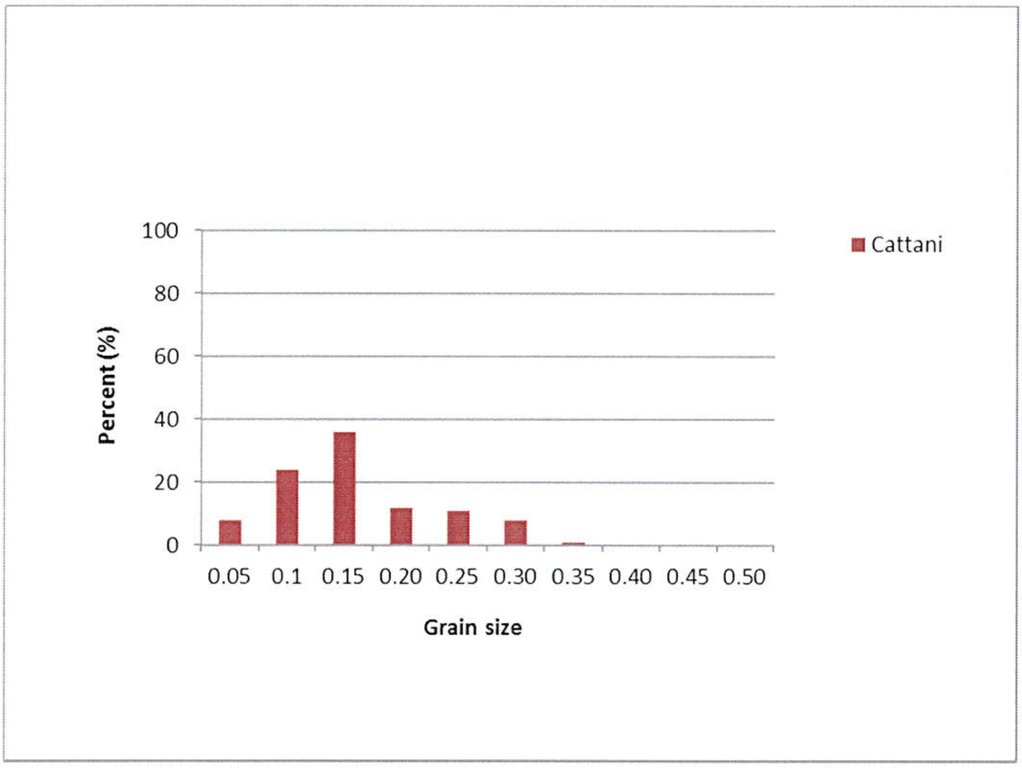



**Figure 2**. Grain-size distribution of the analysed sample.

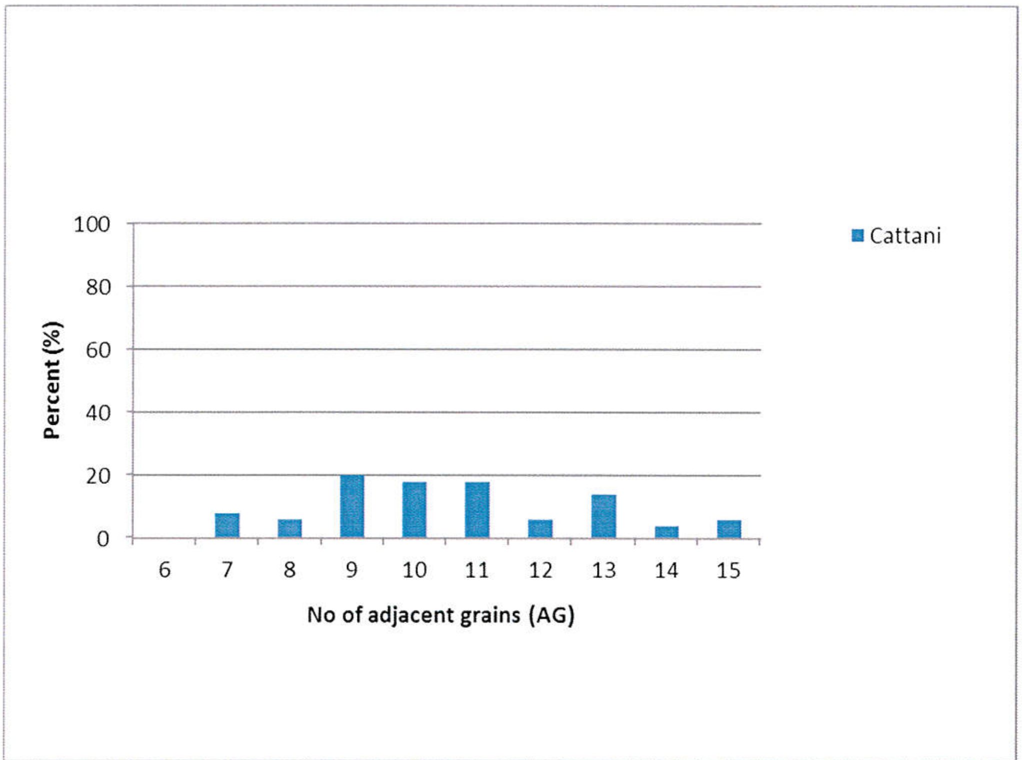



**Figure 3.** The results of the adjacent grain analysis (AGA)

Enclosure 4

## Comments to the results

According to results from bowing measurements on marble claddings in the laboratory and from facades, the marble types with a granoblastic microstructures (low AGA numbers) have the highest bowing potentials. The normal range of AG in calcite marbles are between 6 and 10, where the marbles with 6 AG show the greatest bowing potential. This sample has **10-11 AG**. In comparison with earlier results, it is our experience that it should not have a potential to bow if used as a façade cladding, or it will be minimal.

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